Real Time Systems
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Lecture 54
Routing and Resource Reservation

Good morning to all of you. Today we will take up one more new topic on real time communication that is routing and resource reservation.

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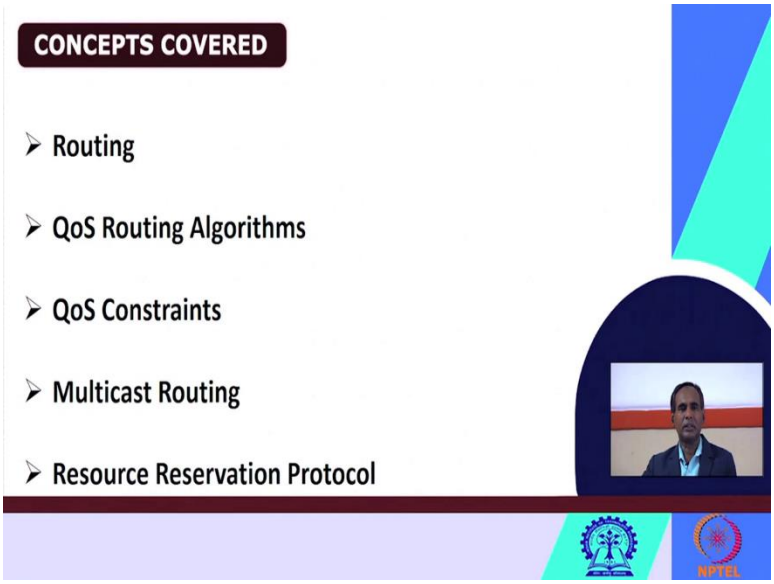

So, we will discuss the following concepts what is routing, how it is performed, the quality of service, routing algorithms, the QoS constraints, what is multicast routing, and we will say one interesting protocol called resource reservation protocol.

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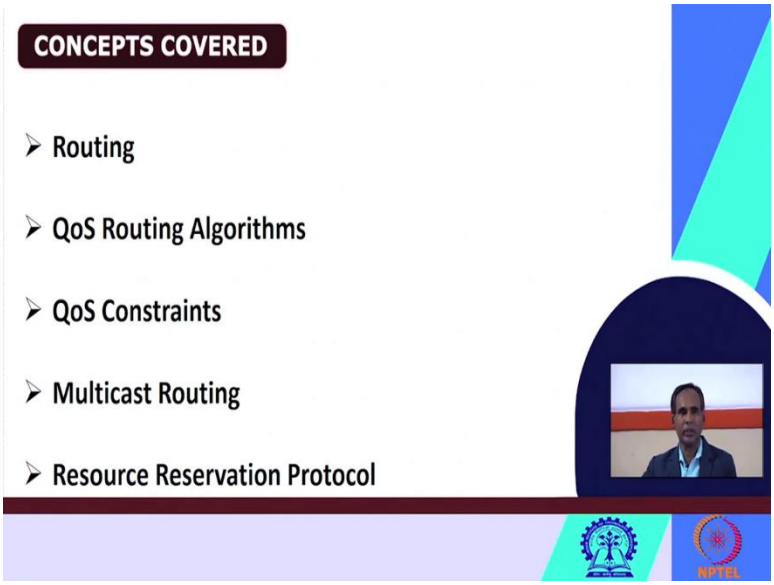

These keywords we will use like unicast routing versus multicast routing, different QoS constraints, concave constraint, how to construct the multicast tree, and something receiver-oriented protocol.

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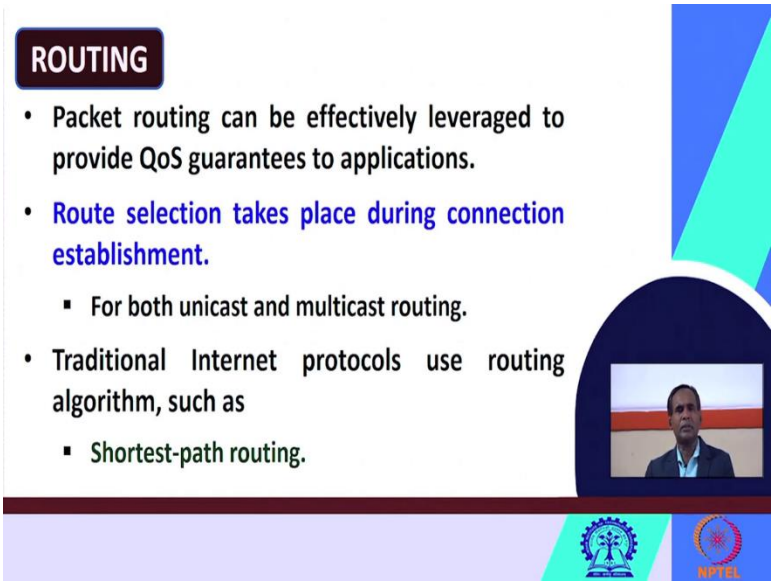

Now, let us see the fundamentals of routing. I again hope that you have already read a paper on computer network in your some of your previous semesters those who have forgotten please have a look into the subject that will be prerequisite for this chapter. Let us again see the fundamental

concepts of routing in real time communication packet routing it can be effectively leveraged to provide the quality of service guarantees to applications.

So, what you can use? Packet routing, packet routing it can be effectively leveraged forward to provide QoS guarantees to provide the quality of service guarantees to different applications particularly here real time applications. The here one important what issue is there that is route selection how to select which route it has to be followed. So, route selection it takes place during the connection establishment in both the cases unicast routing as well as multicast routing.

In both the cases unicast routing as well as the multicast routing the route selection takes place when it takes place during the connection establishment. So, you have non the traditional internet protocols, those traditional internet protocols they use the routing algorithms such as shortest path routing et cetera. So, we will see new what algorithms will be used in the modern day what protocols.

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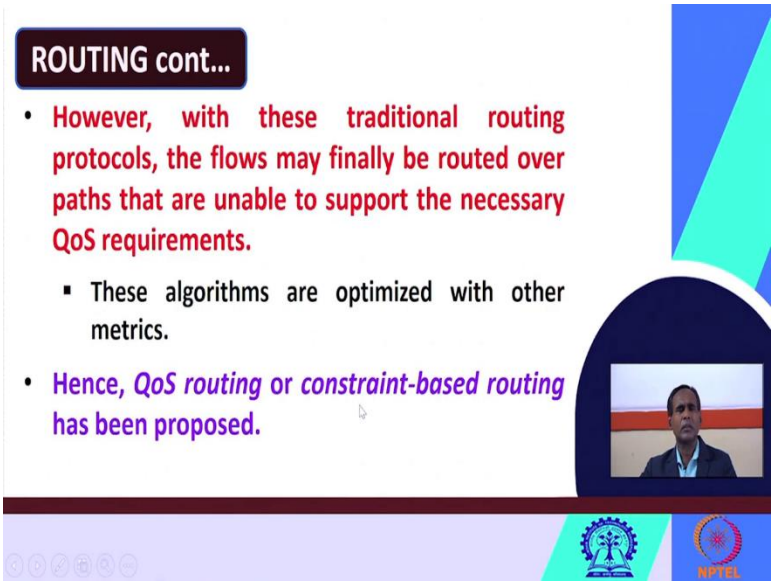

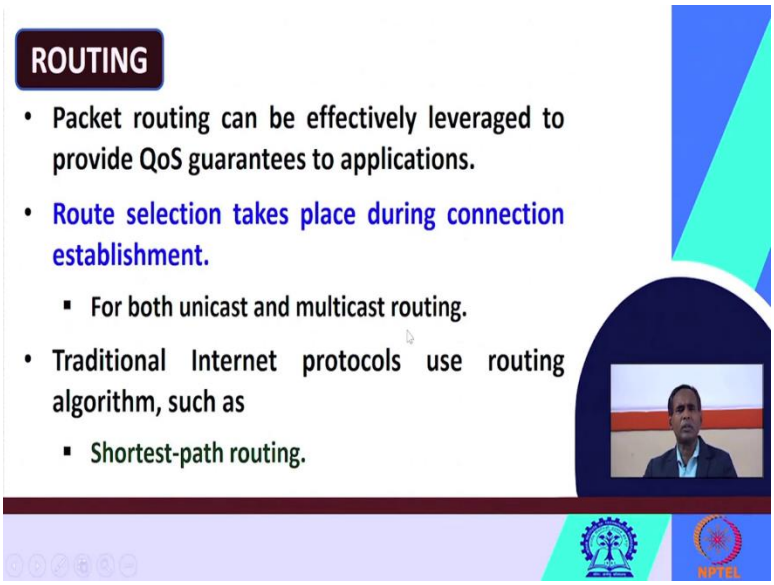

Now, let us see what is the problem with this as I have already told you the traditional internet protocols, they use what some routing algorithm says such as shortest path routing. But what is the problem with this however with the traditional routing protocols the approach may finally be routed over some paths which are unable to support the necessary quality of service requirements that is the problem with traditional routing protocols.

In case of the traditional routing protocols the flows, it may finally or they may finally be routed over some paths which are unable to support the record the necessary QoS requirements. So, we have to overcome this problem. These algorithms are optimized with some other matrix So, here this is the drawback of the traditional routing protocols I have told you. So, then what a terrible So, we require some quality-of-service routing or constraint-based routing that is required to overcome these problems.

So, hence QoS routing or constraint based routing is required to overcome this problem and many researchers have proposed these what QoS routing or constraint based routing. So, hence QoS routing or constraint based routing has been proposed by what some researchers.

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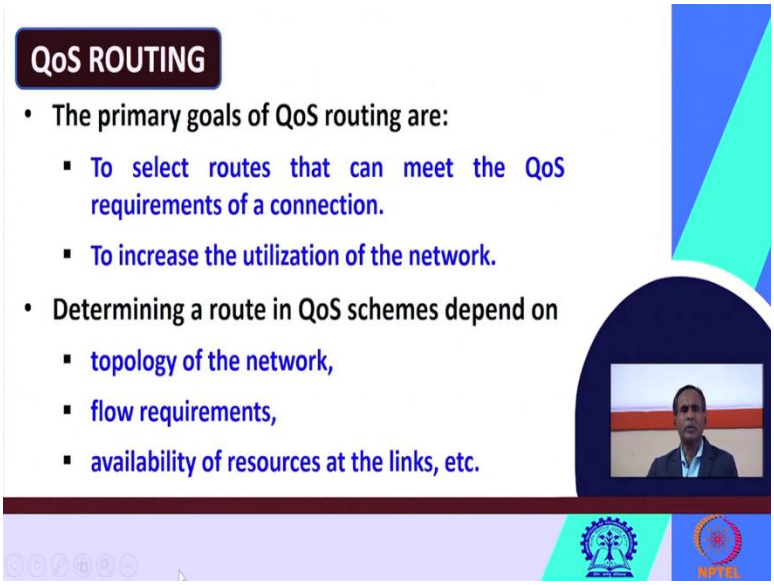

Now, let us see what is the objective of QoS routing, the primary goals of QoS routing are as follows first goal is to select the routes which can meet the QoS requirements of a connection how to select the routes such that these routes they can meet the QoS requirements of the connection that is the number one goal of the case routing. So, the first goal QoS routing is how to select routes which can meet the quality of service requirements of a connection.

And the second objective is the second goal is how to increase the utilization of the network. So, how the utilization of the network can be increased that is another goal of QoS routing. So, Now, how to determine the route it depends upon what factors let us see. So, determining a route in a QoS scheme it depends upon many factors such as some of the factors I have written below like what should be the topology of the network.

It should be ring network, ring topology or bus topology or star topology or mesh topology something else. Also, another important factor is what should be flow requirements. And another important parameter is or another important factor is availability of resources are the links. What resources are available are the different links So, that also it will what govern this that can be used while determining a route in quality of service scheme.

So, these are some of the factors or parameters which should be considered while determining the route in the QoS scheme.

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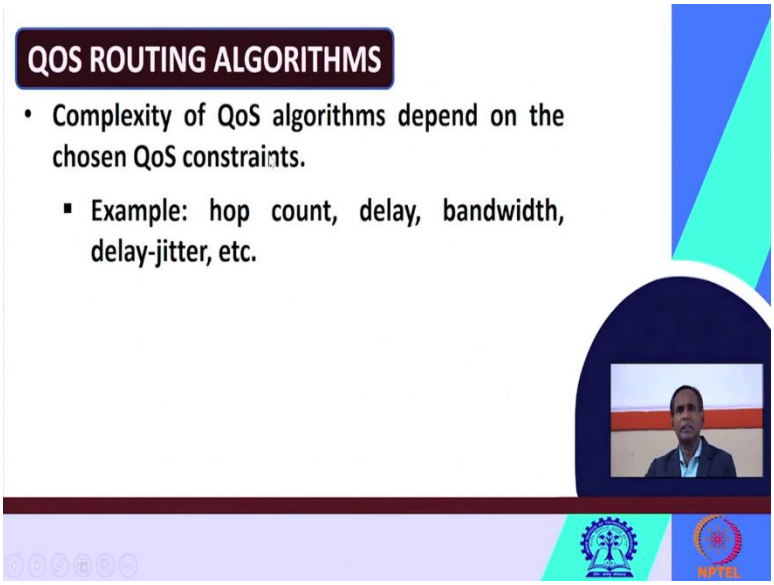

Now, let us say a little bit about these case routing algorithms, what are the complexities? So, the complexity of the QoS algorithms it depends on the chosen QoS constraints, what QoS constraints you have chosen? So, based on that the complexity of the case algorithms will vary. For example, some of the constraints I have written below what should the hop count, what should be the delay, what should be the bandwidth, what should be the delay jitter et cetera.

So, these are some of what QoS constraints on which the complexity of the case algorithms depend on. So, Now, let us see those constraints in detail.

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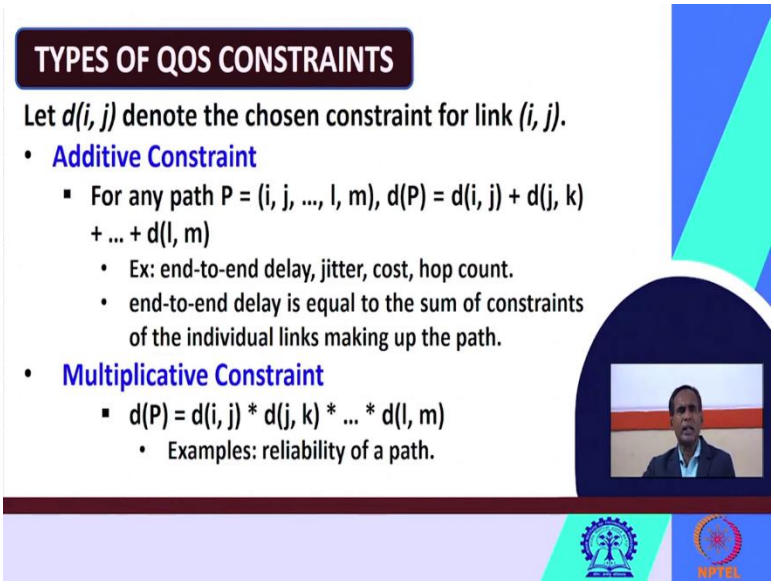

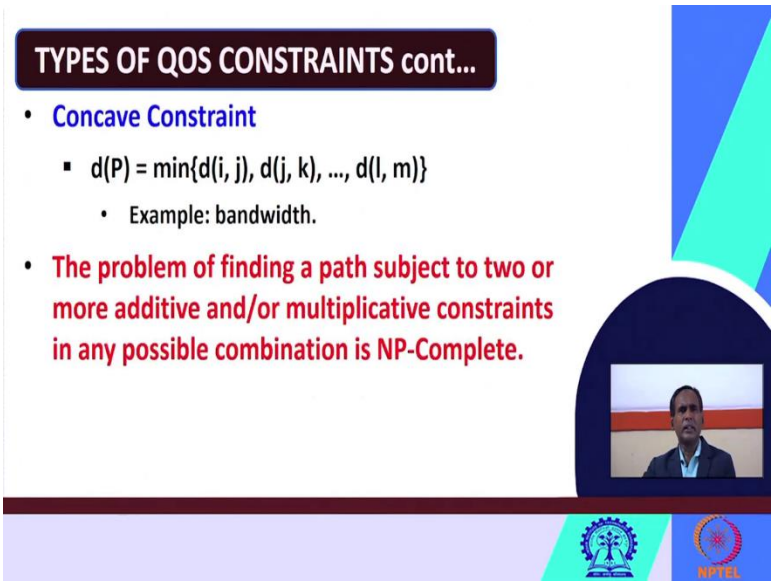

What are the possible types of QoS constraints in real time communication I already discuss about three types of constraints in what real time communication? So, first one will say additive constraint then a multiplicative constraint then concave constraint let us see what is the additive constraint. Let us assume that d I j it denotes the chosen constraint for link I j. This d of I j it denotes the chosen constraint for a particular link I j.

Then let us define additive constraint, the constraint d is said to be an additive constraint for any path p is equal to i j up to l, m if and only if d is equal to or d of p is equal to d of I j + d (j k) ….+ d(l m), What does it mean? That this constraint is d or d d this additive d is equal to or the constraint d of the whole path is equal to the sum of the constraints of the individual links making up the path.

I am repeating again if d i j denote the chosen constraint for link i j then for any path p is equal to i j l m the constraint d is said to be an additive constraint if d of p + d(i j) + d (j k) up to the d(l m). In other words, I can say the constraint of the whole path is equal to the sum of the constraints of the individual links making up that path. So, here I have already told you i j is a link j k is a link.

You take these word constraints of individual links find out the addition whatever value that is equal to the constraint of the whole path then you say that d is a additive constraint. So, several examples of additive constraints are there for example end to end delay, jitter, cost, hop count these are all examples of additive constraint. Let us take a small example end to end how it is defined.

So, end to end delay is an additive a constraint and it is equal to the sum of the constraints of the individual links which is making up the path I am again saying end to end is an additive constraint which is equal to some of the constraints of what the individual links making up that path. In this way we can design additive we can define additive constraint. Similarly, we can define what say multiplicative constraint here the only plus will replaced with the star or the multiplication.

In other words, I can say that the multiplicative constraint d or d will be called as a multiplicative constraint if the constraint the d of the path p is equal to the multiplication of the individual the multiplication of the constraints of the individual links making up that path p.

In this way you can find out the multiplicative constraint a very good example of multiplicative constant reliability of a path while you will find out the reliability of the whole path you have to just multiply the constraints of the individual links making up that path. So, reliability of a path is a very good example of multiplicative constraint. Last the other one is concave constraint. So, d p or I can define concave constraint as follows.

The constraint d is said to be a concave constraint. If the constraint the upper part p is equal to minimum of all the constraints of the individual links d i j, d j k up to the d l m. So, if you will find out all the links they are corresponding what constraints. And if the minimum of these constraints is equal to d of p that means a constraint of the whole path then we will say that that is a concave constraint a very good example of concave constraint is bandwidth.

Now, what is the problem the problem of finding a path subject to two or more additive and multiplicative constraints in any possible is NP complete, I hope you have already understood what is NP complete, NP hard et cetera. So, the problem of finding a path subject to two or more additive and multiplicative constraints or you can say multi additive or multiplicative constraint in any of the possible combination is NP complete please remember it.

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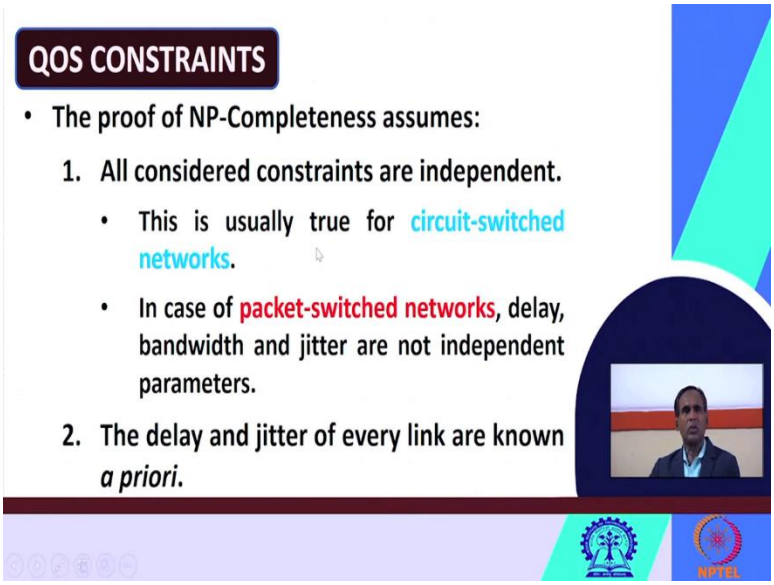

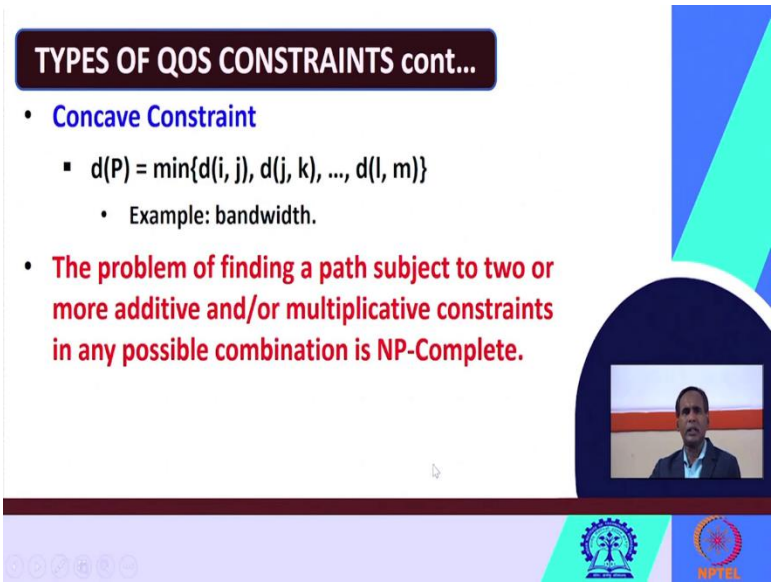

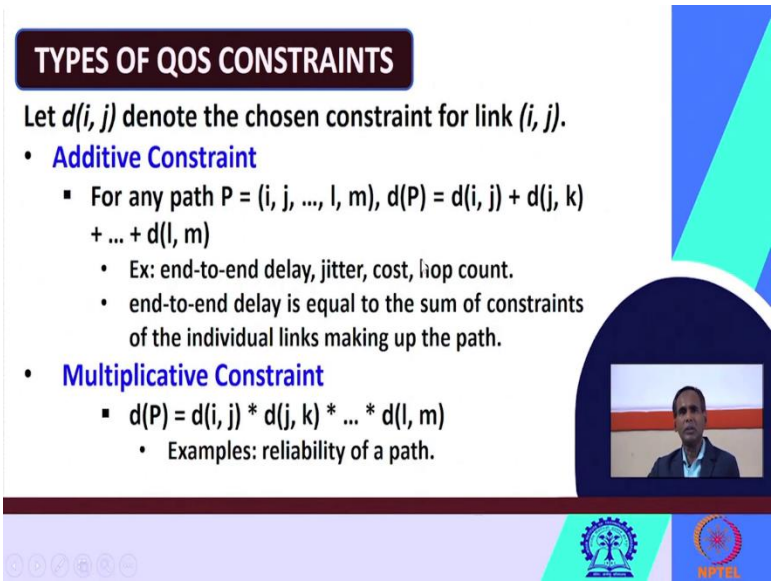

So, now, let us see something more about this QoS constraints the proof of NP completeness assume. So, here we have already told that the problem of finding the path subject to two or more what additive or multiplicative constraints is NP complete. So, the proof will not discuss here. But the proof of this NP completeness assumes two important things, it makes two important assumptions, number one all considered constraints are independent.

So, whatever the constraints we have seen here, although the in the independent constraints, So, all the constraints are independent and second one is that delay and jitter of every link they are known a priori they have known what in advance. So, while you are proving the NP completeness the proof of NP completeness assumes two important things it makes two important assumptions number one all considered constraints are independent.

And the delay and jitter of every link are known a priori they are known in advance. But if you see number one assumption that all considered constraints are independent. This is true for all circuit switch networks I hope you have already known two types of networks in computer network paper that a circuit switch network and a packet switch network. So, this first assumption that all considered constraints are independent.

This may be true or this is usually true for circuit switch network but in case of packet switch network this delay bandwidth and jitter they are not independent parameters they are dependent in packet switch networks the delay, bandwidth and jitter they are not independent parameters they

may be independent in case of for there independent circuit switch networks but they are not independent in case of packet switch networks.

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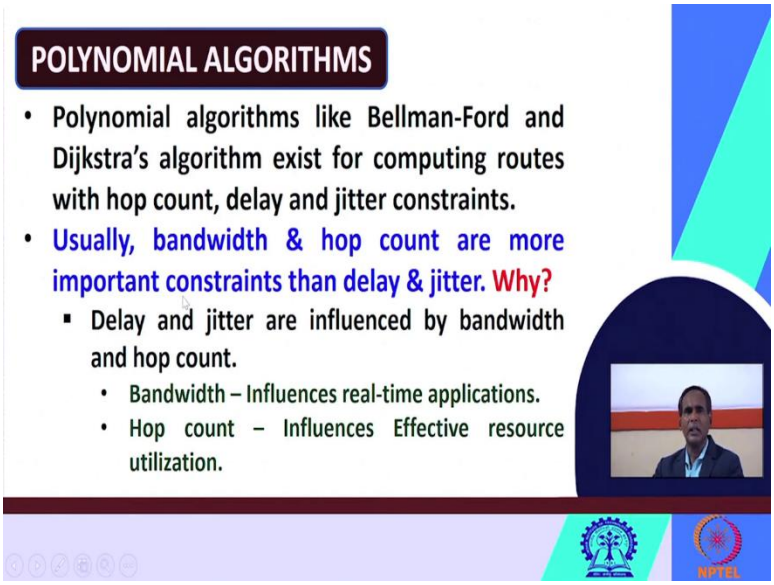

I will see some of the polynomial algorithms for these constraints you can see. There are some polynomial algorithms such as Bellman Ford algorithm, and the Dijkstra's algorithm et cetera. So, these polynomial algorithms exist for computing the roots with hop count, delay, and jitter constraints. But you will see normally what happens bandwidth and hop count these are more these constraints bandwidth and hop count constraints they are more important constraints than the other constraints such as delay and jitter constraints. Why?

Because the delay and jitter these constraints these are influenced by bandwidth and hop count delay and jitter they are influenced by bandwidth and hop count that is why bandwidth and hop count constraints they are more important constraints than the other constraints such as delay and jitter constraints. For example, if you will see bandwidth, it influences the real time applications and hop count it influences the effective resource utilization.

So, we have seen that bandwidth and hop count they are more important constraints than these the delay and jitter constraints.

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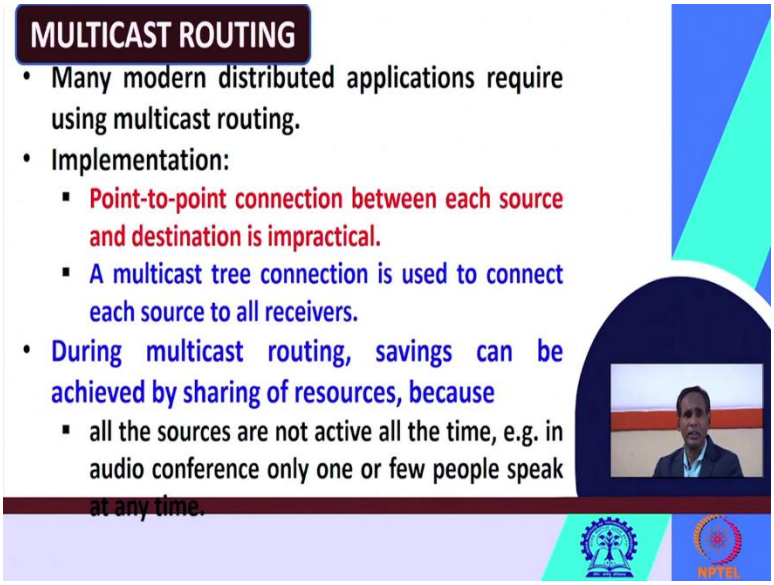

Now, we will pick up another thing that is called multicast routing many modern distributed applications they require use of multicast routing but the implementation if you will see from implementation point of view the point to point connection between each source and destination is very much impractical is difficult. The point to point connection between each source and destination is impractical.

A multicast tree connection is used to connect each source to all the receivers. So, in this case of implementation So, one more what solution is the multicast tree connection may be used. It is used to connect each source to all the receivers. During multicast routing what is happening? During multicast routing much savings can be achieved by sharing what by sharing the resources.

So, if you can say are certain resources then during multicast routing you can save, you can save much savings can be obtained by what sharing of the resources. Because you see all the resources are not active all the time. So, at a particular time if you will see normally in a multicast routing all the resources are not active some of the resources, they remain idle. So, if you can share them then obviously you can save the cost.

For example, you might take this audio conference in audio conference at a particular time. Time. What do either only one or very few people speak at any particular time. Not all the people who are talking at time. So, if in that case if we can share the resources then what will happen because see anyway the resource some of the resources are what still lying idle because all the people are

not talking at the same time only at one or at best a few people are talking in case of a what audio conference.

So, if also some of the resources are still lying idle. So, if you can share the resources then during multicast routing, we can achieve significant savings.

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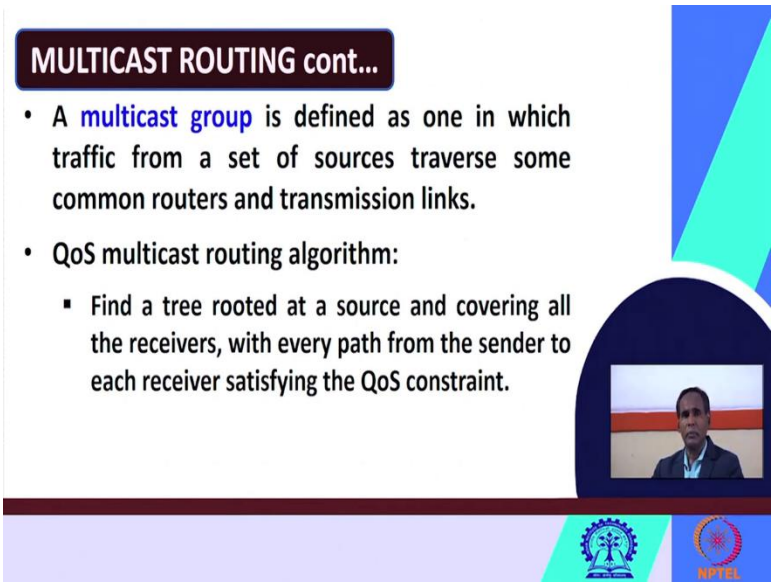

Now, let us see what do you mean by multicast group a term mean multicast routing will be used called multicast group. A multicast group is defined as the one in which a traffic from a set of sources traverses some common routers and transmission links I am repeating again a multicast group is a group which is defined as it is defined as one group in which the traffic from a set of sources it traverses through some common routers and transmission links.

So, that is why the name is multicast group it is defined as a group in which the traffic from a set of sources it traverses through some common routers and transmission links. QoS multicast routing algorithm it involves shorter thing let us see what does it involve. QoS multicast routing algorithm involves finding a tree which is routed at a source and covering all the receivers with every path from where from the sender to each receiver satisfying the given QoS constraint QoS requirement.

I am repeating again if you want to develop a multicast routing algorithm what it should involve QoS multicast routing should involve finding a tree constructing a tree rooted where rooted at a source and covering all the receivers with every path from the sender to every receiver to each receiver satisfying the quality of service constraints.

Then as I have a lead told you in QoS multicast cast routing algorithm we have to find a tree, we have to construct a tree. How can we construct it?

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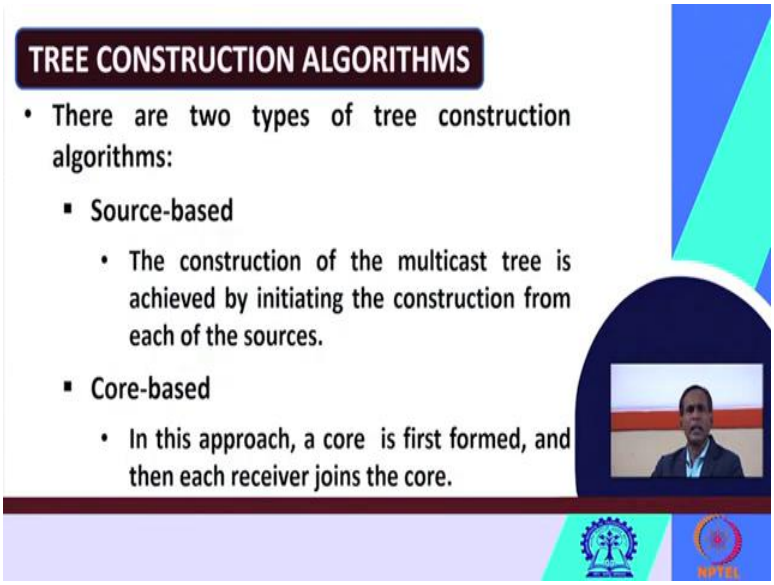

There are two types of tree construction algorithms one is source based another core based. In source based what is happening in source based algorithms the construction of the multicast tree is achieved how? It is achieved by initiating the construction, from where? By initiating the construct some from each of these sources. Whereas in core based algorithms a core is first form you have to first the construct a core.

A core is first formed and then each receiver is added to the core and then each receiver joins the core this is how the source core, source based algorithms and core based algorithms they work they can be used for constructing the tree.

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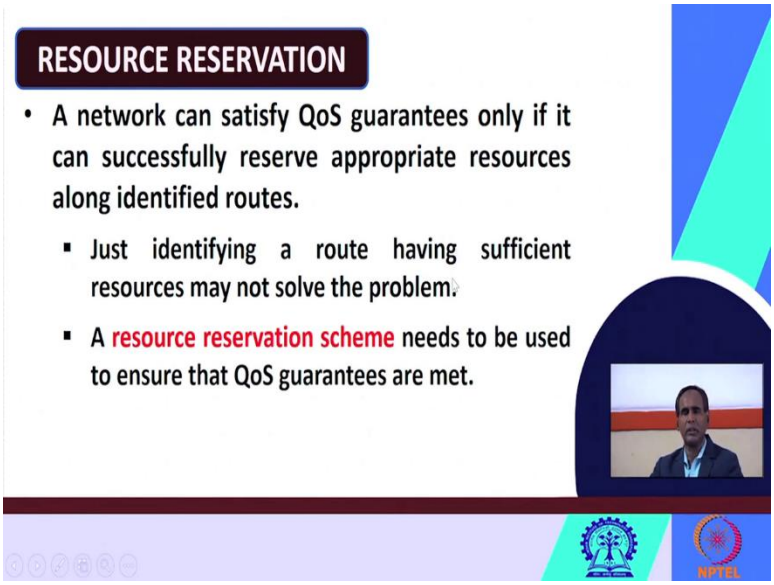

Then it will go to another important topic or larger resources reservation and we will take up a protocol called large resources reservation protocol. Now, let us see why does why resource reservation is required. A network can satisfy the quality of service requirements or quality of service guarantees only if it can successfully reserve the appropriate resources along the identified routes.

So, any network it can satisfy the QoS guarantees or QoS requirements. If it can successfully reserve the appropriate resources along the identified routes along the specified routes just identifying a root having sufficient resources it may not solve the problem. You have to use a particular scheme just identifying a root having these sufficient resources may not solve the problem.

A resource reservations scheme needs to be used to ensure that quality of service guarantees is met. If you will just identify a root and you are having sufficient resources simply it will not solve the problem. What is required? A resource reservation scheme, a scheme for the resource's reservation needs to be used that to ensure that quality of service guarantees is met.

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So, Now, let us see a protocol for resources reservation this protocol is known as resources reservation protocol or in short, we call as RSVP. RSVP was designed in 1993 in Xerox Palo Alto center. There are two major aims of RSVP number one is to scale to multicast communication. How it can be scaled to multicast communication? Number two objective is number two aim is how to incorporate heterogeneous receivers? Because you know, in a communication system all the receivers are not homogeneous. They are different types. They are heterogeneous in nature, So, how to incorporate the heterogeneous receivers.

So, these are the two major objectives of RSVP. So, let us not confuse let us see what RSVP does not do, RSVP does not construct multicast trees. We have already seen earlier about in the multicast routing. We have also seen this multicast trees about RSVP does not construct any multicast tree. Also, it does not use in a admission control decisions. It does not involve any admission control decisions.

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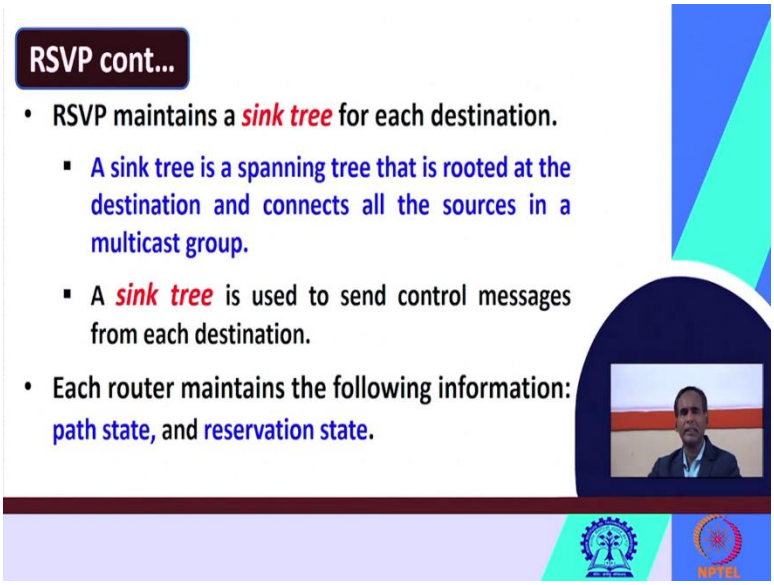

Now, let us see how does it work? RSVP how does it work? So, let us first see some fundamentals then we will go to see how RSVP is working. This RSVP maintains a sync tree RSVP it maintains a tree color sink tree for each destination. RSVP this protocol maintains a sync tree for each destination a sink tree is a spanning tree. So, let us define what do you mean by sink tree a sink tree is a spanning tree.

I hope already spanning tree you have known your data structure paper. So, a sink tree is a spanning tree which is rooted at the destination that spanning tree it is rooted at the destination and it connects all the sources in a multicast group in a multicast group how many sources are there this spanning tree it connects all the sources in the multicast group. So, I am again saying that RSVP maintains a sick tree for each destination.

The sink tree is a spanning tree which is rooted at the destination and it connects all the sources in a multicast group. So, why this sink tree is used a sink tree is used to send the control messages from each destination. So, if you whenever you require to send the control messages So, a sink tree is used. So, a sink tree is use to send your control messages from each destination. In RSVP protocol each router maintains two important information.

One what is the path state and two what a reservation state. Let us see something more about the path state and reservation state.

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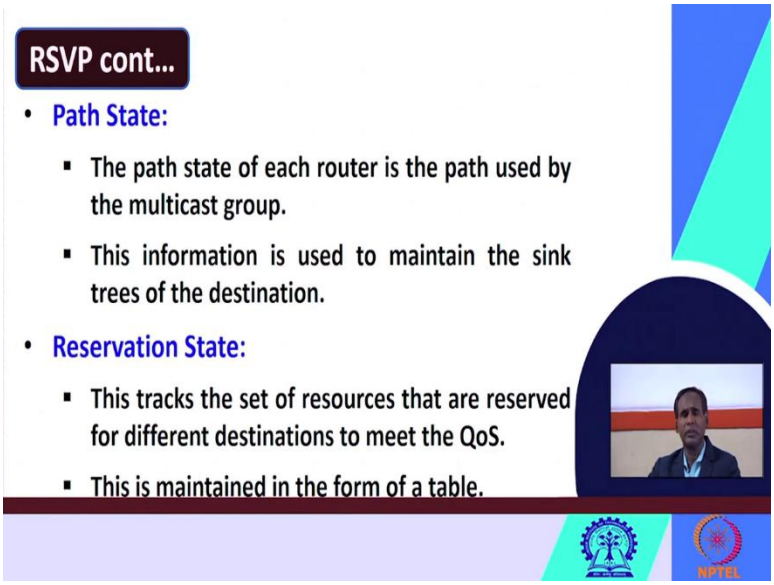

So, why is the path state is required the path state of each router is the path used by the multicast router. So, how do you define path state? The path state of each router is the path which is used by the multicast route. So, why the information contained in the path state required, this information that means the information in the past state it is used to maintain the sink trees of the destination.

So, in order to maintain the sink trees of the destination the information in path state is used. Then what is the reservation state? What does it do? So, reservation state it tracks the setup resources that are reserved for different destination to meet the quality of service. So, in order to meet the quality of what service it tracks the setup the different resources which are reserved for the different definition destinations in order to meet the quality of service.

This is maintained in the form of a table. So, this reservation state it is normally maintained in the in the form table you can just to construct a table in order to keep this information. So, reservation state is maintained in the form of a table.

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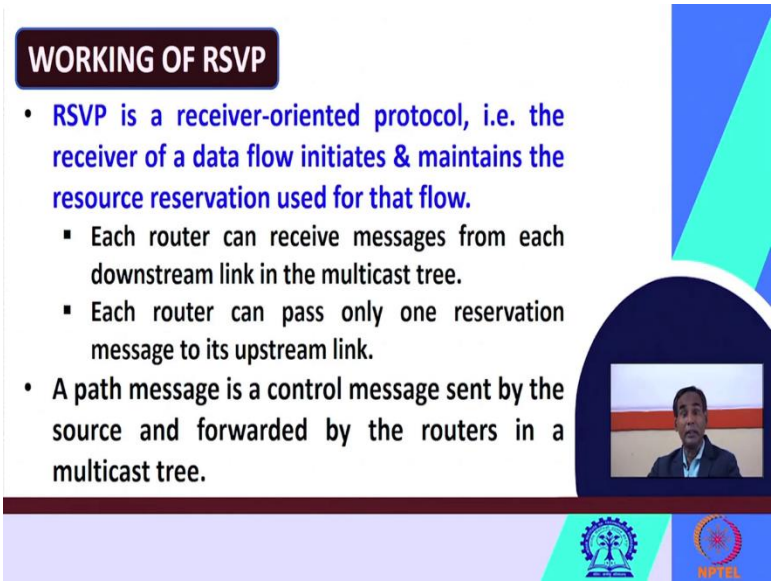

Now, let us see how RSVP works. RSVP is a receiver oriented protocol please remember RSVP is a receiver oriented protocol. What do you mean by receiver oriented protocol? That means the receiver of a data flow it initiates and maintains the resources reservation used for that flow. So, only the receiver initiates and maintains not the sender. RSVP is a receiver oriented the protocol that is in this case the receiver of the data flow it initiates and maintains the resource reservation used for that flow.

Each router can receive messages from each downstream link in the multicast tree. So, in the multicast tree each router it can receive the messages, from where? From each downstream link in the multicast tree. So, then what it will do? Each router can pass only one reservation message to its substrings link. So, any router it can pass at best what one reservation message to whom to a substring link.

Each router can pass only one reservation message to its substring link a path message. Now, let us see what is a path to message? A path message is a control message which is sent by the source and which is provided by the routers in a multicast tree. I am repeating again a path message is a control message which is sent by the source and then it is forwarded by the routers in a multicast tree. This is what is the path message.

Now, let us see. So, I have already told you here that each router can receive messages from each downstream link. And a router can pass only one reservation message to its substring, to its substring link.

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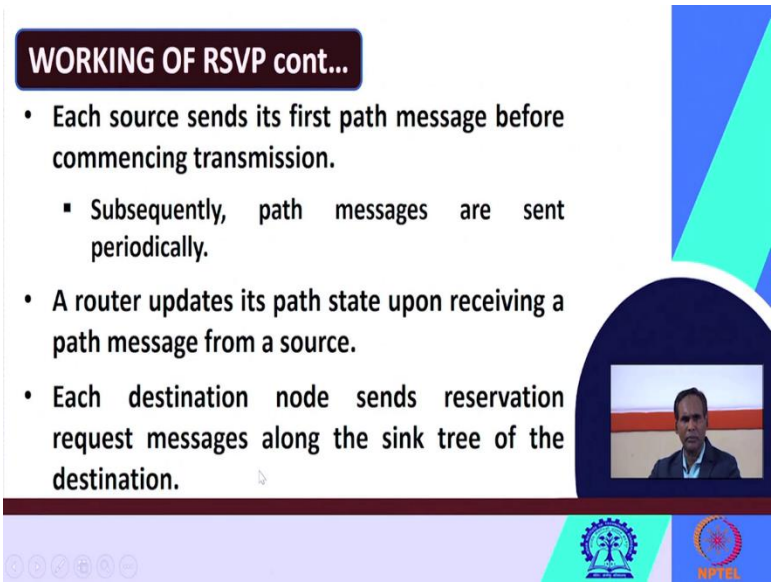

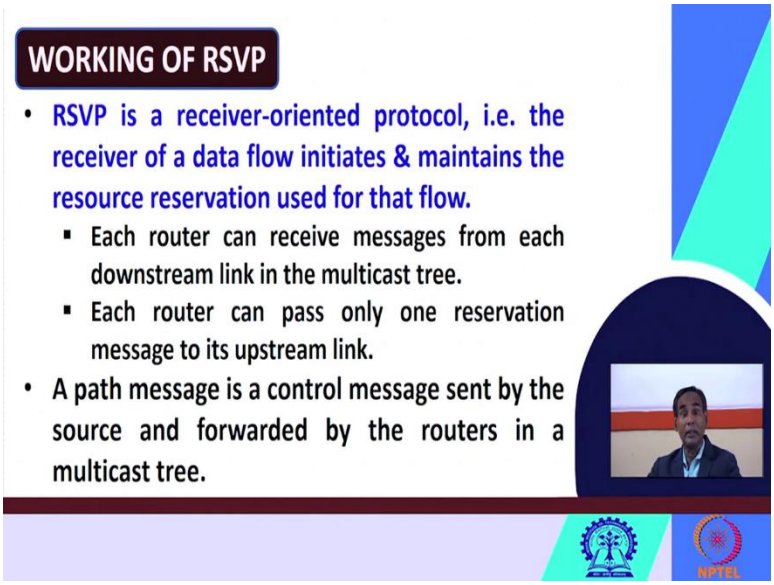

So, each source sends its first path message before commencing the transmission. So, before starting up the transmission each source sends its first path message. What is your path message already we have discussed, each source its sends first message before commencing or before starting up the transmission? Subsequently all the other path messages they are sent periodically. Now, a router it updates it path state upon receiving a path message from a source.

So, whenever a router receives a path message from a source immediately the updates its path state what is a path state already, we have seen. Each destination node what does it do? Each destination node sends the reservation request messages along this sink tree of the destination. So, each destination node it sends the reservation request messages along the sink tree of the destination

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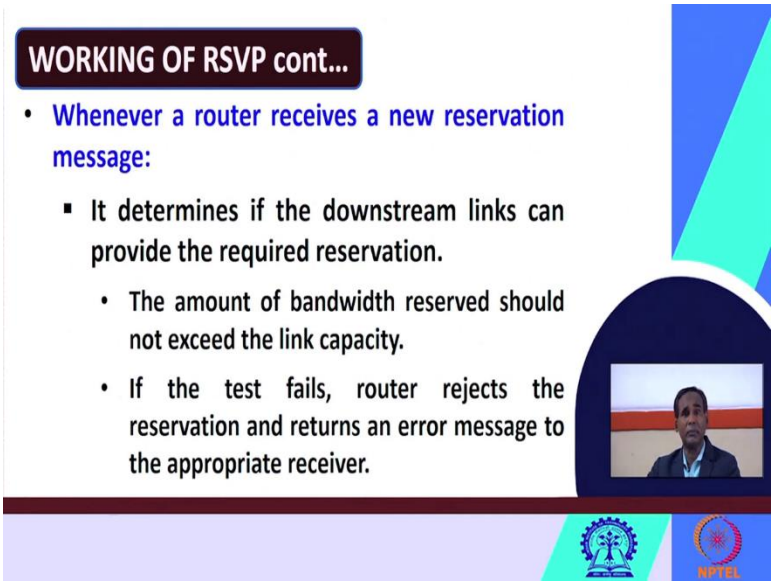

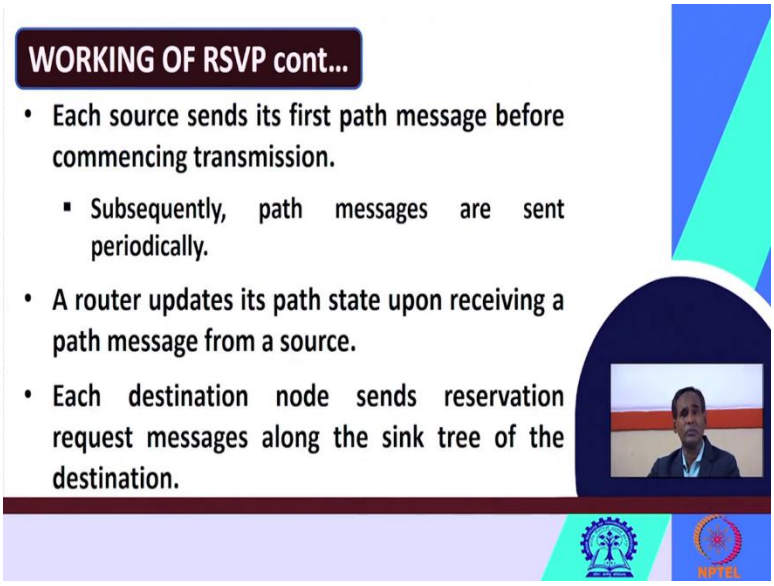

Whenever a router receives a new reservation message. So, see what I have told you who sends the reservation request message? The destination node sends the reservation request messages. How? along the sink tree of the destination then what will happen? Each destination node is

sending the reservation request message. So, whenever a router receives a new reservation message which is sent via destination node, so what it will do?

It will determine if the downstream link can provide the required information. So, whenever a router receives a new reservation message from a destination it will determine if the downstream link it can provide the desired reservation. That means whether it can it will check it will examine whether the downstream link can provide the required reservation the amount of bandwidth reserved should not exceed the link capacity.

So, while it is examining that whether the downstream link it can provide the required reservation or not please remember that these constraints should be satisfied. This condition should be satisfied. The amount of bandwidth reserved it should not exceed the link capacity. Now, if this test fails that means it is observed that the downstream link cannot provide the required reservation.

If the test fails then the router what does it do? It rejects the reservation and returns an error message to the appropriate receiver. So, if it can see that downstream can provide the required reservation and the amount of bandwidth reserved it is not exceeding the link capacity then it will accept it no problem. But if the test fails the router, it will reject the reservation and it will simply return an error message to the appropriate receiver.

Otherwise, the if the test is what passed. So, it will be ensured that yes, the downstream link can provide the required reservation. So, the reservation will be booked.

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Then it will say a destination you know it sends it first reservation message when it receives a path message from a source who the message stream it uses to receive. A destination node it sends its first reservation message. When? When it receives a path message from a source who the message stream it uses to the receive the destination then what does I have already told you it is a destination sends its first reservation message.

When it is receiving a path message from a source the destination then periodically sends the reservation message. So, first reservation message it is send when it is receives a path message from a source. The other messages the other reservation message will be sent periodically. The destination then periodically sends the reservation messages to maintain the reservation. So, this is called soft state and it is used especially for applications which are dynamic in nature.

So, now, I have already told you the first reservation message it will be sent when it receives a path message then other messages will be sent periodically by the destination.

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So, these periodically retransmission of messages in RSVP is an overhead of course. Because periodically you have to retransmit these reservations or what messages. So, this periodically retransmission of messages in an RSVP is an overhead. Note that the control messages incur a lesser overhead than data messages of course. The data messages they incur high overhead than the control messages or the control messages they incur lesser overhead than the data messages.

So, another alternative to reduce this overhead due to periodically retransmission messages is as follows. What you can do? You can merge the control messages from the different host and forward whenever there is no new state information. So, what I can do one alternative solution to

reduce this overhead due to periodically transmission of messages is as follows. You merge the control messages from the different hosts and forward it.

Whenever there is no new state information when there is no new state information then you forward this merge message. These merge messages.

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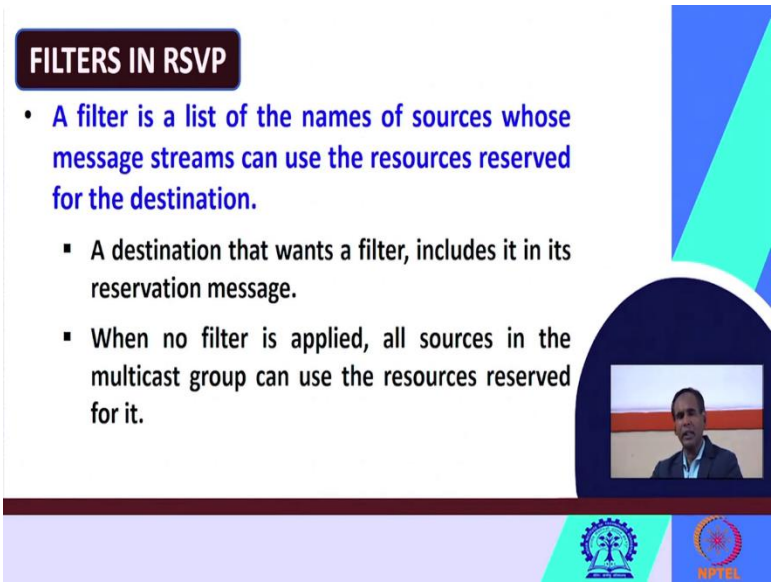

So, one more important concept you will see in RSVP one more important concept is filters in RSVP. What they mean by filters in RSVP? A filter in RSVP is a list of names of sources. A filter in RSVP is a list of the names of sources who the message streams can use the resources reserved for the destination. So, basically a filter means it is a list of names of the sources who the message streams can use the resources which are reserved for the destination.

A destination which wants a filter it includes it in its reservation message. So, whenever destination it wants a filter then it includes it in its reservation message. When no filter is applied then what will happen, when no filter is applied all the sources in the multicast group can use the resources reserved for it. So, whenever you or a destination wants a filter, it includes in its reservation message we have already seen that filter is a list of names whose, list of names of sources whose message streams can use the resources which are registered for the destination when no filter is applied. Then all the sources in the multicast group they can use the resources reserved for it.

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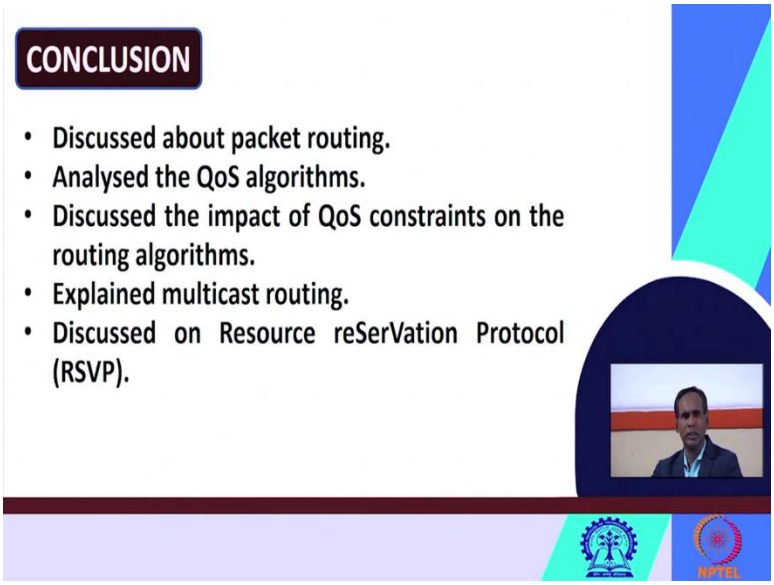

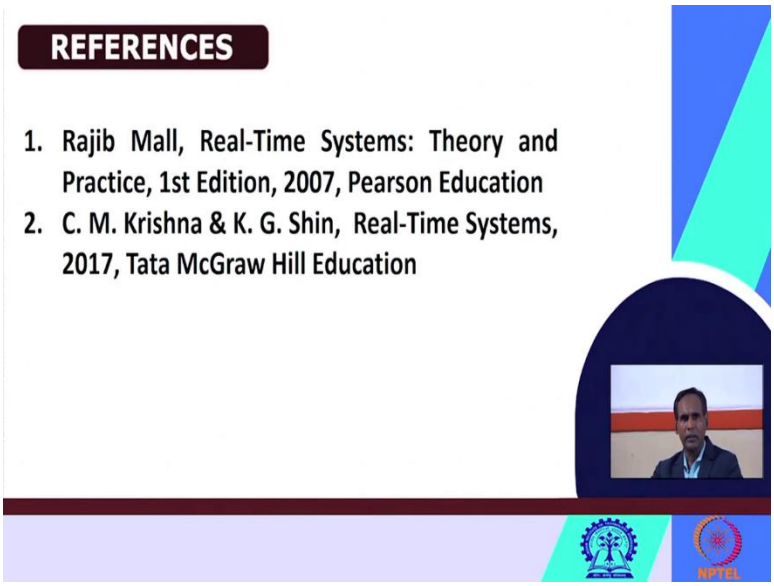

So, today we have discussed the basic concepts of this packet routing, we have analyzed the QoS algorithms, we have discussed the impact of QoS constraints on the routing algorithms. We have seen the three important types of constraints like additive, multiplicative, and concave, these constraints we have seen. We have also explained the multicast routing, we have discussed one important protocol called as resource reservation protocol or RSVP. These are the references we have taken the contents. Thank you very much.