Communication Networks
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Module - 09
Media Access Control Protocol
Lecture - 43
PON and Ethernet MAC

Ok, so far we have started discussing about the effect of different media in the media access control protocol, we are still on layer two protocol. So, at the access part of mostly layer two protocols are most important in the access part, because that is where common media has to be accessed by different users. So, we are trying to now see how a particular physical media and its characteristics affect the protocol design.

And what are the things we need to keep in mind for designing an efficient MAC or media access control protocol for that particular physical media? So, we have started discussing there are three parts actually, one is or two parts rather one is wired and another one is wireless. And for the wired we have identified that there are two things one is with coaxial cable and the other one is with optical fiber.

So, today we will try to do, we will carry forward our discussion of this with fiber the particular network is called a passive optical network, and the other one is Ethernet for coaxial cable. So, these two things we have already started discussing we will go further into the details of this MAC design. So, let us try to see.

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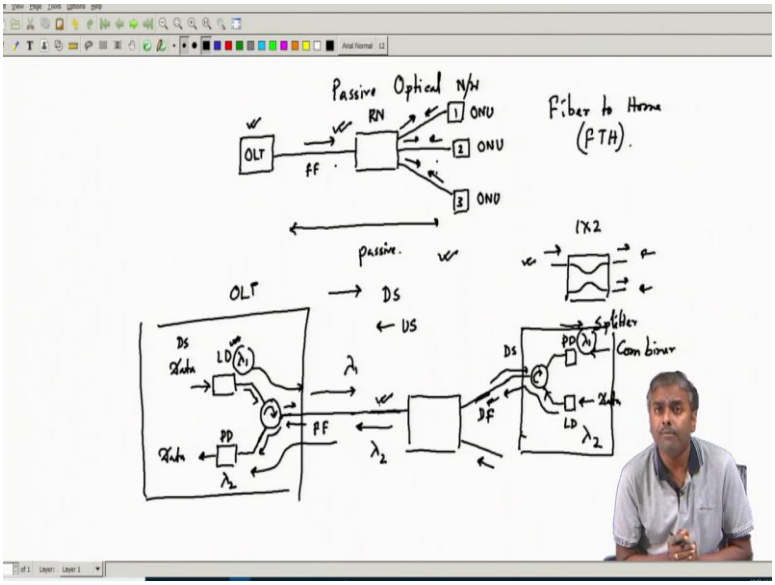

For PON we have already discussed that there is something called a passive splitter, we have a feeder fiber, and we have OLT over here. This is called a passive optical network. The reason is the intermediate node which is the remote node that is a passive splitter. So, it does not have any active functionality. So, basically, OLT will be in the central office. Then in between on the field in the street cabinet or somewhere, this passive component will be kept, and then there will be distribution fibers which will be running to the user premises which is called ONU or optical network unit ok.

Because the distribution part of the network this part is all passive. So, it does not have any active component. So, it is very easy to maintain this particular network. So, you do not have any maintenance cost, basically, it does not have to be power provisioned, and it does not require any maintenance because components are very simple. So, the overall maintenance cost and the cost of the actual physical infrastructure cost that is quite cheap. So, this is why this network has been popularized for access with fiber.

So, this is the fiber-to-home initiative or it is called F T H ok. So, where the entire access network is also realized with fiber, of course, it has huge bandwidth. So, that is why you can actually tell the end user you will be able to provide a huge amount of bandwidth. Now because of its popularity what is happening PON is also being used not only for delivering data to the end users, it is also being the actual backbone of your 5G network.

So, basically, 5G network there is, if we can discuss those parts that also we will discuss. There is a front-hauling part, there is a backhauling part. So, all these things are now being realized by PON because of it is high bandwidth and very cost-effective maintenance installation. So, whatever it is, what we want to see is, how a media which is the fiber media and with this associated component or this kind of tree network, it affects the overall protocol that has to be installed over here.

So, from what we have seen, there are two directions of data. One is this direction which is called the downstream where it comes from the network to the user. So, whenever we are downloading something. So, that is the downstream direction. There is another direction which is the upstream direction when users are uploading something ok to the network. So, that is the upstream direction. So, in the downstream direction because of this device, this device is a passive splitter and combiner.

So, one port is there and we know that if it is just 1 cross 2 so; that means, two users are there, this bent structure of waveguide actually couples the power to both of them same power gets split. So, that is why in this direction; in this direction it is acting as a splitter.

And the other direction whatever power you put that gets combined over here. In both directions, there will be if we have one cross two there will be at least 3 dB power loss apart from the insertion loss whatever loss that will be happening due to the coupling of power and all those things ok.

So, even if we take that insertion loss as negligible, there will be always a 3 dB power loss something we have seen. And as we start increasing the port numbers that kind of loss will keep on increasing. So, that is something we already know. So, it is a splitter on one side let us say on the downstream side, and it is a combiner on the upstream side. So, in the downstream, if you see, whatever data will be given by OLT will be broadcast to everybody.

And then if the packet has a particular header identifying one of the ONU. So, ONU 1 2 3 might have their media access control protocol address or ID if they have one, if OLT puts the ID accordingly whoever data it is can take that data others can discard that data. So, it is a broadcast domain it is very easy. So, every data is broadcasted one after another. And whoever the data is intended to take the data others will not be taking the data. So, this is something we can do.

You can always say there is an issue of security because everybody is getting everybody's data. So, you can always encrypt it or take other measures to alleviate that problem. But whatever it is in the downstream direction it is a broadcast nature. The upstream direction what is happening? So, upstream whatever you give, they are all actually sharing this feeder fiber we have already seen that. So, it is a many-to-one communication in the upstream and they are all sharing the same media I have to somehow time multiplex them ok.

So, that is the functionality that has to be employed over here ok? Generally what happens this OLT and ONUs are implemented like this? OLT will have a because it is an optical communication. So, it must have a laser diode ok it must have a laser diode with a suitable modulator you can directly modulate the laser with the data or you can have an external modulator whatever it is a laser diode means along with a modulator. So, you supply the data laser directly modulates it if it is directly modulated data.

So, and then you launch it into the fiber. So, how do you launch it? There is a device called a 3 port circulator ok the functionality of the circulator is it is a 3 port device. So, whatever the direction of the circle I have shown if you launch power in 1 port it just goes out in that direction of the circle from the other port. So, basically, if the data comes from here it will go out from there, and that is where we connect the feeder fiber.

This particular port connects it to a photodetector, where if the data is coming from feeder fiber again with the circulator 3 port circulator if data comes over here in the circular direction the direction I have specified this direction it will actually come out from this port and will means will be fed into a photodetector. So, it is this circulator just helps in putting the data direction properly.

So, the upstream data from the laser diode goes into this direction and the downstream data from the feeder fiber comes into the photo direct photodetector, from the photo director you get you. So, this is the upstream data you get from your downstream data ok? So, this is what happens at OLT. Similar things will be happening. So, you have a splitter over here, and from the splitter, the data comes out and then it goes to the ONU, ONU will have having similar structure, again a circulator. So, whatever data comes is the downstream data that must be fed into the photodetector.

And whatever data you want to put that you put it into laser diode and that goes over here due to circulator it actually this data comes over here. Now remember this laser diode which is responsible for downstream data that operates at a particular frequency because means you are finally, putting both the as you can see even upstream data and the downstream data when this downstream data as well as upstream data share the same fiber same distribution fiber and same feeder fiber.

So, to put them together you need to do an FDM or frequency division multiplexing. So, that is why generally this laser diode will be at different frequencies, and this photodetector will be at different frequencies. So, upstream data will have a separate frequency let us call lambda 1 ok or wavelength lambda 1 downstream will be. So, this is the downstream sorry the upstream will have another frequency lambda 2. So, that is why they are separated.

The corresponding laser diode laser diode will be operating at lambda 1 this photodetector will be operating at lambda 1 this laser diode will be operating at lambda 2. So, that actually generates the upstream data and this will come over here and this photodetector will be operating at lambda 2. So, you have two separate wavelengths for carrying upstream and downstream data, and all ONUs will be equipped with these things.

The combination of a photodetector and a laser diode whereas, OLT also will have a corresponding combination of the photodetector and laser diode, and the upstream downstream data are at a separate wavelength or separate frequency you should say. So, they are means they have a distinct place in the frequency spectrum. So, they can be easily separated and they will never interfere with each other. So, that is happening. So, irrespective of upstream data downstream data can go.

So, these two directions can simultaneously coexist and you can always transmit. The only thing is that in the upstream you have a collision domain because it is sharing the same feeder fiber. So, when this guy is transmitting upstream data this guy also can transmit data. So, they might collide over here. So, that is why this coordination has to be made so that we can avoid upstream collision. Now let us try to see compared to Ethernet. Do we have the same kind of facility over here?

So, let us say if I wish to design a protocol what is the advantage or disadvantage this has? So, the first thing is, I have a problem over here. Because whenever I am transmitting this upstream data, the other users are they able to listen to this? In Ethernet, that was happening, in Ethernet whenever I transmit data it goes to everybody's receiver ok.

So, intended receiver non intended receiver, so everything it goes to. So, that is why everybody was able to listen to every other's transmission and that is why I could do this CSMA that was possible in Ethernet.

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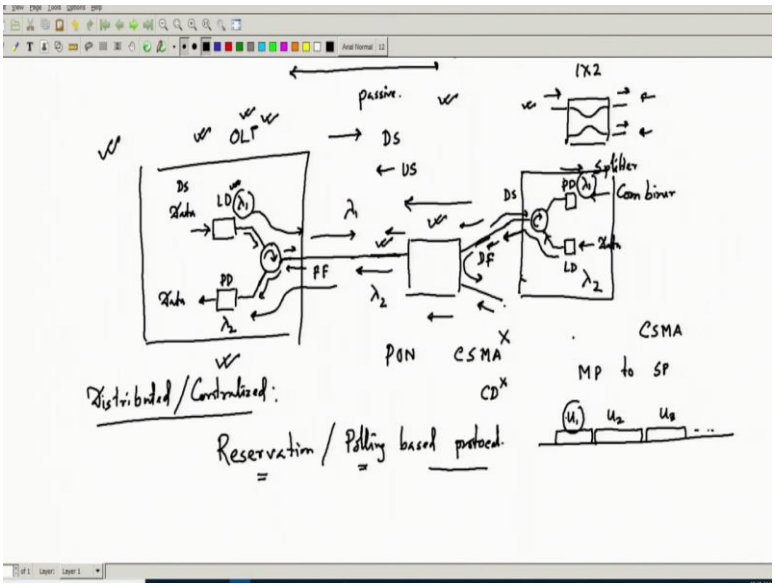

Over here, because of the directional property of this particular device, this passive device only gets data means whatever data you get that only goes in this direction it does not get fed into the reverse direction. So, therefore, everybody's data when he is transmitting to others will not be able to listen to that.

So, in PON CSMA is not possible that is impossible ok? Let us now try to see if CSMA is not possible. So, even if somebody else is transmitting I cannot listen to that. So, collision detection is possible for the user? No, because everybody's data is going in this forward direction.

So, all other users cannot detect collisions. If he is transmitting whether others are transmitting or not he does not know he has no information about it because he cannot

see their data. So, therefore, collision detection also is ruled out. So, now, I have a problem. So, all the devices that we have actually invented or all the devices and all the mechanisms that we have invented this CSMA CD will be giving us the huge advantage we have already seen, that is all impossible now because I cannot sense what others are doing.

So, this is almost impossible for me to see whether others are transmitting at the same time they are transmitting when I am transmitting. So, all these things are not possible. So, therefore, the protocol needs a huge modification. What is a modification that we can do? Now if we ask who has all this information do I have somebody who has all this information? Yes, I can see that, that this OLT that central office that has all the information, whether somebody is transmitting or somebody's data is colliding. So, all this information OLT has everything.

And as you can see, everybody this is a multi-point to single-point communication ok. So, in this upstream direction what is happening, every ONU is transmitting to OLT only which was not multi-point to multi-point communication like in Ethernet. In Ethernet, anybody can transmit to anybody that is not happening over here. Here the transmission is always user to network, then if it has to be delivered to another user the network will or the OLT will decide again to forward that packet to that user.

So, because it is always a multi-point to single-point communication, this central office or OLT has all the control because the data comes to him only. So, he has all the control. You will see whenever we are building up this kind of network. So, there are two kinds of networks that have been predominantly designed, one is this kind of multi-point to-point ok. So, even in wireless also people have done that you have an access point and all the data are generally communicated to the access point.

You have a base station all the data are communicated to the base station, you will see the advantage of that. This centralized communication is where everything goes to one central point and from there, data gets distributed. If it has to go outside in the internet it will be forwarded by that particular base station or access point or whatever you call OLT whatever you call or if it has to be routed locally that also will be done by him only. So, nobody actually gives the data among peers ok?

So, peer-to-peer communication is only via the central point or central controller. So, in this kind of centralized communication sometimes people do that, and sometimes they wish to make it completely distributed as we have seen in Ethernet or in wireless access also we will later on see that there are some facilities where every node can transmit data to every other node ok. So, packet radio access is one of those earlier versions which was means actually started with that aloha protocol, so in Hawaii.

So, that is what we have discussed already. So, there are some distributed protocols there are some centralized protocols. So, that is another distinction that is coming out distributed versus centralized. As you can see it depends on the network structure, over here this OLT to ONU this PON structure that is actually facilitating centralized communication. So, if it is centralized as you can see OLT will have access to every piece of information.

So, now I have to devise a mechanism that is more centralized unlike aloha, slotted aloha stabilized aloha, or CSMA CD kind of protocol that we have devised so far. So, what is this centralized protocol? This is called reservation protocol or polling-based protocol. So, over here what do we wish to do in this reservation or polling-based protocol? So, basically, the centralized node polls everybody ok and it gives access to the media common media to all these users in a round-robin fashion.

So; that means, the overall time will be subdivided user one will access the channel for some amount of time, user two will access the channel for some other amount of time, user three will access the channel, and so on, and then this pattern will be repeated. So, this round-robin fashion. So, this is for user 1 user 2 user 3 and who coordinates this? This centralized coordinator OLT ok in this case access point for other cases or a base station for other cases.

And over here there is a technique called, of course, the OLT will be polling them and then there is a mechanism of reservation. So, reservation means these ONUs might have different data, they want to do statistical multiplexing sometimes ONU 1 might have bigger data and bigger data chunks to transmit whereas, OLT ONU 2 does not have that much data. How do I do that? So, what we can do we can first reserve it, we can say ok I have this much data.

Then OLT accordingly seeing that, seeing those requests actually reserves bandwidth and lets the other users or all other users know that ok this is your status of reservation and this is your polling status. So, now, I am polling you to transmit the data, next, I will be polling somebody and he will be transmitting the data. So, he coordinates all these polling activities and beforehand he makes that reservation and accordingly, he controls his polling.

So, with that in a Round Robin fashion, he will be able to actually coordinate this transmission so that at the upstream you have a collision-less or collision-avoided transmission and it is also catering to everybody's need. So, that statistical multiplexing is properly happening ok.

So, this is something that will be mostly applied in centralized transmission. As you can now see the structure of PON was not facilitating distributed communication because it was not having this CSMA not having this CD facility.

So, because that was not there each user could not do anything, or distributed communication was not possible. For distributed communication, you need to understand the channel, and you need to get feedback from the channel. They were not getting the feedback from the channel, if they transmitted whether that was successful or not they were not even getting all that feedback ok. So, that is the disadvantage which was there inherently due to the structure of the network.

That is why we were talking about this physical layer and how it affects right. So, we need to really understand this part and then accordingly we should devise our algorithm ok. So, now, that we have seen already these kinds of centralized structures, what should we do? So, what protocol in the next class we will try to do? We will try to give a very nice polling and reservation protocol, which has been employed for PON that is something we will try to appreciate.

How do we coordinate this reservation, request, and then polling? How do we coordinate all these things from the centralized node? How the timing is precisely being maintained? So, that is something we will try to see after that we will again go back to the distributed part which is in Ethernet and we will see the contrast between these two.

Thank You.