Communication Networks
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Module - 08
Media Access Control Protocol
Lecture - 35
Aloha/ Slotted Aloha

Ok. So, so far, we have discussed uh ADSL, DSL and uh dial-up so, these things how actually in the access part of the network, the broadband access is being introduced uh, the initial part and that has been continued. Now, what we will try to do uh? We will try to see the layer 2 that we have discussed. So, in layer 2, that is called the data link layer or DLL uh.

So, the major functionality is media access control because it is generally, why we are discussing layer 2 we are now trying to discuss the access part of the network and in the access part of the network, the major functionality is there is a common media, and everybody has to somehow in a disciplined manner access the media ok. We have discussed this earlier, and we have seen how people actually a common media they talk to each other.

So, there are some protocols that we maintain and some decorum that we maintain. So, similar things we want to see in the uh protocol implementation of a data network so, for common access of a channel or media. So, this is something we will try to explore today, and we will try to see how in the access this particular very important aspect of layer 2 has been addressed over the year, historically how it has been addressed and we will also try to see how we analyze the performance of them.

We have already seen ah DTMC, CTMC, and all those things in our Marco process. So, the application of DTMC into the analysis of these media access controls is also something that will be our means which ah will draw our attention in this particular section. So, what we will try to do?

We will try to understand some of the very basic protocols that were initially introduced for a common radio media, how we basically if multiple stations are there or multiple machines are there who want to access them, and how they coordinate among themselves in a distributed manner, this is something we will try to see and the protocol, associate protocols are well known as aloha or slotted aloha a higher version of that ok. So, we will try to discuss about aloha first.

So, let us see what happens in this particular protocol called Aloha ok? This came, this particular name also of the protocol came from uh uh particular terms so, it is; it is hello uh, this is the uh; this is a term which was defined in colloquial language where this particular protocol was defined.

So, basically in Hawaii, it was actually uh this protocol was uh devised in Hawaii University uh when they were trying to connect between few computers in a wireless fashion ok. So, uh taking the help of wireless media, they were trying to define this particular protocol and there the messaging of uh or saying hello that is in their colloquial term is termed as aloha so, that is why that protocol was termed as aloha.

So, let us try to see if its probably the simplest protocol of media access control. So, basically, what has happened? So, we have multiple stations with some wireless antenna ok?

So, these are all computers probably located and at the same vicinity and they have the common media with the same frequency band remember so, they are using the same frequency band so, no no uh particular things of uh FDMA is applied over here that they will do frequency division, multiplexing so that uh there are four guys uh, suppose this guy wants to talk to uh this guy and this guy wants to talk to this guy simultaneously, they can take frequency f 1 and f 2 where these two frequencies are non-overlapping.

So, this is f 1 and that is the information you put, and f 2 this is the one and this is the. This is always something you can do, but there is a restriction because as many pairs are there so, which will be as many stations are there if n stations are there, n c 2 pairs will be there or communication link you have to uh create that many frequency slots you will have to give, that will be too much.

So, most of the time that will not be utilized because not everybody will be talking to everybody all the time, and for data networks probably, this utilization is much lower, it is very busty, sometimes there is data, and most of the time there is no data. So, this is the case, we do not want to do that, we want to just pick one frequency and we want to time utilize it or we want to do a TDM utilization, but of course, that TDM must be statistically multiplexed that means whoever has data, he will be able to access, this is what we want to do over here.

How do I facilitate that? So, if this guy wants to transmit, he will be able to transmit at that time probably, uh at some other time this guy will be able to transmit using the same frequency. So, this is what we are trying to do.

Let us try to see what are the assumptions behind this. So, basically, the first assumption is that all of them have a packet that needs to be this is a data transmission so, they have a packet to transmission so, the packet size is fixed, or the message size is fixed, and everybody has same message size so, all station; all station have same packet size so, suppose packet size is D, same D. So, everybody, every packet has a duration which is let us say D ok in time ok, it might be also specified in terms of uh bytes so, it is D bytes. So, whatever it is, whichever way you want to specify, but the message size in time and uh uh this one, it is all fixed.

And everybody employs the same modulation scheme so that is why the data rate is the same. So, basically, if the message size is fixed, then it will lock by the same amount of time in the channel ok. So, this is what we are trying to see. At that time, there was nothing, no concept of uh channel encoding or uh sorry not channel encoding no concept of uh adaptive modulation and all those things, depending on the channel what kind of modulation we will put so, that was not there.

Everybody was employing the same modulation, it was well understood from the beginning, everybody knew which modulation format to employ so, they would get the same data rate, they would be using the same frequency. The only thing is that if they simultaneously try to transmit, then they will collide ok.

So, what was the protocol? Protocol was probably the simplest one, this protocol was something like this. So, in the timeline, let us say I am talking about this as user 1, I am talking about user 1 so, whenever user 1 gets data, he immediately occupies the channel, and he occupies it for a D amount of time. So, this is the protocol, you do not do anything else, you just whenever you get the channel means whenever you get a packet, you immediately occupy the channel and transmit the packet.

So, basically, this is the simplest version of protocol where there is no protocol actually, it is; it is almost no description protocol. So, just whenever you have something, you do not worry about what is happening in the channel, whether others are transmitting or not, or whether others will be transmitting later on, you do not worry about that, you just occupy the channel and transmit it. So, remember if user 1 does that, all other users also will be doing that.

So, what is the possibility? The possibilities are that he will not be colliding with anybody else's data, and then whichever destination he is targeting u 2, u 2 will receive the packet successfully ok that is again our assumption, the channel does not make the packet erroneous so, this is again another assumption that we will be taking, we will list down all those assumptions later on when we will be actually doing slotted aloha analysis.

But right now, let us try to see if a packet size is fixed that is one assumption, second assumption is that there is no channel-induced error in the packet. So, the packets are if there is no collision, packets are transmitted successfully of course, this assumption can be relaxed, but right now, we are not talking about that. So, whenever we transmit the packet, the other side will receive the packet if nobody else was transmitting at that time. So, that is one thing.

And whenever there is a successful reception of the packet, then what he will do? He will proceed to the next packet ok. So, how he will proceed? He will wait for the next packet to come; this is what will be happening ok? So, let us try to see what can happen to the other station and due to that, what impact he can get.

So, let us say I have another station which is let us say u 3. Now, this is the time he has started transmitting, let us call that t. u 3 if you now try to see, if he has a packet because all packet sizes are the same. So, if he has a packet within this t minus D up to this ok just after t minus D if he had a packet, he will be also transmitting because his protocol is also the same whenever I get a packet. So, if he gets a packet at just after t minus D, he will be transmitting and that will collide with whatever fraction it is, it will collide ok.

And if he gets a packet within this t plus D any time, that also will come over here because he will transmit and in both cases, he will be colliding. So, can you see the vulnerable period of the packet getting collided is if he starts transmitting from this t time, then from here up to minus D and from here up to plus D, within this any other station if they have a packet, then immediately there will be a collision ok? So, that is something we are trying to understand over here.

So, we just try to see with this protocol what can happen. So, as long as nobody else; that means, no other station has a packet within this duration, I do not have any collision right. So, this is the whole situation that will be happening. So, let us try to see what is the probability that there will be a collision. So, let us try to analyze this from our Poisson arrival.

So, what we will do? We will do our take our III assumption. So, the assumption was packet size D is fixed for all users. Channel-induced errors are negligible ok uh. III assumption is, what is the III assumption? In the III assumption, what we are trying to see? We are trying to see what will happen, if means all the arrival process that follows Poisson, that means, the Poisson arrival ok.

This is remember, this is an aggregated arrival so, Poisson arrival with rate lambda ok. So, this is what we are calling aggregated arrival. So, overall, the arrival will be Poisson. What does that mean? That means if there are multiple stations on an aggregation, they will be making arrival overall, Poisson arrival with rate lambda ok.

So, if there are m stations and all m stations are identical, then we can also assume that as if they are all independently also making Poisson arrival with rate lambda by m, they are all independent so, when they come together, Poisoned margin we have already discussed, that that will be addition of all rates so, lambda by m multiplied by m because m such station will be bringing lambda by m so, all will be added. So, this overall arrival rate will be lambda ok.

We can also in this factor we can take this m tending towards infinity. So, this is another assumption that it is an infinite node approximation that means, that whatever rate they will be bringing this lambda by m, will be vanishing towards 0, but the overall arrival rate is lambda because there are infinite stations.

So, whoever makes an arrival, you can already see he will not have almost not have any arrival in the future. If another arrival happens, that happens in another station ok, this is an assumption of course, we are trying to analyze it so, we will be giving an approximate analysis of this. So, this is one assumption we are taking so that there is no queuing over here so, we are deliberately avoiding queuing over here.

So, that means, for user 1, it is not that he is transmitting that packet in between, he also gets another packet, this will not be happening because then he will have to store that packet in the queue. So, that is something we do not want to do. So, that is our we should say that is our IV assumption, infinite user or buffer less transmission ok. So, there is no buffering.

A pre-new arrival that happens must be in another station and there are infinite such stations. So, we just approximately try to analyze. Of course, these things can be relaxed we will see that later on ok. So, these assumptions can be relaxed, this is a first cut means the analysis we want to do is simplified enough. So, the infinite user or buffer-less transmission is what we are assuming.

And if there is a collision, then what will happen? So, we also think that there is somehow there is immediate feedback given, what is this feedback? This feedback will tell whether there was a successful transmission, or the transmission was not successful so, this feedback will be given immediately.

So, after this transmission happens, if there is no collision, then after user 2 sends feedback, he has a feedback channel, and that feedback channel we are right now not bothered about somehow has a channel, he will be able to tell just this one-bit information whether that transmission was successful or not to the source.

Once the source knows that it was a successful transmission, he will discard this packet otherwise what he has to do is the retransmission policy. So, he will reattempt because the packet was not successfully transmitted, think about that it is a; it is part of your email and if it is not successfully transmitted, then you have to retransmit it so, that is the retransmission policy. So, that is another assumption.

So, what is the retransmission policy? The retransmission policy over here says the following things: it says after this when he will be attempting that is random, what kind of randomness we will have that is something we will discuss later on. Right now, what we can say is that from here, he will be again putting an exponential time and then, he will again attempt ok. What will be the strength of that exponential? So, those things will be discussed later on ok?

So, if this is exponential and this is independent of the arrival process, then again whatever that retransmission as you can see this retransmission is an extra attempt, so that means, that must be again added, everybody will be doing this retransmission and that will be added to my traffic. So, that new traffic will be termed as G which is also this G is the rate like lambda, but it will be greater than a lambda, there is a possibility ok, that this g will be greater than lambda because if there are collisions, then he will be retransmitting.

So, if he is retransmitting, then whatever arrivals are happening on top of that some more arrivals will be happening due to retransmission those are also Poisson distributed, so they will also be independent, so they will also be added. So, the overall string will be Poisson again that Poisson strength will be greater than some lambda whatever lambda we have defined which is the actual arrival rate, that will be greater than that, but that will be the actual arrival rate to the system so that the retransmission I can still take him as if he is a fresh arrival at some later time that will be happening ok.

So, again no buffering policy because he is retransmitting after he sees that my packet was not successfully transmitted after getting the feedback. So, once he gets the feedback and the feedback is negative that means, in the feedback, I see that there is no successful transmission, then I go for a transmission ok.

So, accordingly, there will be a retransmission rate so that retransmission rate again is Poisson and that is an independent Poisson so, I can add them with the lambda and I get that effective rate G ok. So, this is ah we can now tell that there is an effective rate of G arrival and all those are being addressed ok.

Now, we have to see how many of these G arrivals are being successfully transmitted ok, let us try to see that probability. So, if he makes an arrival G and the packet duration is D, so, what is the possibility that there will be no collision? So, suppose one transmission is going on, at time t, and one transmission has been initiated by one user ok?

Now, overall, what can happen? The rest of the nodes and all those retransmission means putting up together overall with G rate there can be arrival and what is the vulnerable period from t minus D to t plus D within this 2D period, anything arrives that will be making this collision happen ok.

So, if the other arrivals respect this arrival that I am targeting, with respect to this arrival if the other arrival has a rate of overall G because all other stations and all ah retransmissions are all coming together if they are all coming together with a rate of G, then within this 2D period if any arrival happens, then I can immediately say that there will be a collision. So, that is the probability of collision.

The probability of collision means that some arrivals are happening within this D, 2D sorry. So, some arrival is the collision probability. So, what is the success probability? P s that means, within 2D no arrivals are happening, this is something I can evaluate because it is a Poisson arrival. So, within 2D, no arrivals are happening, what is the probability? (Refer Time: 20:47) probability is e to the power minus whatever the time duration that is 2D into rate G. So, this is the probability that no arrival will be happening within this 2D. So, that is the probability of success.

What is the overall distance? Overall rate of arrival I have an overall rate of arrival of G ok within 1 second. So, how many are getting successful? Within G, I have an overall rate of arrival G ok. So, that is; that is the average rate of arrival G and success probability is this. So, therefore, G into e to the power minus 2DG says that per unit of time, this many will be successfully transmitted.

Now, always for this one, D I can take it as a unit. Whatever the value of D, I can make that as a unit that is my time unit ok. So, D if I make it 1, then this will become G e to the power minus 2G ok. That is telling that within unit time, how many successful packets will be transmitted because this is G is the rate of arrival which means, how many packets are arriving within unit time.

This is exactly telling how many packets are successfully being transmitted because each packet is also of unit time so, that is the overall success and that will be then our throughput also. So, that is very simplified, that is why we have taken so many assumptions and all these assumptions have facilitated us so that we could get a very nice throughput analysis.

So, this throughput if you now plot, how that will look like? So, what is the variable? Now, G can be a variable I can; I can decrease, or increase G of course, my lambda is the variable, which is the arrival rate, on top of that, there will be a collision overall the arrival rate that is happening is G.

Now, if I vary G, I can plot this, this has been observed that it appears to have a graph like this, if you plot this with respect to G you will see that it gets a peak at G equal to 0.5 or half and what is the value of that? So, you will see that it will be half into e to the power minus 1. So, it is actually 1 by 2e. So, this value will be 1 by 2e which is the highest throughput that you can get at the value of G 0.5 means half value.

As you can see if G is half and my D is 1 so, half, this is a lambda or let us call that means, G is the effective arrival rate, so the arrival rate is half, and my packet size is which is x bar, and this might be lambda which is 1. So, therefore, overall traffic intensity is half Erlang according to our earlier definition. So, with half Erlang, what is the throughput I get? 1 by 2e, this roughly comes towards 18 percent ok.

So, what we get is effective throughput, the maximum effective throughput in this chaotic transmission where I do not obey any rule, I can transmit at any time, and I still get an 80 percent success rate or 80 percent of the time, I am successfully transmitting things that is a wonderful result because this is probably the simplest protocol you can get where you are not coordinating anything, you do not coordinate anything.

Without doing that coordination also, you might achieve, we can see that we might occasionally with the proper rate adjustment, we can still get an 18 percent success rate which means, 18 percent of the packet can still be successfully transmitted which is a good thing because now, I have 18 percent chance of successfully transmitting the packet if I operate at the right region.

Of course, if you operate in this region or this region, it will be less than 18 percent. Even if you go to these regions, it might be very low that there is a possibility, but I can always optimize my rate towards achieving this higher one which is the 18 percent ok.

So, later on, what we will try to do can we mean by means of protocol, over here there was no protocol actually, we just whenever I have things, I will transmit. If I now see that I can put some discipline into it, can I really increase this rate, rate of success? That is what we will be now trying to target and that is how all the protocols have been developed.

So, coming from aloha to slotted aloha, you will see slotted aloha will immediately double this, then from there CSMA, CSMA CA, CSMA CD, you will see we can push towards almost 18 percent utilization with those protocols, those fancy protocols and we will slowly develop those protocols and we will see that what is the effectiveness of those protocols, how that brings some kind of nice understanding among the nodes in a distributed fashion.

Remember this is a completely distributed protocol, nobody is coordinating over here, every station in Aloha, every station coming immediately, he is transmitting, but nobody is coordinating. So, in this chaotic distributed fashion also, we will see how they can coordinate among themselves without exchanging or with exchanging very minimal messages, without wasting the channel by exchanging control messages. So, that will be our target and we will next, we will try to see how to achieve that part.

Thank you.