Computer Networks and Internet Protocol
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Lecture - 11
Transport Layer – 1 (Services)

Welcome to the course on Computer Networks and Internet Protocols. So, in this course we are talking about the 5 different layers of the TCP-IP protocol stack. So, till now, we you have a good idea about this 5 different layers of the TCP-IP protocol stack and professor Shivmog has already given you a broad overview of the different applications that can run on top of the network protocol stack.

So, today I will start with the second layer of the protocol stack, that is the transport layer of the protocol stack and we look into different services which are there at the transport layer of the protocol stack and how it helps you to provide end to end connectivity between 2 machines and transfer data from one machine to another machine.

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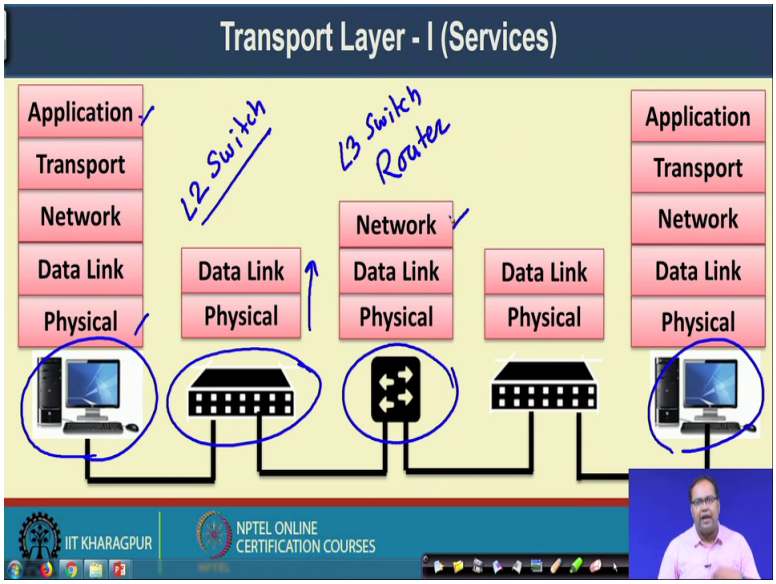

So, we look into the various aspects of transport layer protocol stack. So, before going to that let me give you a brief overview about how different devices in the network are connected. So, at the 2 ends so we have 2 different devices or 2 different machines, so these are the 2 different hosts which are transferring data between themselves and at the 2 end host we have all this 5 layers of the TCP-IP protocol stack. Starting from the

application layer where you are running certain kind of applications like the browser applications or like the chat applications.

Then you have this transport layer which provides the end to end connectivity between the 2 layers of the protocol stack, after the transport layer you have the data link layer which will help you to find out a suitable path between 2 devices in the network through multiple intermediate devices right, like the routers at the switches. After the network layer you have the data link layer, the task of the data link layer is to provide you the channel access mechanisms when multiple nodes are trying to transmit simultaneously and they are utilizing the same communication media like the same wireless channel or the same wire network.

And finally, you have this physical layer of the protocol stack which takes care of the physical layer signaling techniques and the different modulation and the coding schemes. Now the 2 end host in the diagram they have a both the 5 layers of the protocol stacks starting from the application layer and the physical layer.

Now the intermediate devices they may not have this all the 5 different layers of the protocol stack say. For example, sometime in the network you have this devices which we call as the l 2 switch or the layer 2 switch, the layer 2 switch has the protocol stack up to the second layer like up to the data link layer. Then you can have this layer 3 device these are we call as the layer 3 switches or a router.

So, this layer 3 switch or the router they have up to the network layer of the protocol stacks. So, they help you finding out the paths among multiple hosts or multiple devices in the network, when you are trying to make an end to end communication. Now the transport layer it sits on top of the network layer and the transport layer is only there at the 2 end host and the task of the transport layer is to ensure the end to end performance or the end to end functionalities of the network.

So, we will look into the details that what are the different end to end functionalities in the network, which can be utilized or which can be implemented as a part of the transport layer and interestingly you can also write your own program to support or to configure the transport layer to make 2 end devices communicate with each other or talk with each other.

So, we look into all those details in subsequent classes where we will look into something called as the socket programming, to find out how you can send data end to end between the 2 end host. So, before going to that let us look into the various aspects or various design primitives of the transport layer, which is been utilized by the network to ensure reliable and high performance data delivery between any 2 host in the network or any 2 remote hosts in the network.

So, these 2 remote host can be sitting in 2 different countries or 2 parts of the world. So, it may happen that 1 machine is residing at say here in IIT, Kharagpur another machine is residing in say at the Google office at USA.

So, whenever you are trying to make these 2 nodes talk to each other, it is just like that you need to have set up of multiple end to end functionalities. Like the lower layer of the protocol stack first of all they are not reliable, there can be packet loss from this lower layer of the protocol stacks. So, the transport layer ensures the reliability of a data transmission at the same time it also offer multiple other services, so let us look into the details of how this different services are implemented in the transport layer of the protocol stack.

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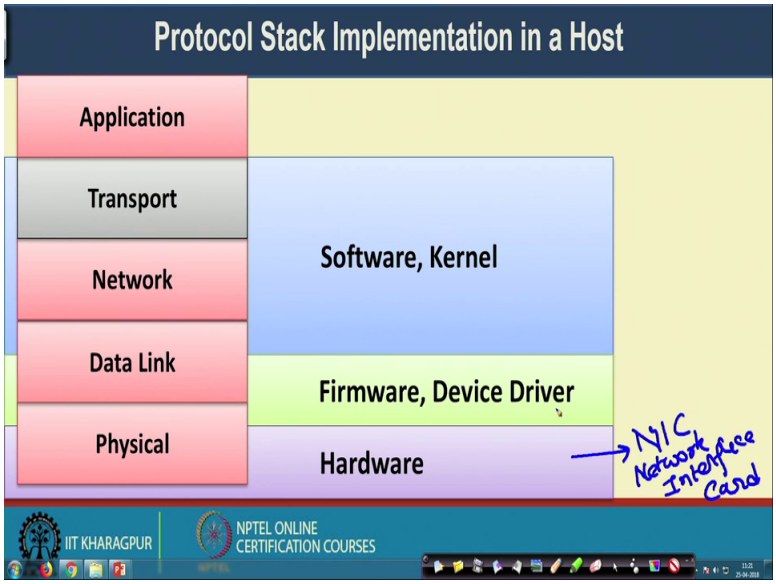

So, well so this is this diagram actually gives you the implementation semantics of a different layers of the protocol stack, if you look into the perspective of an individual computer or an individual end host. So, if you look into an individual computer a

computer per primarily have 3 different modules, like at the bottom you have the hardware module of a computer. Here in case of networking devices this hardware module contains your network interface card or the NIC, NIC or we call it as the network interface card. So, these network interface card provides you the hardware layer functionalities.

So, this entire physical layer it is implemented as a part of the hardware it is a part of the network interface card. Then on top of the hardware you have the firmware at the device driver. So, this firmware at the device driver it provides you a way to interact with the physical layer, so this firmware of the device driver that has the implementation of part of the data link layer and the part of the physical layer. It varies from a different variant of network and different variants of vendors.

Say for example, if you think about the wireless network. So, the physical layer it is entirely implemented in the hardware and also now a day's some part of the wireless data link layer protocol it is also implemented as a part of the hardware to make it fast or to make it make it robust in the context of a large number or large amount of delivery. On the other hand many of the device drivers in wireless environment as well as. So, wired environment the data link layer is implemented as a part of the device driver of the firmware.

So, the device driver of the firmware that you install for your network interface card that primarily have the MAC layered implementation. Then a part of the MAC layer which is later on we will see that it is called a logical link control module. So, a part of the MAC layer and then in the upper part of the protocol stack like the network layer and the transport layer implementation, they are implemented as a part of the software at the kernel of your network protocol stacks.

So, it is it is the part of the kernel if you think about the Unix type of operating system, where inside the kernel you have the implementation of the higher part of the data link layer which we call as the logical link control and then the entire implementation of the network layer or the sometime we call it the IP layer in the context of TCP-IP protocol stack and then the implementation of the transport layer.

The different type of the transport layer protocols which are implemented as a part of your software or operation system software or in a UNIX type environment it is the

kernel part of the operation system that implements this transport layer and the network layer. Then on top of that you have multiple applications running.

So, this different applications are design by different network designer or different application designers, we will also learn how to implement a network application which can talk over 2 end to end devices. So, this application can be the browser application to access web data or that application can be certain kind of chat application where multiple parties want to chat with each other or it can be something like a standalone applications.

So for example, in a android based operation system you see there are multiple application the Facebook application, the twitter application the YouTube application that access data over the internet. So, all this different applications are implemented as a part of your application layer. Now in below the application layer we have the transport layer of the protocol stacks. So, you can think of that this transport layer it makes a interface between the user application and the operating system. So, whenever the data from the user application is going to the operating system it is going where the transport layer.

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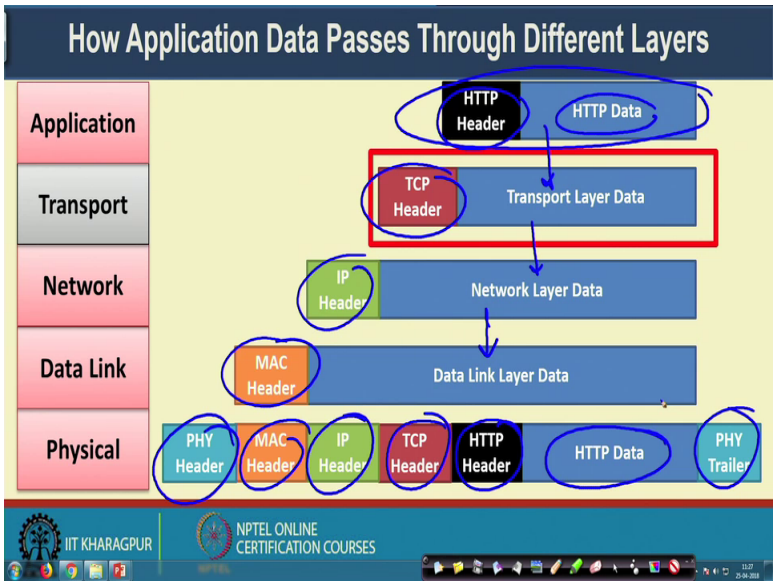

So, let us look into that how this different layers of the protocol stack adds up their own header, in the initial discussion of the TCP-IP protocol stack you have got up brought up over view about how the data is being passed through multiple layers of the protocol stack.

So, in the application layer if you think about the context of an HTTP application which is sending data on top of a browser, so you have this HTTP data that is coming from the browser and on top of that the HTTP protocol it is it adds up it is own header.

So, this HTTP header information it contains the various information about the application layer connectivity, then this entire data the HTTP data along with this HTTP header that comes as a part your transport layer data. So, these transport layer data it is the inter data which is coming from the application layer and with this transport layer data we adopt a transport layer header.

So, we will look into the different type of transport layer protocol like the TCP protocol or the UDP protocol and various are the transport layer protocols and they are like RTP.

So, every individual protocol whichever you are going to use. So, as an application developer you have to mention that which particular transport layer protocol you are going to utilize, you are going to use for your purpose whether you are going to use TCP type of application or whether you are going to use UDP type of application. So, that the difference between TCP types of application and the UDP type of application, we look into shortly.

So, so the transport layer it adds up it is own header with the application layer data at contains multiple information for managing the transport layer protocol. Now this inter transport layer data and the transport layer header it comes as a data to the network layer and the network layer adds up it is own header then it comes to the data link layer. The data link layer again adds up it is own header we call it as MAC header in the context of the data link layer and finally it comes to the physical layer. So, whenever you are coming to the physical layer you can see that you have a small amount of data which is coming from HTTP and then different type of headers which are being added by the different layers of the protocol stack.

So, the application layer it has add up the HTTP header, then the transport layer it has added up it is own header then the IP layer it has added up the IP header. Finally, the data link layer had adds up it is own header and the physical layer adds up physical header and sometime for some protocol it also adds up a trailer to actually identify an end to end frame. So, that way the entire thing gets deliver over the network.

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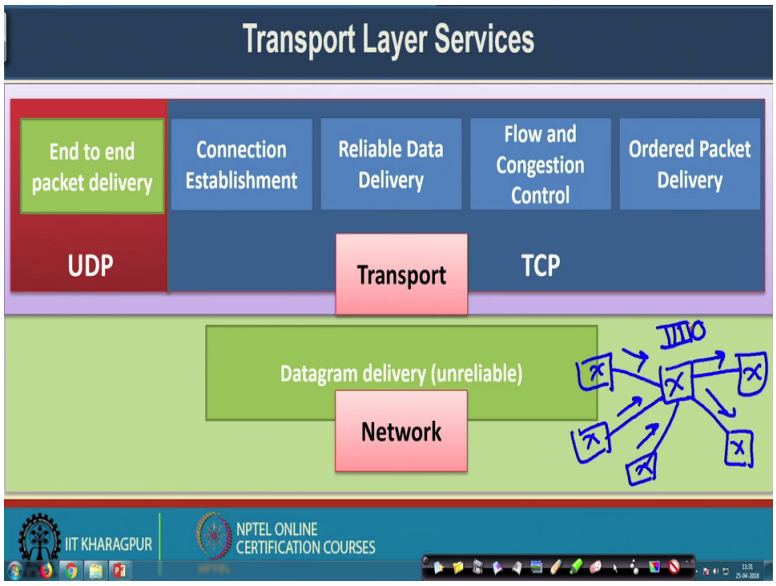

Now, if you look into the context of the transport layer, that why do we require the transport layer in the internet. Now, just below the transport layer you have the network layer and the functionality of the network layer is to ensure the datagram delivery. So, when you say it as a datagram delivery it indicates that the network layer whenever it will receive a packet in the packet or in the network layer context we call it as a datagram.

So, whenever it will receives the datagram in the datagram it there is this source address and the destination address felt. So, the task of the network layer is to look into the destination address and accordingly forward the packet to the next hob. So, the network layer basically ensures that data delivery among multiple hobs in your devices say for example, say you want to transfer a datagram or transfer certain data from 1 machine at IIT, Kharagpur to another machine which is residing at Google user say you are going to access www dot Google dot com.

So, whenever you are going to access that and your data need to be transferred from your machine say currently I am at Kharagpur. So, the machine of at Kharagpur the data need to be transfer to the Google server which is there in the USA. Now in between there are this multiple routers which are there we call it as the layer 3 switches or sometime people call it as a layer 3 devices. So, there are multiple routers there in between so the task of those routers is to forward the packet to the end host.

Now whenever the routers are forwarding the packet the packet to the end host and here we are thinking about the packet switching principle or packet switching architecture in the principle of packet switching, packet switching architecture or packet multi placing architecture what happens that the intermediate routers they have a finite amount buffer and the packets are pushed to that buffer.

Then the router performs a route look up on the by looking into the header of the packet and then decide that which particular out going interface the packet need to be a transferred. Now when a router is doing this task and by the time it has receiving multiple data from multiple data neighboring routers. So, the architecture of this entire network is really little complicated.

So, let me just give you 1 one example, so you have 1 intermediate router here whose task is to send the data and it is also receiving the data from multiple other routers. So, it is receiving the data from all this different routers and then it is task is to send this data to some next of router 1 or 2 multiple next of routers.

Now this particular router it maintains an interface Q and that interface Q will temporarily hold all the packets. Now in any devices this stem this particular host or this particular device it has finite amount of buffer space within it, because it has finite amount of buffer space within it. It may happen that because of high load in the network the buffer become full, when the buffer will become full the packet will start dropping from the inter intermediate routers.

So, that way the network layer all though it is task is to find out or it is task is to send the data from one end host to another end host many of the times it fails to support reliability. Reliability in the sense that there is no guarantee that your particular data that will be transferred from one end of the host to another end of the host. It may happen that at intermediate routers the packets get dropped because, of this kind of buffer over flow apart from buffer over flow there can be error in [du/during] during the physical transmission of the packet, there can be a channel interference which can happen in the case of a wireless network.

So, there are multiple reasons because of which a packet can get dropped. Now when ever a packet is getting dropped or the packet is being lost while doing a end to end delivery of the packet by the by the data network layer. So, we say that the network layer

provides this datagram delivery but this datagram delivery is unreliable, so it supports unreliable datagram delivery.

Now whenever you are providing unreliable datagram delivery at the network layer, then at the transport layer your task is to ensure that the packets or the message which are you trying to send from one end host to another end host that messages are transferred correctly.

So, in other words what we can say that the application should not get hampered by the loss of the data from the intermediate routers or the intermediate network devices. So, the transport layer it takes care of this particular thing. So, the transport layer it provides reliable data delivery on top of this unreliable data gram delivery, which is supported at the network layer. So, the task of the transport layer is that to monitor whether a particular data is being transferred at the other end host or not if it is being transferred.

So, it is happy if it is not being transferred then the task of the transport layer would be to monitor that and if it finds out that will certain data got lost while doing transmission. It task would be to support or to retransmit the data, so that eventually the message that the application was trying to send to the other end that is getting delivered. So, one important task of this transport layer is to ensure this reliable data delivery, so to ensure this reliable data delivery transport layer can provide other services like this connection establishment.

So, the concept of the connection is just to say a hello to the other end hosts. Say for example, whenever you are making a telephone call, so once the other end picks up the phone your first voice is or first message is a kind of hello message.

So, through the hello message you want to ensure that the other end is properly able to receive the message that you are going to transmit. So, once the other end also acknowledges your hello message by saying another hello and both of you have established the kind of logical communication or a logical connection between yourselves, then you start talking or start sending other messages.

So, in the data transfer perspective these connection establishments are just like this hello messages, say one end of the devices it wants to make sure that the other end is alive and the other end is ready to receive the message.

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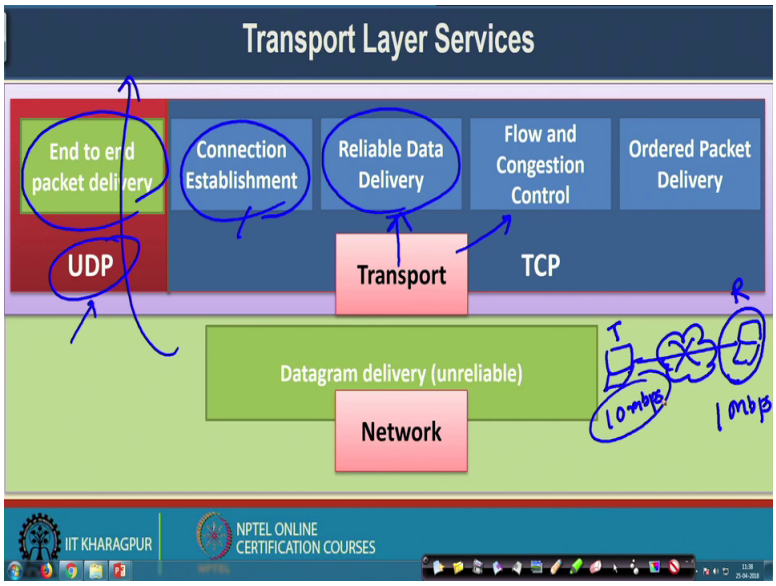

So, that is the connection establishment service which is being provided by the transport layer then the transport layer provides end to end packet delivery. So, there are 2 different groups of transport layer protocol 1 transport layer protocol is this UDP or the user datagram protocol.

So, UDP is not like a transport layer protocol or it does not provide any special transport layer services. So, what UDP does? UDP just work like a wrapper of this network layer protocol stack or the IP layer of your protocol stack. So, the task of the UDP layer is that whatever data you are receiving from the network layer you directly pass that data do some small checking and then directly pass that data to the application. So, why we require UDP because, certain kind of protocol certain kind of application they do not require reliability, but the importance is the performance.

So, you can understand that whenever you are implementing this multiple type of services at the transport layer. Obviously, it will introduce certain amount of delay in the network and whenever the transport layer is introduced in this certain amount of delay in the network the other end it will suffer from large considerably more delay compared to normal datagram delivery, because you are providing additional services at the transport layer.

So, some time the application requires a real time reception of the packet, but it can tolerate the loss the channel loss. So, the application does not require reliability that are

getting a packet quickly is the major importance. So, in that particular case you do not implement any transport services at all.

So, we just use this UDP protocol and the UDP protocol helps you to embed this entire network layer data and pass it to the transport layer and give the data to the am application which is demanding for a service, which is important for which is important for application perspective in the context of having application layer data delivery and it does not demand for a reliable transmission of data. The transport layer also provides certain additional services like the flow control and the congestion control.

So, this flow control and the congestion control it is just like say whenever you have 2 different hosts which are trying to transfer data among themselves and there are this intermediate network this intermediate network am can introduce multiple delays or packet loss in the network.

So, the flow control ensures that well this particular end, say it may happen that the receiver can receive the data at a rate of 1 mbps and the transmitter can send data at a rate of 10 mbps. Now if that is the case under this transmitter. So, I am naming it as T and the receiver I am naming it as R. Now if the transmitters send data at a at a rate of 10 mbps and the receiver can receive data only at a rate of 1 mbps.

So, what may happen that the additional data that you are pushing in the network, that is making the network or that is having a over it at the network. But those particular data not getting delivered at the other receiver like it is making, the network congested by pushing additional data in the network. But it is it is not making the reviver to receive the data at that particular rate.

So, during that time this particular additional transmission of data from the transmitter side it is wastage for the network perspective and that is why transmitter and the receiver need communicate among themselves the transmitter and the receiver need to agree among themselves. So, that the transmitter can only send the data that the receiver can receive, so this particular concept we call it as a flow control. Now there is another thing in the network which is called as the congestion control.

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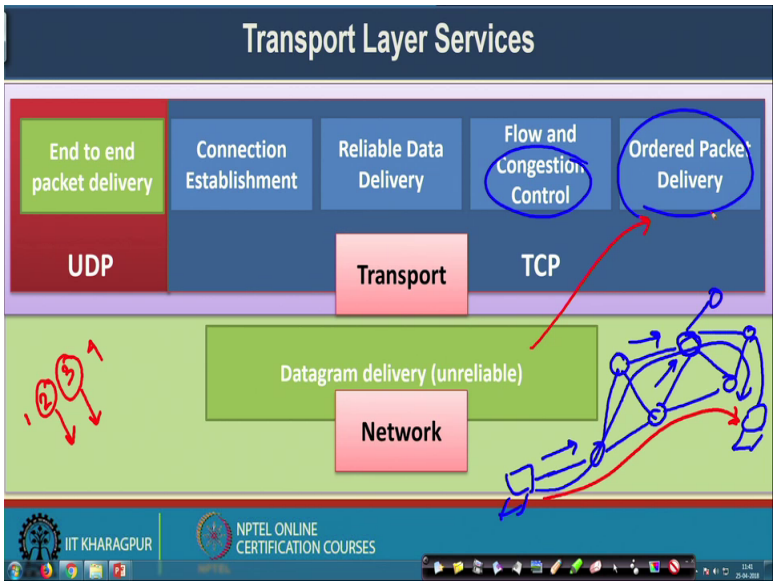

So, that congestion control is something like this so whenever you are transferring data in the network, if I just represent the network as a graph where every network devices is represent at a node. So, in that case this particular node if you just think of an intermediate node it receives data from multiple other paths.

So, you can just think of this entire network as a anonyms to a as a synonymous to a road traffic network. Now in case of a road traffic network in a in a road junction in a in a road junction point, if traffic is coming from multiple road in that case it may happen that well this intermediate junction becomes congested.

So, this transport layer of your network protocol stack it supports congestion control. So, it avoids congestion whenever you are receiving packets from multiple different paths. Another functionality of the transport layer is to support ordered packet delivery, so what is this ordered packet delivery the ordered packet delivery is.

So, whenever you are transferring the data between 2 end-host, it may happen that well some of the data is being say you are you are sending data from this host to another host, which is connected at a different end and whenever your transferring the data it may happen that well a part of the packet some packets are using this path to reach the host, where as some packets are using this path to reach at the end host. Now because of the delay difference between this 2 paths it may happen that well certain packets reach earlier than other packets. So, you are say I am giving every packet at a sequence number

1 2 3 4 that way because, of this delivery to multiple paths it may happen that packet 3 has reached first and after that you have received packet 2.

So, you can receive this kind of out of order packet, so the task of the transport layer is to ensure that even if you are receiving out of order packets this out of order packets. So, will be eventually get ordered and it will be delivered to the application under as a order sequence of data, otherwise the applications will not be able to able to find it that what is the sequence of data which is being coming. So, the applications need to always get the data in sequence.

So, this particular module in the transport layer it will ensure the order delivery of the packets over this, unreliable datagram delivery which is been supported at the network layer. Now in a nap cell what we can say that well whenever you are transferring data over the network layer the network layer just ensure of delivering of data gram at the other end host, which is their am your which is working like your destination. But the network layer it does not support the various required services which are important from the application perspective.

So, in that particular context it is important to provide certain level of end to end service in the internet. Now this transport layer it provides this sets of end to end services over the internet. Now in this particular context will have multiple different services which are been provided by the network layer and we see that well this TCP protocol the transmission control protocol.

This TCP protocol provides all this different services which is being required at the network layer, like this connection establishment reliable data delivery flow control and congestion control as well as the ordered packet delivery. Whereas, UDP protocol is just work like a wrapper of the network layer protocol to transfer the data directly to the application layer, without providing any such services like this connection establishment reliable data delivery flow control and congestion control or order packet delivery so on.

So, that way we broadly have 2 groups of protocol at the transport layer, one group of protocol it task is just to ensure that that data is being sent or the data is being transferred to the other end, so whatever is being supported by the network layer that services that directly provided to the application layer. So, the UDP protocol belongs to that group of protocol where we do not support reliability ordered delivery and all this services and in

this case the application requirement is to ensure only to deliver the packet and it can tolerate the loss itself.

For example, certain multimedia protocol can do that it can tolerate the loss up to certain level because, whenever you are receiving data frame by frame wise the important thing is that the frame is being received. But even if certain frames in between are being missed, then the multimedia protocol they can do an averaging of the first frame receipt and the third frame receipt and from there it can approximate the second frame and play it.

So, that way up to certain level of data loss it can tolerate this kind of multimedia protocols, but transferring the data within a pre defined time out is very important. So, because if you implement this kind of services at the transport layer that will take certain amount of time for processing the data and if there is a loss it will give more priority on retransmitting the loss segment or retransmitting the loss packet, rather than transferring the new packet you will experience more delay if you are going to implement those levels of services at the transport layer.

So, UDP provides a service where this loss or reliabilities not important, rather transferring the data within some timeout duration that is important. On the other hand, for applications like say file transfer or the web data transfer, reliability order packet delivery this particular functionalities are more important so we use TCP kind of protocol. So if you look into the protocols like HTTP FTP those kind of protocol they uses TCP type of protocol at the transport layer, where as protocols like certain multimedia protocol as well as the DNS protocol at the application layer it uses UDP type protocol.

So, in the next class we will look into the different services which are being provided by this transport layer and we look into the details of those services a starting from the connection establishment. So, see you all again in the next class where we look into the connection establishment paradigm in the context of the transport layer.

Thank you.