Communication Networks
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Module - 08
Media Access Control
Lecture - 36
Slotted Aloha

So we have started discussing about PD access control protocol. So, that is the data link's clear main functionality we should say. And it is it is generally used in the access portion of the network. What we have done.

So, what we have discussed about a very basic protocol which is the aloha and we have seen that already kind of a maximum 18 percent throughput can be achieved by the aloha protocol, which is a very basic random access protocol where all the users just whenever they have packet they transmit. We have done some analysis with some approximation ok. So, we have done that and with that, we have seen the maximum throughput that we can achieve.

In the due course of this discussion, we will try to see how this intuitive understanding of the analysis actually gives us a better understanding of protocol and a better proposal of a protocol.

So, this is something which will be throughout the next few lectures we will try to appreciate exactly how in the developmental phase a protocol has been developed through the extensive use of this Markovian analysis that we have already taken into account and have learned. So, we will try to see how that has been applied in the history of the development of media access control protocol. So, that is something which we will be trying to approach means appreciate.

In the meantime, we will also try to see what the approximation, means how in a particular analysis the approximations are taken how they are being relaxed, and what the consequence of them ok. So, this is something we will try to understand. So, in our journey let us try to go to the next step which is the Slotted Aloha, let us see how a very simple intuition gives us a better understanding of a protocol.

So, let us try to see, when we have talked about aloha what were our approximations, because we have also talked about any analysis then approximation is very important. So, what is the system model for Aloha? It was like this.

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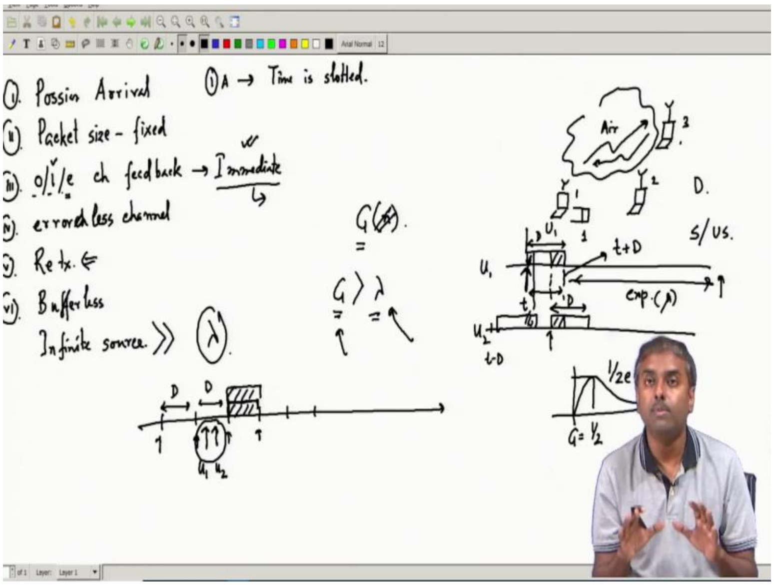

You have a common air media where all the stations have wireless interfaces and the system is something like this or the understanding is something like this, they are getting packets the first approximation was the Poisson arrival. So, that was the first assumption that everybody was getting data independently with Poisson's arrival. So, that is what they are getting.

The second assumption was that the packet size was fixed. So, that was another assumption that everybody has something to transmit that packet size is always constant of size D ok, both in time and in terms of the number of bytes they have. So, in time also it is fixed because they have similar transmission rates. So, they are their interface is at the same frequency with the same modulation scheme and all those things. So, basically, they have similar interfaces.

So, that is happening and what they do, they randomly access the channel ok. Randomly means completely randomly in a completely distributed fashion. So, whenever he has a packet he immediately launches that packet in a time frame if you see. So, this is user 1. So, whenever he gets the packet immediately he puts it off duration D. If this is user 1 that should be like this. If user 2 is there, whenever he gets a packet he will immediately put it of duration D.

Now if they have a common region because it is a common media. So, the packet will collide and you will not get anything. Both the transmissions will be erroneous. So, this is what we have assumed whenever they have a packet they will immediately transmit.

What are the other assumptions that we had? So, the other assumption was regarding what happens to the packet once he transmits it. So, if he transmits the packet now we have to see what happens, and what are the possibility. Whenever he transmits there are few possibilities or if he does not transmit.

So, there are a few possibilities, the one possibility is that the packet will be successfully received at the other end. So, if he is trying to transmit it over here, the package will be successfully received that will only happen if no other transmission is coming within this, within this period of his transmission. So, that happens then the packet goes successfully.

If there is a collision, the packet will not be received successfully. So, whether it is a successful transmission or unsuccessful transmission these feedback the station must get. So, that is the feedback. So, we call it 0 1 e channel feedback and this is immediate. So, 0 means no packet transmission, 1 means successful packet transmission, and e means multiple stations are transmitting packets simultaneously so there is a collision ok.

The fourth assumption was that due to the channel, there was no error. When I transmit the packet if it is successful then there will be no other errors. So, it is an error errorless either that or the error has been already taken care of by the source coding. So, this has been done.

So, this is our next assumption and the feedback must be immediate. What does that mean? That means whenever this transmission is done immediately by some mechanism the station that is transmitting will get the feedback. We will later on see how this immediate feedback can be accounted for.

Because either the feedback can be that he actually transmits an acknowledgment. This is something we will appreciate later on or by some other mechanism from the physical channel only you can get feedback that also we will try to appreciate. So, how this feedback is this immediate feedback is given to the user, this is something we will try to see how physically we can make that. So, that is another thing. So, these are the means basic four assumptions.

What are the other assumptions? The other assumption is that when there is an unsuccessful transmission what do I do? So, then I do retransmission. So, basically, it is like this he has a buffer whenever the packet arrives, he immediately transmits it and keeps that in the buffer ok. Remember that buffer has only size 1 which will come in the next assumption. So, it keeps the packet over there in the buffer and whenever he sees that the channel is free he immediately tries to, whenever he gets the packet immediately he transmits the packet and keeps that in the buffer this is what he does ok?

So, once he has done that ok. So, this is what he does, he keeps the packet, if the packet is successfully transmitted then immediately he will be getting feedback by some means, whatever that immediate feedback we are talking about he will get that feedback, and then he will discard that packet and wait for the next packet to arrive ok.

In between this process if another packet arrives our assumption is no other packet arrives, if it arrives we discard that packet ok because the buffer size is a maximum of 1. He can only hold 1 packet. He will just hold it till the retransmission or till the transmission has been successful. If the feedback comes as unsuccessful he will attempt retransmission.

How he attempts retransmission, is another part of the protocol, a description of the protocol that he probably randomly chooses a later time to transmit it. We have said that it is again exponentially distributed time after which he tries to retransmit that packet. How much exponentially distributed is something we have not commented on ok?

Somehow with some exponential distribution, he tries to do this ok. How he does that is something we will try to understand slowly as we go inside the protocol. So, this is what will be happening.

And then the last assumption, 6, is what we are talking about that either it is bufferless; that means, he has only one buffer he does not he cannot store multiple packets. The assumption is either rate at which he is getting packets is so slow that he can only think about one packet after a long duration the other packet will come. By that time there will be some successful transmission.

So, either it is like this or we can also assume that if in between some other packet comes that will be discarded or the other version of this approximation is there are infinite sources, together all source gives a packet transmission rate of lambda; that means, an individual has infinitesimally small rate. So, therefore, they will never get the next packet because their rate is infinitesimally small. So, inter-arrival is almost infinite.

So, therefore, each of the stations will never get the next packet. So, it is like this every packet comes from a new node ok? So, as you can see these are all restrictive approximations, and with that approximation we have done some analysis.

The only thing that we have still not characterized is this retransmission. This is something that will be characterized now later on, we will see that ok slowly because initially, our assumption was ok it is some adjustable Poisson rate, when I am doing the retransmission if this is unsuccessful, after this with some exponential distribution time he will be again reattempting. So, this is that reattempt thing that we are talking about.

That we have still not characterized, what the parameter of that. So, if this is mu what should be that particular mu we have not characterized it as ok. We will we will try to see that. I said somehow this will be done and then the overall arrival rate we have talked about is some G n ok or G. Let us forget about this.

The overall arrival rate will be G which is greater than this lambda because there are some more arrivals that are happening due to this unsuccessful transmission when you are trying to attempt retransmission. They are also independent because the inter-arrival is exponential so, they are also Poisson, they will be merged to this Poisson, and overall things will be some G. So, with lambda some more things will be merged.

They are all independent Poisson, so overall things will be still Poissoned with arrival rate G, and with that, we have done some analysis we have seen the characteristics. Something like this ok. And we have seen that it reaches up to 1 by 2 e ok which is basically the 18 percent that we were talking about ok, approximately 18 percent ok. And it reaches half, hence when G equals half ok. This particular graph also we will we will try to describe it in a more genetic fashion when we go to slotted aloha then we will understand it properly.

So, far we have done this. Now on this, we will add one particular description which is called the time is slotted. So, let us say 1 A we do and we say the time is slotted that is when slotted aloha comes into the picture we want to see this. So, where from this has come let us try to analyze that, it is embedded in the analysis itself. So, in aloha what was happening? Suppose I want to transmit a packet, what is the overall vulnerable time when this packet might collide because that is what I am interested in.

So, if he gets the packet at t we have seen that up to t plus D, so this time t plus D any other station gets a packet it is vulnerable; that means, there will be a collision. Not only that beforehand if I consider up to time t minus D within this if somebody had arrival and that was already being transmitted that also will be vulnerable because there will be a common zone, a common region of time where they will be simultaneously transmitted in the channel and this will be creating a collision.

So, overall if you see t minus D to t plus D that is the vulnerable period that is 2 D amount of vulnerable period is there where I have to make sure that no arrival is happening if I just make time slotted. And just do a little bit of modification of this. We say it is like this if I have a time frame this timeframe is slotted every slot distance is D which is the exact time of a packet transmission. So, every slot is of duration D, I do the time slotted.

The additional thing that I will have to do which makes the system more complicated that everybody has to have this synchronous sense essence of time so; that means, they know exactly when these time slots are started and when they are ending. There is a global synchronization and this synchronization is somehow being maintained among all these distributed nodes user 1, user 2, and user 3. So, if it is user 1, user 2, user 3. So, it is distributed among all these nodes and they all know about this synchronous timing this is something that is approximated.

The transmission now I put a restriction on. What is happening now? I say earlier whenever they were having arrival I was immediately transmitting, over here he was getting an arrival over here, immediately he was transmitting right, he was putting the transmission. So, whenever there was an arrival he was immediately transmitting.

Now, what we want to do we do not want to do we will restrict it. So, the arrival might happen over here, but the restriction is because they have a synchronous time essence they will only transmit over here the slot boundary. So, the previous slot whoever has received the packet will attempt immediately in the next slot boundary. This is exactly what we do ok. So, every arrival will not be immediately transmitted they will wait for that slot to be completed, and for immediate next slot, they will immediately transmit.

Again they do not consider what others are doing, they will do their things. So, if suppose user 1 gets an arrival over here and user 2 gets another arrival over here, both the user will start transmitting over here, user 1 transmission over here, and user 2 transmission also over here, and then there will be a collision of course, ok.

So, now, what is happening? Within a slot duration D if there are multiple arrivals then there is a collision can you see the vulnerability period has been reduced just by doing this because earlier within 2 D any arrival was creating a collision ok.

So, if one transmission is going on within 2 D anybody makes an arrival I will have a collision. Now what here has happened only within D is if more than 1 is arriving then there is a collision, if nobody arrives then nothing happens, the slot remains idle nobody transmits. So, if suppose within this slot, then the next slot remains idle. So, that is why this 0 1 e is happening.

So, 0 means no arrival in the previous slot, 1 means 1 arrival in the previous slot, and e means multiple arrivals in the previous slot. I am talking about arrival there is something more also because now there is retransmission also.

So, now, let us try to see with this particular scenario what happens to my retransmission. So, let us try to understand.

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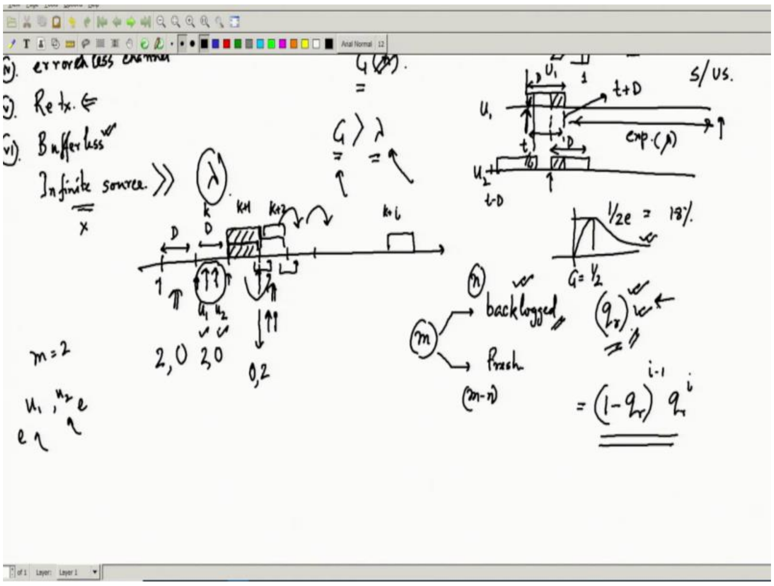

So, let us say there are m number of stations ok. So, m number of stations are there. So, I am now taking a finite station approximation, not the infinite source. This infinite source I am not taking, we will come back to that later.

So, a finite number of stations with bufferless approximation; means, they have only a single buffer, just for retransmission the packet will remain over there till he gets a successful transmission, once he gets successful transmission he will discard that and then wait for the next arrival. In between if any arrival happens he will discard this ok. So, this is what? This is the approximation we are taking.

So, there are m station ok. Out of this m station what might happen, I can segregate them into two classes of stations one is called a backlogged and these are fresh. So, what do I mean by this fresh and backlog, backlogged means he has already attempted a transmission it is is kind of memory he has attempted a transmission, but his last transmission was unsuccessful; that means, when he was transmitting multiple other nodes were also transmitting. So, because of that there was a collision and his transmission was not successful. So, that is why he is now waiting with his packet in the buffer to get a chance of retransmission.

So, earlier we gave a vague when we were trying to describe the scenario for Aloha we have given a very vague description of when he will be transmitting the packet that some exponentially distributed time after. Now over here we will quantify that. Now the time is slotted I can quantize. So, what I can say is that next slot he will attempt, but with some probability let us call that q r is his attempt probability.

If he has been unsuccessful he gets immediate feedback. So, suppose 2 has arrived over here user 1 and user 2. So, let us take this scenario user 1, user 2 has arrived over here only 2 users are there. So, m equal to 2 we have only user 1 and user 2, earlier user 1 and user 2 do not have any data. Both their data arrive at this particular time ok? So, let us say this is timeframe K, this is K plus 1, this is K plus 2, and so on.

At K 2 arrival happens immediately next slot both of them will be attempting. So, they collide. So, the feedback goes to both as e, how this will come, we will not think about that. We will assume that immediately after the transmission he gets immediate feedback and no more time is required and somehow he has some resources to get that feedback. So, he gets this feedback that transmission has been collided for both the users. Now both these users will be backlogged.

So, now this out of m if we say that n number of users are backlogged and m minus n number of users are fresh users who can take new arrivals. So, what has happened; earlier at this point how many users were fresh? 2. How many users are backlogged? That was 0. At this instance still the same thing ok. So, basically, 2 users had made arrivals, but still, they have not transmitted. So, they are still not backlogged. So, 2 users are fresh 0 users are backlogged.

Over here collision happens, immediately they will know that ok, these 2 users are backlogged. So, immediately at this instant the state will be changed. So, he has 0 fresh users both of the users are backlogged. Now, for the backlogged user what we are saying is this is the protocol that they will be transmitting immediately in the next slot with the probability of q r ok. What will be the value of the q r that we will decide later on? So, that will be our part of the analysis.

But this is what we are saying immediately in the next slot they will be transmitting with probably some probability q r, nothing else ok. So, what does that mean, is that memoryless now that when he is transmitting let us try to understand this particular part? So, next slot he will be transmitting with probability q r, but what about the next slot again with probability q r? So, what is that constructing, what is the probability that he will be finally, transmitting at the next K plus i-th slot?

You immediately know that in between all this I minus 1 he does not transmit so; that means, 1 minus q r is the probability that he will not transmit to the power I minus 1 and then i-th slot he will be transmitting q r to the power I that is the probability that he will be attempting at the i-th, K plus i-th slot. This is a non-distribution we already know this. This is a geometric distribution which is again a memory just distribution because the time is slotted now everything will be discrete.

So, this distribution also becomes the means discrete version of our exponential distribution just geometric distribution. So, as we can see almost all things remain the same, whatever we have decided earlier almost similar things remain over here, our description remains over here where we are talking about a particular geometric distribution now ok for every station. So, they will attempt this.

What will now happen, if both of them collide why we are putting this probability value also there is a reason for that. Let us try to think if 2 nodes go into backlog, it might be 2 it might be more than 2 whoever goes into backlog in the next slot immediate next slot if both them attempt they will again collide and this will never be resolved because they will keep on colliding in every slot. So, the entire this one, entire time slot will be all collision and nobody will be able to resolve the collision. So, by putting this probability we are randomizing who will be transmitting.

If more than one station has transmitted; that means, I have to now resolve the collision otherwise I would not be able to actually give a chance for transmission to one. So, this collision resolution is coming up with the very basic idea of putting this probability q r as you can see. This also gives you a very basic idea in aloha what we have told that takes a random this one randomly driven exponentially distributed amount of time after which you will be attempting.

So, immediately next you do not attempt. Over here we are giving a chance to do this transmission immediately next, but that is with the probability again that makes these things random. So, basically, whenever there is a collision we are somehow resolving this collision by randomizing these things; that means, putting a probability of q r into this.

So, now, as you can see what will be the possibility of transmission over here that is now a mixture because some of the nodes might be backlogged? So, it might come from their attempt or some new arrival can also happen if there are some fresh nodes. So, it is a combination of these two that will be attempting a transmission, and then from there, you have to understand whether there is a collision happening or not.

I hope that makes the whole system very clear crystal clear. So, this extra thing we add to this whole description of Aloha. So, I had a very simple method, and now we are putting some extra description to it, and with this extra description, the first description we are given we have slotted it.

We have also observed why we have slotted the time because the vulnerability period we could reduce was the intuition that was coming into our mind while implementing this. So, we could reduce that vulnerability period and after doing that reduction with respect to this distributed feedback and retransmission mechanism we have devised a particular mechanism.

And why we are devising that mechanism? Again we are putting this probabilistic retransmission because we want to resolve the collision. So, this is probably the first method probably towards resolving collision. So, once we are in a collision state we need to resolve the collision it is always true.

Suppose I can give you a very simple example. Suppose you have a narrow doorway and then 2 fellows are trying to attempt if you keep on attempting nobody will go through this. What we do, we make an understanding among ourselves. So, whenever there is this one just one of the guys says ok you go first because if you go then the door will be cleared and then I can get the chance.

That same thing is happening over here. 2 nodes who have collided are in a distributed fashion they are trying to resolve this collision. So, that conflict which was happening at the entrance of a doorway, the same thing is happening over here between 2 stations; who do not know each other ok. So, they are trying to resolve it. How they can resolve this? By randomizing this. So, this probabilistic attempt is the main architect behind resolving collision.

You will see that later on. We will try to describe this in a more means more detailed fashion later on, but this is the basic idea behind it. So, after all this description can we now analyze this let us try to see that. So, is there a possibility that we will be able to analyze this?

So, for analyzing let us try to see how I analyze this, it is all random, exponential arrivals are happening you have this attempt also is some probabilistic thing. So, it is a random process, of course, and this random process has to be analyzed.

Can we see that it is a Markovian process? Why it is a Markovian process? Because the retransmission of all the events' arrival is Poisson ok. So, arrival is Poisson, time is slotted of course, and this particular retransmission attempt is also we have given this probabilistic description and once we have given probability description it has become again geometric which is again memoryless. So, everything all events are memoryless.

So, therefore, it is it has the potential to become Markovia and the time is slotted only things that are happening are at the boundary. Of course, arrivals are happening over here, but with arrival what I am doing is at the boundary. So, basically, from the system perspective, it is still at the slot boundaries only. So, discrete times events are happening.

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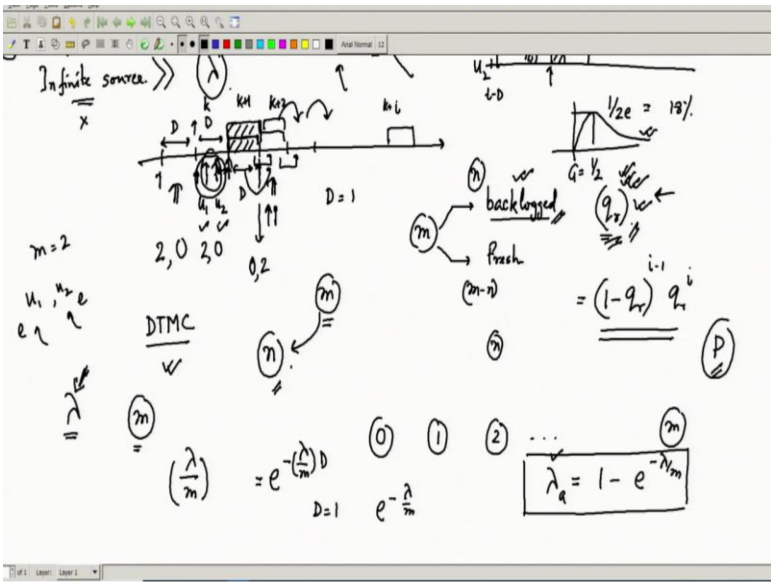

Therefore I can say it is a clear candidate for DTMC. Once I have this understanding this will be analyzed by DTMC. Now can I go one step forward to see how I describe the state?

So, now I have to describe the state in such a manner that that strap means that the state summarizes everything, I do not need anything else. So, let us try to see if is there something that summarizes everything.

The thing that summarizes everything carefully think about that is the amount of station which has gone into backlogged is n ok. There are m stations among them and the station has gone into backlog. So, always what will be happening, after every attempt there will be this backlog station which will be modified.

And that is summarizing everything you do not need any other description. Because what will happen, is if multiple fellows attempt then they will all go into backlog. So, the backlog will be increased, number of stations that are backlogged will be increased. If nobody attempts means nobody comes over there and no retransmission attempts are being done then it will go idle so the backlog remains the same.

If some new state means suppose there are means a successful transmission, then what will happen? One of the backlog stations might have a successful transmission. Then he will be relieved from this backlog to fresh or he will come from backlog to fresh the overall backlog station will be reduced.

If a new station attempts and no other backlog station or no other new station attempts he will be successfully transmitting, again the backlog station will remain the same. So, this is the only number if you keep track of several backlog station that describes the whole state very nicely you do not need any other description.

This description of when this has arrived is not required because it is all about Poisson's arrival it is exponential. So, I can take that memory out, I can think that all these thoughts have freshly arrived over this boundary, that we can do we have already seen that.

And how much time he is in the backlog that is again geometric so, it is memoryless. So, for every slot, I can forget about that memory, how much time he has a station, and if he is in backlog how much time he is in backlog. I do not have to consider that because that is again a geometric distribution. So, it is a memoryless process.

So, therefore, just taking the number of stations in backlog describes my state ok. So, it can start from 0 goes to 1, 2 up to m at max m number of stations all stations might be in backlog that is the whole thing that is my state description. Now I need to populate the transition matrix with the P matrix, this is where I have to see from the system description can I get the description of this transition matrix ok?

So, for the transition matrix one probability I have got for the backlog station. If he is in some backlog station means backlog state n from there each of the stations with probability q r will be attempting transmission in the next slot.

So, in the next slot what will be happening that probability I have to get, because probably transition matrix is this that at time K it is in some state let us say it will be 0, 1, 2, whichever state he is assuming from there at time K plus 1 where he will be going. So, in that transition matrix, I want to calculate, where he will be going and what is the associated probability. This is what we want to calculate right.

So, if we wish to calculate that we will have to now see how do I get this probability calculation. So, one probability value we have already got already q r, now for the fresh station or the station that has not been in backlog for them how do I calculate what is his transmission capability or transmission attempt?

The overall arrival rate is lambda. This is actually a Poisson merged function of m stations. So, basically m station there is a total of m stations which makes arrival Poisson arrival and they are all identical stations, they make poison arrival and with that overall arrival actually I get a composite Poisson arrival of lambda ok.

So, if that is the case then each individual how much arrival strength they will be having? They will be having lambda by m because they are all symmetric and they are all homogeneous. So, each individual station will be attempting a poison arrival of rate lambda by m right.

Now, within a slot duration ok let us call it D and we will take D as a unit, and D as 1. So, within a slot duration of 1 or D whatever it is, what is the probability that one particular station will be attempting a transmission? So, how do I calculate that? So, that attempt we are characterized by lambda a. So, this is something we want to characterize that the value of this lambda a-ok, that a particular station will be attempting transmission.

How can I calculate that? First, let us try to see what is the probability that he will not arrive in this D or in this unit time. So, that is e to the power minus lambda by m that is his strength into D, or if D is 1 that will be 1. So, if D is 1 D is equal to 1 it will be e to the power minus lambda by m. So, this is the probability that he will not be attempting any transmission or he will not be having any transmission within this D. What is the probability that he will be having this lambda a? That must be 1 minus this, 1 minus e to the power minus lambda by m.

So, we have got these two probability, one is this and one is this one ok q r. So, these two probability we have got. Now in the next class what we will try to do, is take these two probabilities we will try to see how I calculate or how I populate this P matrix of this particular Markov chain. This will give you one essence or one example of how to develop a DTMC and then how to analyze that ok.

Thank you.