Communication Networks
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Module - 06
Data Networks
Lecture - 29
Introduction to Data Networks (Contd.)

So, far we have started discussing, we have finished our discussion of the means of this circuit switch network, and we have started discussing the Data Networks right. So, we will continue the same thing in this class also. So, we will try to see means why this data network has come into the picture and what are the salient features of this particular data network. So, let us try, last class whatever we have discussed from there, let us try to see what are the summary we have got.

So, there were a few observations, when DARPA first started initiating this connection between machines for information exchange between the machines we saw that there was some experimentation done regarding the traffic. For any network design now you have to understand probably, that traffic is very important traffic is the source that will be going through the network. So, all network design has to cater to that traffic.

So, first I need to characterize the traffic that effort was done by one of the seminal papers by Sally Floyd and V Paxson, we have already discussed that. So, there they started enquiring about those data traffic and we could see that because of this human-machine interaction and the way humans behave. So, there is a different kind of pattern compared to the voice traffic. So, voice traffic was something like I actually initiate a call and after that the way actual voice traffic is still human things.

So, of course, it will also have some on-and-off period. So, there is something called the part of the talk and then there is some silent period, but the actual way we have encoded voice it does not matter whether the person concerned is talking or not we always sample it, if he is not talking even the noise gets sampled ok.

So, with a constant interval of 125 microseconds that is the Nyquist sampling rate we have already discussed those things. So, we just sample the voice signal and we get a constant bit rate, 64 kbps for a single voice right, we have seen that.

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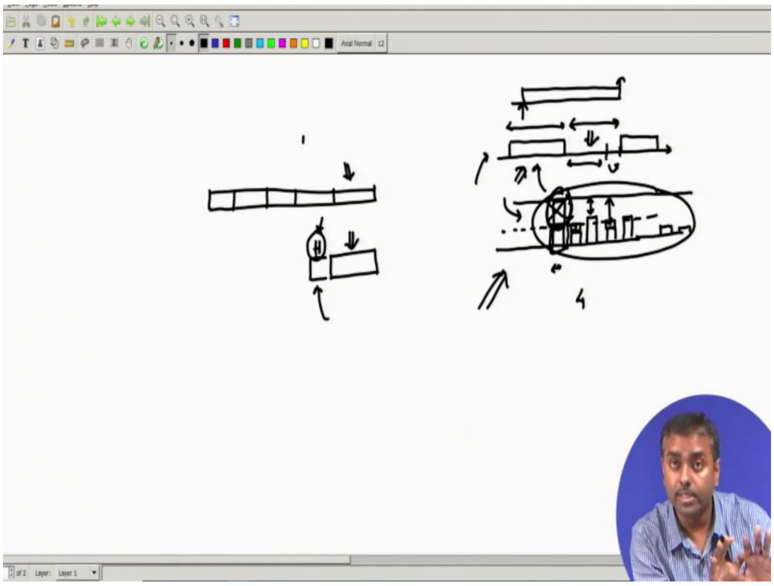

So, it generates from the start of the call to the finish of the call, it generates a constant bit rate this is something we have seen for voice ok. That is because of the encoding the way we do PCM encoding.

Whereas, for data traffic what could be seen because of this human and machine interaction? So, it will be a little bit different, we have already discussed that some of the portions of time are the general behavior of humans that they will be on they will be doing some activities and then they will be resting, next, they will be again doing some activities.

And these events are random all random. How much time I will be active, and how much time I will be inactive, that is all these on-off patterns are very random. Also, Sally Floyd and Paxson have measured them and they could see that the distribution of this on period and off period they are all independent.

And they follow some kind of other distribution, not exponential not memoryless it has a memory property, that also if you try to understand it has a memory property because of human nature. So, if I keep on working; that means, if I keep on doing something I will get tired. So, more time I do more possibility is there that I will end that session ok end that on period.

Again, off also I will get bored. The more time I wait I will get bored. So, that means, it does not have that property of memory lessness, it has a property where the more time I elapse I have a different distribution of when I will be next doing things. So, that is the reason why there are some memory processes we have seen that have some long-range dependency like all these Pareto, Weibull, or normal kinds of distribution.

So, which has a heavier tail, which also we have discussed. So, that kind of thing happens for each traffic. So, that will be the traffic case ok. Some amount of time a huge amount of traffic will be coming whereas, some other times there will be no traffic. Now, what will be happening multiple such users will get integrated and they are all independent. So, that is the kind of traffic that will be actually generated due to this machine-to-machine communication.

So, when I reconnect machines, the way the internet we see these days it sits unlike the telephony network right? So, over there because of this human entity sitting in every machine. Of course, now the next generation of traffic coming where robots will be communicating. So, it will be completely machine-to-machine communication.

So, that is the different kind of thing, that might have a different kind of traffic. So, next-generation traffic might be even more different, but for the time being for internet traffic what we could see that this is the kind of traffic that we have termed as self-similar, and self-similar is characterized or a bursty kind of traffic, it is characterized by these things, that whenever you see the traffic it has random burst.

That means, some amount of time a huge amount of traffic will be coming, next time there might be some less traffic and so on. Some kind of this random pattern will be, sometimes it is nothing is there, sometimes very low amount of traffic. So, something like this kind of bursty nature we will be observing and this burst; why it is called self-similar? This burst does not go away.

So, even if you for exponential traffic there also traffic is coming randomly, sometimes more traffic sometimes no traffic, but if you take a sufficient amount of time it gets averaged out. So, then you will be seeing an almost similar amount of number of packets or number of customers arriving. If you take a huge amount of time, that does not happen on the internet. So, this is the beauty of it.

So, because of the nature of those distributions and associated human property. So, basically, you see that even if you take a longer duration, you will almost see a similar pattern again, similar burst will be coming. So, therefore, the burst in this kind of traffic cannot be eased out that is the whole property that we are trying to emphasize. Whatever you do whatever amount of time you take and then clear things your burst will not go away.

So, it will still look bursty that is something we have to keep in mind. So, if it is so bursty then what do we have to do? Now, let us try to understand the design criteria. If we wish to do the same kind of TDM switching that we are aware of then there is a problem because what will happen, if I do TDM switching, suppose TDM can handle per unit time ok?

So, only 4 packets, let us say it has a fixed rate right? So, per unit time this is 4 packets or 4 whatever unit data unit it can handle ok. Now, suppose the 4 is over here, this is 4 this is kind of average. Sometimes it is much higher, sometimes it is much lower sometimes it's much bigger than 4, maybe 10 are arriving, sometimes it is almost 0 or 1 or 2.

So, what will happen to TDM, whenever it's having this huge thing he can only take these things because he can only accommodate 4. So, he will take four and he does not have any buffering. So, he will be discarding all these things. So, there will be huge data loss so imagine that your email is coming to you with some intermediate words missing.

So, they have all been lost or some image is coming to you where some of the things are randomly missing because of your network. That is not the quality you want from, because you are transferring information.

In voice, some of the things are still missing we can construct the voice right, but, for data, it is very important that you are supplying some data, suppose a Wikipedia page I am opening and some lines are missing intermediate, which will not be good experience for me or some image there are some blank pages here and there spotty blank or black spaces that is something we do not want. So, therefore, we need to do something. What I can do? I can still have the TDM switch, I can still do TDM.

But I give the peak one peak bandwidth ok. So, if he can handle 10, then he will be able to capable of handling everything. So, I do not have any problem. So, every time I give 10, but he is not able to utilize it, only occasionally whenever that peak rate is coming, peak burst is coming he is able to take that whole thing rest of the time he has this residual capacity which he is not able to utilize it.

First of all, as an engineering designer, I will have a problem with that because I am putting resources that are not being utilized this is one thing. But the second thing is this problem peculates, what happens I will be integrating such things. Now, for everybody if I wish to give this much bandwidth think about this when all these things are aggregated at the core part of the network will it be able to handle that capacity no, it's not, it is not possible.

Either I will have means I will not be able to support that many users or I will not be able to give quality to those users, that is the problem that was coming in TDM switching, this people understood very well. Then they started thinking can we do something about it? So, that is when in our previous few lectures lecture 2 or 3 we started discussing putting buffer over there and putting a very interesting kind of multiplexing which is called statistical multiplexing.

So, in statistical multiplexing what do we do? We do not drop things over here, we actually store them. So, we start introducing a buffer in the switch. So, in switch, if I do not have capacity, I know that I have bursty traffic. So, right now probably too many packets are coming I know that there will be a period where packets will not be supplied at that time those free places I can store things in a buffer and I can clear that buffer.

So, what is happening I am putting now random delay with this statistical multiplexing, but with a lower capacity at the output exactly what we have demonstrated in lecture three with the lower capacity I will be able to supply all these things, but that has a high inside also.

In TDM what was happening? My location was my address now that is not the case because I am jumbling up the location in time because I am buffering them randomly, how much time I will be buffering depends on all other things how much packet has come earlier, how much space is there left in the next one next slot. So, depending on all these things I will be able to clear.

So, when they will be cleared I do not know beforehand, it completely depends on the traffic which is random to me, I do not know the characteristics of that traffic. So, therefore, I need to whenever I am putting buffer I need to know those packets are getting jumbled up, and the times are no longer addressed. So, I am missing the address altogether where they are coming I do not know right now.

Because times are no longer the address earlier time was address. If I am having in the first slot I know where it is coming and where it will be going that is not happening, because randomly I am shuffling them. So, the next switch will not understand whose packet is this or whose data is this. So, therefore, along with the packet now I have to put some header that identifies the packet.

So, therefore, what I will do? Earlier I was actually just taking samples and transmitting that, now I will not do that I will take the whole data chunk which is what is done in packet switching. I will subdivide it into small packets we call that packets that might be a fixed size, that might be a variable size we will see those things. But right now just some chunks will be divided, and some small amount of these things can be handled what should be the optimal size also we will discuss later on.

But I will divide it into some chunks, it should not be too small you will also see why it should not be too small it should also not be too big. So, we will see all those things. So, for some chunks of intermediate size, I will take each chunk, and then I will add a header to it. So, that is why it should not be very small.

Because this header is completely redundant. If I for 1 bit I put a 1000 bit of header, then I am only transferring the header. All the way every packet will have 1 bit only information and all others are headers which are not required just for networking purposes I am doing it.

Because I am buffering them because the address is lost. So, that is why I am putting them. So, therefore, this header portion of this means that compared to this actual data portion, the actual information portion must be much smaller. Otherwise, I am transferring, I am wasting my bandwidth to transfer garbage information which is not actual information. This is only my added information so that I can handle them inside the network, this has nothing to do with the end user ok.

So, that is why the packet cannot be arbitrarily small, we will later on discuss why the packet cannot be arbitrarily big also. So, that is also something we will discuss later on. So, you do that, you add those headers that identify the packet. So, now, no longer I have to be worried about which time slot they are in and that is their address. I do not have to do that I can randomly shuffle them around I can randomly delay them, and I can randomly store them in in buffer.

Because the packet itself carries a header that identifies where from he is coming, and where he will be going all the related information is already there. So, therefore, each switch now has an additional task. He does not just do switching like the TDM switching we have seen, it has slot by slot a particular switching logic that has been given he just keeps on switching like that.

It is not as simple as that now I will have to for every packet I will have to read the header, and from the header I have to infer what I need to do with the packet, and then I switch them, accordingly I decide which particular port I will be forwarding them ok. So, that is the change of switch that has happened. Why that has happened now you should understand, the whole purpose was the bursty nature of traffic.

That is why it is so important I keep on telling this multiple times because it should be registered in your mind that everything is done because of the traffic, you have to characterize the traffic first and then you start initializing the network design.

So, after traffic characterizing we could see it is bursty. So, because of that, we started introducing buffer. So, with a lower capacity, we can handle things. We can even out the burst ok.

So, whenever there are bursts, some portions are extra over here that we can divide and put wherever the extra capacities are free. So, I keep doing that. So, that the overall link output link capacity looks like a CVR kind of thing, this is what we will be doing. We will be trying to do this statistical multiplexing and associated we call this packet switching, it is no longer circuit switching it packet switching along with its called packet switching because all the switching instructions are given with the packet, in there in the header I read the header and accordingly decide.

So, I do packet-by-packet switching not the entire circuit I create and then all data goes through that circuit we do not do that any longer ok? So, this this particular facility is called the statistical multiplexing, we have already discussed that. So, this is what we will be concentrating on why we do now we have understood why we do packetization why we do statistical multiplexing why buffers are required, and why a header has to be added.

So, these very basic parts of packet switching or data networks are now understood I hope. Once we have understood that let us try to understand some more things, some more features of this network. Let us try to see what is going on over here.

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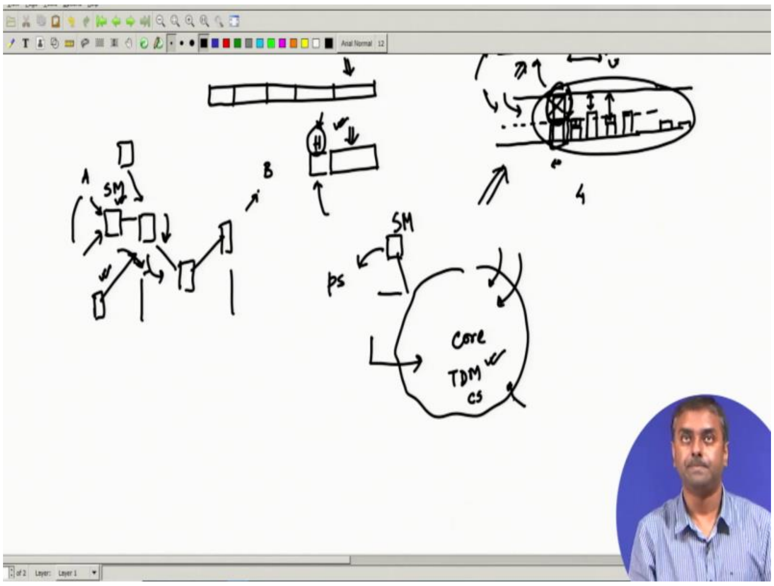

So, I have a network, let us say I have some node A that wishes to connect to B ok? So, it is geographically separated and A wants to communicate to B, A generates this kind of data traffic which is bursty in nature and it is targeting B. Now of course, in networking, we know that directly I do not give a copper wire or something fiber wire or wireless link from A to B, we go through networking we put switches and all those things.

So, it will go to a switch, the switch is something like this kind of switch pack packet switching, it does statistical multiplexing. So, it is doing statistical multiplexing from there I will be constructing an output ok. What will this output look like? Now, let us try to understand. I have an input traffic that is bursty in nature, I do statistical multiplexing and I generate an output.

The output must look smoother because that is why I am doing statistical multiplexing right. So, that output will look smoother. Now, what should I do? Should I continue doing this packet switching all through the entire network? So, rest of the switches I do that or should I do something else?

Let us now try to ask ourselves what should be the best way of handling these things. One thing is I can continue doing packet switching no problem in that, but the problem will be that as I go penetrate inside the network. So, more and more aggregations are happening. So, this will get data from multiple switches, this switch gets data from multiple users.

So, more and more aggregation is happening, more and more aggregation means the data rate is getting increased because if one user is there I have to probably let us say I have to give him some 2 Mbps data rate. So, good average 2 Mbps I am giving. Now, if from a locality I am taking a switch to the next locality then I am probably aggregating thousands of users.

So, 1000 into 2 Mbps that will be the rate now. So, it is 2 Gbps, now at 2 Gbps doing all these tasks of every packet you open read the header, and then do the switching this is going to be a daunting task, you will not be able to scale up to this particular speed. So, for that what we need to do we can over here we can see we have two advantages I already know tdm switching that operates very fast because he does not have to read any switch, which means any header.

He does not have to do any means he does not have to change anything in the switch matrix every now and then with every packet or every data bit that comes. Once I construct the circuit, it just keeps on going in the same fashion of operation because all the times are slotted everything is synchronized, and it's all TDM multiplex.

So, I do not have to do those things. So, there the switches are very fast, can I leverage those things towards the core part where more aggregation is happening, for that I need this I cannot do statistical multiplexing over there. If I go to TDM switching, but fortunately I can see my statistical multiplexer at the beginning stages is actually smoothing out traffic, input bursty they are actually constructing more smooth traffic that is exactly what we are doing.

We are underprovisioning the things we have already seen in lecture three that if we take three lines sometimes something is there sometimes something is not there with appropriate delaying and buffering, we can actually with a lower rate we can transfer the things.

So, the aggregated rate is under-provisioned, and that is what I want. I want to encash, that we have already seen that this I could have given the peak rate and aggregated all the peak rates, but that is a wastage. I want to take the average rate and I should aggregate. So, I will be giving a slightly lower number of these things so that that gets filled up and I get smoother traffic.

Once I get smoother traffic, I am capable of doing circuit switching at the center part of the network because then I have two advantages one is my switching becomes faster, I can actually do things and because of this statistical multiplexing, I have already reduced the rate.

So, there the aggregated rate is also reduced, all those bursty traffic he is catering to these things. The second thing is the second advantage I get, once I do the intermediate part I do TDM switching. I do not have additional delay it's just one go, it has a bypass path through all the switches and there is no delay. If I do time switching only every time switching you have already seen that, every time switching probably that 125 microsecond delay I will be offering ok.

So, that is the delay. If I have space switching I do not have any delay, it's instantaneous. Only the propagation delay will be there, no switching delay will be provided over there. Whereas, if I do statistical multiplexing I have to queue them, I have put them in a buffer then according to the availability of the output they will be served. So, the queuing delay will be added to every intermediate node.

So, therefore, my network should look like this, the core part of the network must be TDM multiplexed and must be circuit switched. Whereas, the access part which is the interface towards the user, user to the core network is where I must be doing statistical multiplexing and I must be doing this packet switching that should be the network.

That is the network and that is why we have put so much effort into understanding the TDM switching, because you might be asking TDM switch was a voice network that is becoming ancient history now. Who needs to study that? That is a waste. No, it is not waste; it is still being used and it will be used in the near future.

This is absolutely required because with statistical multiplexing and IP rooting and all kinds of other switching, all packet switching you cannot survive at the core part of the network. Where the network means traffic volume is increasing in such a high manner that you will not be able to do that kind of packet-by-packet switching header reading and packet-by-packet switching.

Whatever you do you will be always required to put some kind of TDM multiplexing so that switching becomes easier, the hardware-related hardware is easier to implement at that high speed because the speed is daunting. This philosophy you will have to understand is what happens in today's network and in the near future also if something does not drastically change this is what is going to happen. This also historically has given us some other advantages.

What was the advantage of networking always remember it looks like everything coexists, why you know because it is the infrastructure you put in, a huge amount of cost goes into putting that infrastructure, do you want to next day you have a newer idea? So, you take out all this infrastructure that might have cost you billions of dollars or billions of rupees.

So, why do you want to take out that entire infrastructure and go to a new technology? That nobody does in networking, because it is cost a huge amount of cost is required to install the network infrastructure. So, overnight if they are not, means you can repair them you can replace component by component.

But you do not throw away the entire technology and as a green field deployment you deploy the whole thing overnight you do not do that. You will be doing it gradually and this particular philosophy actually helped in that also, that the core part I can still keep whatever was there. Till day today also things are all happening with SDN or SONET switches which are TDM multiplex things ok.

So, therefore, whatever you do in networking always has to be with this philosophy. So, in a way you can see philosophically it gives me an advantage because, I can actually do statistical multiplexing I can reduce the traffic and then I can do TDM switching because

I will have faster switching over there, I do not have to I do not have to cater any delay over there.

So, the core part of the switching will be faster and we do not have any delay over there, that is advantageous end to end user if you see they do not want to add delay one after another, then if I am doing online gaming or if I am doing some newer application like augmented reality or factory automation you will not be able to do those things.

So, therefore, that is the thing that we will be trying to do over here, this TDM switching is very important over there, and that is really required. So, that is one thing; that means, circuit switching kind of thing. So, circuit switching is not because of the they are history that they were used in telephony networks, they are not going away they are pretty much staying over here with a bigger role of course in today's modern network which is the IP network we keep talking about.

So, it is a more data-driven network data data-centric network, even voice is now being converted to data, like voice over IP we are doing. So, voice r or VoLTE you are doing voice over LTE. So, voice is converted to data and they then taken as data video is converted to data and taken as data.

So, we no longer have concepts of analog video or analog voice and or PCM-encoded voice, actually, everything is now being converted to data. So, it is predominantly becoming data, but probably predominantly becoming data in the access part of it. That is something you should be taking in means you should be taking that concept with caution, That does not mean that TDM switching is thrown out of the park, it is not the case, it is pretty much there in the central part of the network.

It has a huge role to play and most probably you will see the more complex the network becomes even though that core part will penetrate means higher and higher inside the network, towards the access part this will be happening. All you will have to do you know that the fact is the data will be always bursty. So, you have to put a statistical multiplexer at the front end ok?

So, what will do next after understanding this big philosophy we will see how the network has evolved and how there are separations of zones. Now, you can see some core parts we are talking about where TDM switching will be there. Access part probably some statistical multiplexing has to be there or packet switching has to be there.

So, we need to understand how in networking we segregate the network, core, metro, and access we will talk about that. And once we segregate, why we segregate because their networking predominant technology is different, the philosophy is different. We have to also see how they coexist from one to another, and how smoothly they can transfer because it is an overall one network. It has to be orchestrated properly so that it functions as a unified network. So, this is something we will be discussing next ok.

Thank you.