Communication Networks
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Module - 09
Media Access Control Protocol
Lecture - 44
PON and Ethernet MAC contd

Ok so, in the last class, we have already started discussing centralized versus decentralized protocol designing, depending on the physical media and associated network architecture.

So, we have seen the structure of PON and we have also discussed Ethernet. Ethernet MAC will be probably the decentralized version whereas, PON is a more centralized version of this part we have understood.

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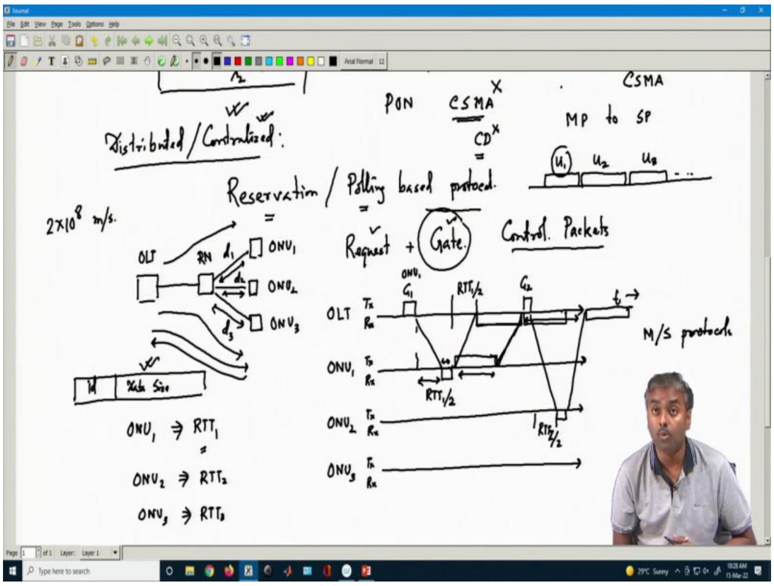

So now, let us try to see how we devise this individual mechanism knowing that one can have CSMA CD, the other one cannot have CSMA CD.

So, let us try to see for PON what happens. I have an OLT over here, feeder fiber followed by a remote node which is a passive splitter and followed by a few ONUs.

So, as we have talked about this reservation. So, what might happen, there must be two separate packets that are means responsible for this request and reservation. So, one is called request and the other one is called the gate. So, these two are separate control packets.

Now, you can see already we are talking about the control information exchange ok? So, that is part of the protocol actually, this is how we are designing the protocol. So, these are control packets, that have nothing to do with actual data transmission it is not actual information transmission, it is a packet or a control packet that facilitates the actual transmission.

So, now let us see how we use these two things to actually activate our reservation. So, this is let us say this is ONU 1, this is ONU 2, this is ONU 3, and only three ONU are there let us say in my network. Of course, it can be extended to any number of ONUs ok?

Now, we have talked about this timing diagram, so we will again do that. So, protocol is all about the timing and how do you adjust this events in time. Let us say this is the timing of OLT, this is the timing of ONU 1, ONU 2, ONU 3 ok. So, time goes in this direction.

Now, what will be happening, see because it is a reservation based protocol or polling based protocol. So, if OLT does not say something, ONU will not be doing anything. So, it is a kind of master-slave protocol. So, all ONUs are slaves of a master called OLT. So, basically whatever OLT guides ONUs exactly does that same thing, if they are not obeying OLT then the entire protocol will be failing ok. So, this is like the previous one, this is their transmitter and receiver, transmitter-receiver, transmitter-receiver and it also has transmitter-receive.

So, whatever OLT will be transmitting that is received by all ONUs remember, that is something we have seen. Of course, these distances can be different ok, this might be d 1 because it depends on where the house is. So, basically, these distances might be different, because these distances are different so the propagation time from OLT to a particular ONU, let us say ONU 3 might be different from the propagation time of OLT to ONU 1.

So, this is something that is there physically, because they have different distances, and it's an electromagnetic wave which is light actually flowing through them. So, basically, they have different times to reach.

So, the propagation delay will be different this is something we know. Of course, the transmission delay will be the same because everybody is operating at the same wavelength with the same data rate. So, same transmission rate. So, therefore, the transmission delay will be similar for everybody, that is something we know.

Now, let us try to see how do we actually mechanize or devise this reservation part. So, what we do, is being done by gate message. So, OLT whenever he is willing to poll somebody will be issuing a small message which is called a gate and this gate message is a control message. It does not have any information, it will probably have OLT ID and it will have the one whom he is trying to poll, one whom he is allowing to transmit.

So, that ID he will specify, and from that ID others will know which particular one he has requested only that guy will respond back and the expectation is he will be immediately responding back. So, all ONUs receivers will be awake. So, whenever this message comes they will just read that so that reading time will neglect that is negligible. So, they will read that, they will see if that is his ID then he will be able to transmit.

So, the gate message also needs to give specific information that how much time he can transmit or how much data he can transmit. So, that is a very important criteria.

So, the gate message might have the following field, the most important field is the ID of the node whom he is allowing and the amount of packets. So, data size that he is allowing him to transmit ok. So, these things should be there, these two messages have to be encoded over there and then he will transmit it.

So, whenever he transmits according to different different; suppose this is the gate message for ONU 1 ok, then according to his propagation delay ok, so let us call that propagation delay. Generally, we do not talk about this propagation delay, we talk about the round trip delay, and there is a reason for that.

So, what is the round trip delay? It is the delay of this going over there and immediately if he responds back his response coming over here this entire round trip delay. So, OLT will be issuing some packets he responds back immediately and whatever delay is from the first bit to go over there and from the response to the first bit to come over here, what is the overall delay that is called the propagation delay ok.

So, a particular bit getting transmitted over there and then a response coming back, whatever the delay. So, it is the overall propagation delay to and fro so that is called the round trip delay. So, let us call this ONU 1, let us say that is RTT Round Trip Time 1 ok. That might be some microseconds, so let us say 100 microseconds or 200 microseconds depending on the distance. So, what is the distance between that and light velocity so you know that?

So, generally, light velocity over the fiber will be 2 into 10 to the power 8 ok meters per second. Generally, it is 3 into 10 to the power 8 in free space, but because of the refractive index of fiber, it becomes 2 into 10 to the power 8 meters per second.

And from there depending on the distance if it is 10 kilometers or 20 kilometers whatever it is depending on the distance you will be able to calculate this round trip time of ONU 1. Similarly, there will be a round trip time of 2, let us call that RTT 2, ONU 3 also will have a round trip time of RTT 3. Now, the protocol goes like this.

So, he issues a gate message, he tells ONU exactly how much to transmit. So, basically that gate message with how much time it will travel to him. So, this timing will be RTT 1 divided by 2 because it takes half time to reach this particular user and this is the transmission time gate message will be a very small message. So, it will not take a huge amount of time to be transmitted. So, that is the transmission time.

So, at this point, he will be knowing exactly what to transmit. Taking the processing time negligible ok we can add a little bit of guard time probably over here including the processing time and all those things. So, then he can start transmitting whatever amount of data is mentioned over here.

So, only that much amount of data can be transmitted. Even if he has less than that data he will be padding it, he will be exactly making whatever data has been specified. So, OLT has specified some amount of data. So, he will be putting that much data and he will be transmitting. So, this was the downstream transmission, this is the upstream transmission.

This will again how much time it will take? So, from here it will actually take RTT 1 by 2 and it will be received over here, it is exactly the same amount of data ok. So, these two should be parallel ok?

So, once this is being done. Now, what should be happening, is this data coming to OLT, what OLT wants to do is he might wait for this entire thing then he can issue another gate for let us say ONU 2; so this is the polling ok? So, polling means one by one you are taking turns; but if I do that let us try to see what will happen.

So, suppose he issues another gate message over here. So, this is gate 2 for ONU 2, if he issues that; that will take some amount of time. So, what will be that time? That will be RTT 2 by 2, then he will actually receive the gate message after that he will start transmitting and then from here only you will be getting the data ok? So, whatever the data size he has specified how much data he will be transmitting.

Now, the problem with this is you can see a huge amount of gap is being created due to this polling. So, one by one if you do polling, that is really unnecessary because then at the OLT receiver you can see it is getting underutilized or the feeder fiber actually is getting underutilized, because if you take turn due to this round trip time and all those things it will be really late and there will be huge amount of wastage in the channel.

So, that will reduce the throughput, like earlier also we have seen in distributed things also because of collision and all those things we had a huge wastage. We were we slotted Aloha at max, with all stabilization and everything at max we were getting 36.8 percentage of utilization. Over here also if we do this there will be huge wastage, but can we do something better than this? Let us try to understand this.

So, what I wish to do is because I know ONU 1's data will be finished over here, can I do something? So, that ONUs 2s data exactly sits over here. So, I want to push this data over here; what OLT can do? So, this is something which we wish to check.

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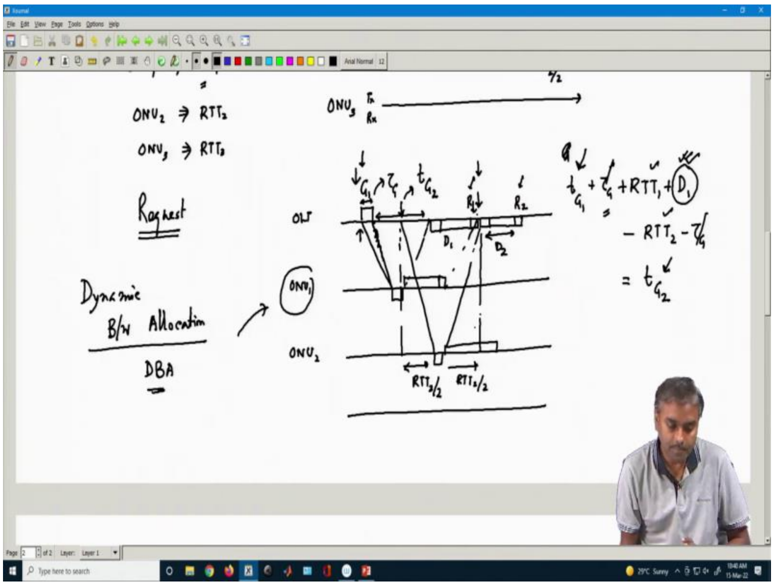

So, let me try to draw a fresh diagram and then try to understand this part. So, this is OLT only two ONUs will suffice because we want to demonstrate this. So, gate 1 comes over here after RTT 1 by 2, it is received and then he starts transmitting data whatever is specified that goes over here after again another RTT 1 by 2. So, this is what we get ok.

Now, can I sitting at OLT in advance can I calculate this time? Probably yes. How can we calculate? So, this is this when I am issuing the gate I know that. So, gate issuing time let us call that as t G 1. So, this time is t G 1 for gate message transmission let us say that is some tau G. So, this is actually tau G, that is fixed ok that is a control message transmission time I know the transmission rate, I know the size of this control message. So, tau G is known.

So, this t G 1 plus tau G that time I have got. After that when the data will be coming back? As you can see this will be how much that should be. So, that should be my round trip time ok, because as you can see ok. So, probably I have drawn a little bit wrong. So, this first bit goes over here so that is not the correct thing ok.

So, from this time to this time instance that should be actually RTT 1 ok, because Tau G has been already included over here. So, t G 1 plus tau G for his transmission and rest of the time will be the round trip time. So, plus RTT 1 plus how much data I have allowed him that is something I know.

So, this is how much time he will be taking that t 1 I already know because that is my allocation. So, I already know how much data I have told him to transmit, I know the data rate I immediately know what will be his overall transmission time. So, plus D 1 if I do I come to this point. So, that particular time instance I can already calculate from this. So, from t G 1 I can calculate when that time will be coming, when the first ONU data transmission will be over.

Now, what do I want to do? I want to actually schedule the second one over here only. Now, can I do a back calculation? So, if I wish to schedule over here. So, what will be happening is I have to actually do it in such a manner that he will be transmitting from here which is this portion will be RTT 2 by. Again, if I do back calculation, so he must have received his gate over here. So, when I will be issuing the gate that will be again this timing should be RTT 2 by 2 ok.

So, from here if I now subtract these things, I can get to see when I should issue my gate 2. So, basically from here, if I now subtract my RTT 2 ok and subtract by tau G, then immediately I get my t G 2 time. So, basically by knowing all these things I will be also able to calculate when should I issue the second gate message so that user 2 will be exactly coming after user 1 without creating any collision. And all this information D 1, RTT 1, RTT 2, tau G tau G anyways gets canceled. So, these are already known.

So, if I know the timing when I am issuing the first gate message then immediately, I can calculate, by knowing this round trip time of each user, I can calculate when I should be issuing the second gate message and when I should be issuing the third gate message. So, that is what they do to utilize the channel in a very nice fashion. So, almost 100 percent utilization we can get barring this control message. Of course, due to control messages. So, this also will have some header.

So, those will be the only waste other than that we will be able to almost reach 100 percent throughput that is a big achievement over here it is completely centralized control and we can reach up to 100 percent throughput as we can see now. Due to just this mechanism of devising the protocol. So, that part is very nicely done, so polling has been beautifully done.

Now, I can keep on continuing this. So, once I know t G 2, I can also know how much data I put in D 2 I can also calculate t G 3. So, I can keep on scheduling one after another in a round-robin fashion. So, 1, 2, 3 then again 1, 2, 3 I can keep doing this with no problem ok.

So, this polling is very nice and collision avoidance is very nicely mechanized by this centralized control. As you can see OLT is controlling everything, OLT is polling telling them he is calculating all this t G 1, t G 2 he is telling how much data everybody can transmit. So, it is a completely master-slave protocol.

Now, let us try to see that reservation part, the reverse part. So, what do we generally do? We have to reserve. Reserve means ONU has to see the data coming at ONU, OLT does not know how much data ONU is getting. So, how much data ONU 1 is getting, ONU 2 is getting that feedback I am not getting? So, we need to now devise a mechanism so that I can give that feedback.

So, for that; the next message which is called the request message, has been devised. So, what do we do we generally piggyback, piggyback means it is actually whenever I transmit the data at the end of the data I also put my request. So, the request is another small message that I attach to my data at the end and OLT also will be giving me that provision, because he knows that everybody will be sending requests.

So, in the request message again I say how much data I have left in my buffer. So, that OLT whenever this goes to the OLT; the OLT will know from here what data is remaining in his buffer. So, he just tells him the buffer status; that means, in my buffer some data you have now allowed me to transmit, I still have this much data in my buffer that request he will be able to tell, that this is the data I have to clear. Like that, every other ONU also will be doing that. So, ONU 2 also does a request 2, he does a request 1.

So, what happens all these things he will have in mind, in the next cycle when OLT is deciding the gate corresponding gate he will be able to tell, knowing this request what should be the data that will be transmitted by ONU 1, ONU 2, and ONU 3. So, this is the reservation mechanism, by this request message in a delayed fashion what you can do, you can every previous cycle you can let OLT know what is the data situation in your buffer.

Doing all these things OLT can schedule in the next cycle. So, it is a little bit of delayed feedback, but only if you make the cycle time quite small you will see that; that delay will not be significant, and then you can actually get the feedback from all OLTs in a distributed manner.

So, even though it is a centralized protocol you are getting everybody's data and then you are wisely devising a protocol so that everybody gets a fair chance for doing the statistical multiplexing.

So, that is the end-to-end protocol that we can devise by this. So, now, you know how in a particular scenario where collision detection and CSMA were not possible we could actually devise this centralized algorithm to alleviate collision.

That means we have resolved collision now, we have also mechanized a reservation scheme where every user can tell what exactly they are having and then you can actually devise a nice protocol to basically do this nice allocation of all these data in a statistical multiplexing fashion.

So, basically, you can facilitate statistical multiplexing over here no problem with that, distributed was also doing that, but centralized also you could do that. You do not have to do really TDM that ok, you have round robin means we know that give some fixed amount of time to one guy, a fixed amount of time to another guy fixed amount of time to the third guy. If you do this way then somebody might not have data he will be wasting it. Whereas, somebody who has data you are not able to use it. So, it is a TDM kind of thing where you are wasting resources.

Whereas, because the data in access we have already talked about is bursty, somebody might have data sometimes might not have data sometimes at that time somebody else might have data. So, you have to facilitate this statistical multiplexing and that is also possible due to this reservation.

Of course, it is delayed feedback one cycle you report and the next cycle you get scheduled and this particular statistical multiplexing from the perspective of PON is referred to as dynamic bandwidth allocation. There are different kinds of or it is called DBA, and there are different mechanisms of this dynamic bandwidth allocation. Seeing all these requests how do you come up with how much data I should give to everybody, to make the communication fair, to reduce the delay, or to enhance the throughput whatever it is?

So, there are multiple schemes of dynamic bandwidth allocation algorithms. So, there you devise algorithms to achieve something, either you enhance the throughput or you reduce the delay or you make fairness among users you do delay fairness. So, all kinds of things you can do, depending on that you will be devising this algorithm ok.

So, now we have seen the PON protocol, the centralized one. So, we have seen the PON protocol and how to actually devise the PON protocol. So, our target was just to show you that whenever we come up with some physical restriction, how do we devise a very nice algorithm to take out the physical restriction and enhance our whatever target like bandwidth utilization? That is something we want to enhance, that is what we have been doing for CSMA CD also. So, here also we are trying to do the same thing.

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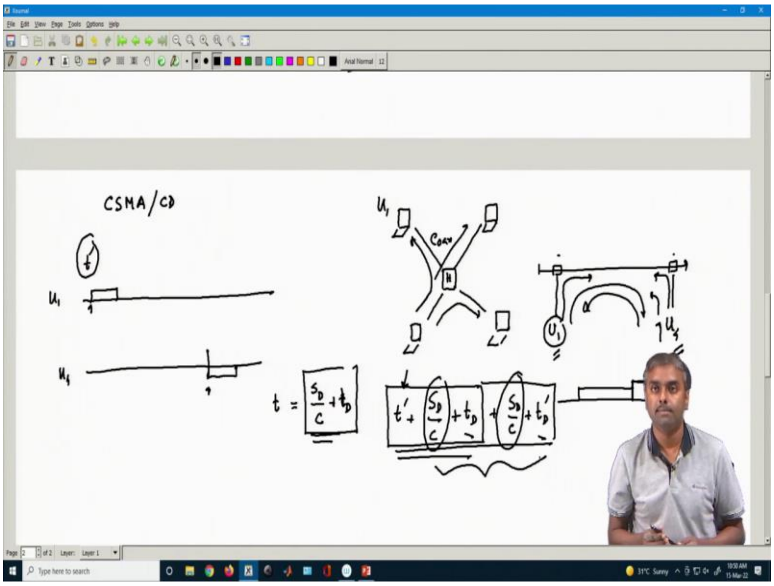

Now, let us try to see where CSMA CD is possible. So, which is the Ethernet hub protocol? So, let us say this is the hub, all the Ethernet nodes are connected through coaxial cable. Now how do we devise the protocols ok? So, once we do that and talk about the Ethernet protocol, then we can probably go back to our other part which is the wireless protocol.

So, let us try to see over here what we do. So, over here this is not a centralized protocol because nobody is masters over here everybody is independently operating. So, this is a decentralized protocol we have already discussed.

So, now let us first try to see how I detect a carrier sensing ok. So, let us say in the time let us say this is user 1. So, user 1 starts transmitting something ok. So, that is the time when user 1 starts transmitting something. Now, whenever user 1 starts transmitting there is a propagation delay, like the previous one also.

So, there is a propagation delay to reach each user, through this hub, or even if it is a bus same thing happens. So, if user 1 starts transmitting and if user 4 is connected over here user 1 starts transmitting. So, there is a propagation delay after which user 4 will be getting the data.

So, if let us take the farthest user, means if user 1 starts transmitting that is the farthest user let us say u 4 is that one ok, so that will be the highest propagation delay. So, let us say this is user 1 and whenever I start transmitting this first bit, will be received by user 4 at this time. So, that is the highest propagation delay.

So, now if you take this highest propagation delay when exactly user 4 will be able to know that user 1 is transmitting ok that should be whatever the span of the network. So, that means, the distance between these two is divided by the propagation, so this one time of electromagnetic wave. So, let us say that is C, the velocity of electromagnetic wave that I take as C, and if I take the highest distance span distance as S D. So, S D by C is the time taken for first bit that you start transmitting from user 1 to reach to the farthest user ok.

Up to that time user 1 user 4, let us say if that is user 4, that is the farthest user he will not know that there is something in the channel. So, as you can see this S D by C time plus if I take a detection time, some amount of time I have to put that integrator and some amount of time I have to integrate before I can conclude whether it is above threshold or below threshold. So, that time, let us call that a t D or detection time ok?

So, this amount of time is required for detecting whether somebody is there ok; that means, for channel sensing. So, if user 4 decides to transmit at the same time, what might happen when user 1 actually starts transmission at least this amount of time will be required for him to detect that before this time he can start transmitting.

So, if he starts transmitting just within this time. So, S D plus C plus t D after he has started transmitting let us call that t dash. So, t dash plus this within this time if he starts transmitting he will also be able to put data. Now, as you can see two copropagating data are going through.

Now, what will happen to user 1? When he starts listening there is a collision. Because now, the collision has happened, user 1 has started transmitting within this amount of time, at most of this amount of time user 4 can still transmit because he cannot sense the other user or, the presence of the other user because of the propagation delay and detection time.

So, he can start transmitting. How much time it will take for that data to come over here? So, that will take another S D by C amount of time for him to receive that. So, at that point what will be happening, is he has started transmitting after this S D plus C, S D by C plus t D that is the worst where he can still the other guy can still transmit. If it goes beyond that he will not transmit, he will abort transmission because he knows about CSMA.

So, he knows if somebody is present, if his detector says somebody is already present he will not be transmitting. So, he will abort transmission if that is the case then what will happen this guy can still transmit and again another S D by C amount of time it will take for this one to come to user 1, and then user 1 will see that there is a collision. After that for collision detection also he has to give another t D. And after this time the dash was the time when he started transmitting and after this much amount of time, he will be able to detect a collision ok?

So, this much amount of time is required for CSMA and this much amount of time is required for somebody who has initiated transmission to detect a collision and this is the worst-case scenario because we have taken the farthest user and we have taken that he is just starting transmission at the boundary up to which things are still vulnerable, he cannot detect the presence of other one.

So, if we take these things into account, what we can see is that again a round trip time comes into the picture. Among the farthest users whatever is the round trip time that if we consider together ok. This and to and fro this entire S D by C plus S D by C. So, that round trip time plus detection time one is a detection for career sensing another one is a detection for collision, these two times if it can be also different. It might be the same it can be different, one might be t D, and one might be t D dash ok.

So, whatever it is that is the time required for actually detecting means, basically this amount of time will be required or this amount of time might be there where things are still vulnerable. So, this is actually this particular time is called the vulnerable time.

So, if you start transmitting within this time another one can start transmitting ok. So, if you see that this t dash you are transmitting within this S D by C plus t D somebody else can still transmit. So, that is the vulnerable period, where even if you employ CSMA you can still be vulnerable.

So, two fellows within this time difference can still transmit this is the vulnerable period, and if you take both of them that is the collision detection period. So, this is the vulnerable or this is the amount of time it requires to resolve or detect collision.

So, there will be a time when this collision detection, due to collision detection this vulnerable period will be always wasted or this is the worst case where this time will be wasted. So, that is why you need to keep your timing designed accordingly.

So, what we will try to see in the next class is how we take these things into account and come up with a very nice timing and feasible timing protocol so that all these things can be taken care of, this propagation delay maximum these things. So, their effect can be taken care of and the protocol runs very smoothly irrespective of wherever the users are they will be able to resolve their collision.

So, this is something this is the nitty-gritty that we have not taken care of earlier. Earlier we were almost thinking that the propagation delay is negligible, whenever somebody is transmitting immediately as if I will be able to detect it, but that is probably not the case.

So, we will carefully now see what is the effect in protocol designing of this vulnerable time, where there is a finite propagation delay between users. So, whenever users start doing something it is not immediate that other users will know that. So, how to take care of that thing, that will be our next discussion ok?

Thank you.