Broadband Networks
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Lecture No.24
Multiple Label Switching (MPLS)

So as we were discussing in the previous lecture that, how the paradigm of MPLS was born and so what we had seen really is that, while IP protocol in the internet has the properties of having a robust routing protocol and also the scalability and flexibility in terms of having hierarchical address, but one of the disadvantages of the internet protocol was a, the performance bottleneck due to the longest prefix match and b, the difficulties in traffic engineering that is obtained due to the IP protocol in the internet.

Now, as long as the performance bottleneck due to the longest prefix match is concerned several algorithms recently have been proposed which has tried to alleviate this problem to a large extent. So we have several IP address look up algorithms today that can scale to high speeds like oc 48 or oc 192 but as far as the traffic engineering problems are concerned that is still continues to be a problem due to the IP protocols. So therefore the approach that was adopted by the service providers to address the challenges of traffic engineering was to have ATM or a frame relay based backbone networks.

So in the core there was an ATM network and in the edges, there were these IP routers and what was done is that in the core that traffic engineering issues were resolved by exploiting the virtual circuit routing capabilities of the ATM networks. So while using vc routing, the traffic engineering problem in the core networks was alleviated, but this led to different kinds of problems and one of the problems that it led to was because of having IP over ATM layers.

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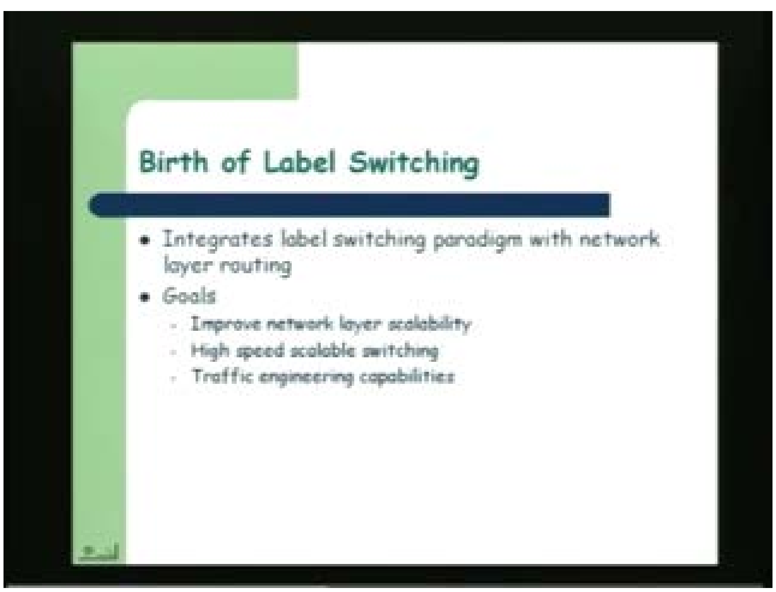

There were problems in terms of segmentation reassembly overheads, because the IP packet needs to be chopped off into 53 bytes ATM cells at the ingress port and then that needs to be reassembled again into IP packets at the ingress port. So there was this problem of segmentation and reassembly. Another problem of IP over ATM was having it run you know because the two routing protocols were used. There was an excessive overheads in terms of network management and complexity also associated with having to manage to separate routing protocols and the third problem in this over layer model is because the IP layer is over led over an ATM layer, the problem associated with that was you require a complete or a partial mesh of order n square if there are n routers at the edges.

So order n square virtual circuits to be set up and that led to a problem in terms of overheads in the routing updates. So, to address these problems then what was proposed is that that why not have ATM switches participate in the IP routing also a and then instead of switching ATM cells why do not they switch IP packets themselves and instead of having you know IP based forwarding in the core of the networks have a forwarding based on some kind of a label which is very similar to the virtual circuit identifier in the ATM cell. So, with this idea you know a multi-protocol label switching and or an MPLS was proposed.

Now there were several precursors to the MPLS networks. The most notable among them was IP switching by Epsilon. There was a company called Epsilon. So the most notable among them was IP switching. Another one precursor to MPLS was Cisco’s tack switching architectures also that was proposed, then IBM’s Errise architecture was proposed, then Toshiba’s cell switch router CSR that was also proposed. So, there were several precursors to the MPLS networks and when the ITF standardized started standardization on the multi-protocol label switching, it took a combination of some of the features of these precursors of the MPLS protocol.

So now all broadly all can be classified under the term what we call as the label switching. So now let us look at the some of the key features of the MPLS protocol or a MPLS architecture. Now how the key feature are as we have seen, now what we are saying now is that, in the edge of the networks, we have an IP router and in the core we have network which is based on MPLS, then what is done is that path is established between two end points.

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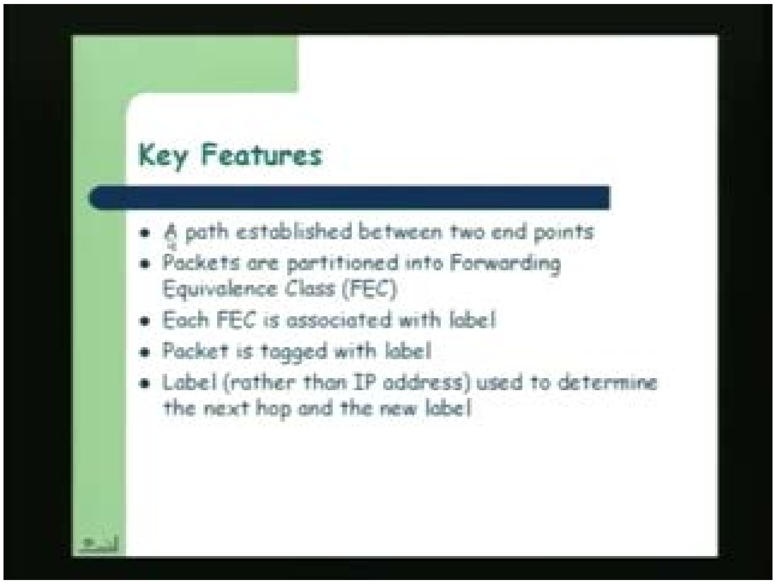

Now this path could be establish either by using standard IP routing protocols or by using traffic engineering extensions of these IP routing protocol. Now, what we are saying in the MPLS is that first we will establish a path between two end points. Now, this path may have a certain quality of service attributes also associated with it. Now what is then done at the egress at the egress of the network packets are partitioned into what we call as the forwarding equivalence class. Now the granularity of the forwarding equivalence class may vary from at courses level of forwarding equivalence class may be very similar to a destination IP address prefix.

So at the very cores level an FEC may be associated with a destination IP address prefix and at the very fine level of forwarding equivalence class may also be associated with an application flow. So now it is up to us really that a virtual circuit path which in the MPLS we call it to be a label switch path. Now there is a correspondence between an FEC and the label switch path. So whether we want to setup a separate label switch path for every individual application flows or whether we want to aggregate these flows and whether we want to set up a single label switches path for all the packets which are distinct towards a destination IP address prefix. So now that is a decision that we can take it as a classification rule and apply those classification rules at the ingress of the network and then classify the packets in to appropriate forwarding equivalence classes.

So as i said, the granularity of a forwarding equivalence class may vary from destination IP address prefix at the cores level to an application flow also at the fine level and this forwarding equivalence class may also have a certain quality of service attributes associated with that. So now that aspect we will see later. But right now, what we are saying is that the ingress of the network the packets will be classified into forwarding equivalence classes, then what happens? Each FEC is associated with a label. So each forwarding equivalence class essentially gets mapped to a label switch path and a label switch path or a virtual circuit is identified with a label, then at the ingress of the MPLS network, a packet will be tagged with a label.

So you attach essentially a label and then in the core of the networks, it will be the label rather than the IP address that will be used to determine the next hop and the new label. So, a label will be now used to determine the next hop and the new label. Now, as i already discussed that very similar to the ATM switches, MPLS also follows the paradigm of the label swapping and as you recall in my lecture on the ATM switches, i had discussed the importance of this virtual circuit identifier the vci 16 bits vci swapping. The reason being that this vci space can then be reused and therefore this virtual circuit identifier will be unique only between two ATM nodes only on that link it will be unique.

So, on the other hand a particular virtual circuit may have different vci associated with it as it traverses along different nodes. So, as it traverses along different nodes you may have different virtual circuit identifiers associated with it. Otherwise, you know if you keep the vci label unique from the source to the destination, then you can have only 2 raise to power 16 virtual circuit path to be established in the entire networks. So, to alleviate this problem, the principle of vc swapping is used and the similar principle that is the label swapping paradigm is also used in the context of the MPLS network.

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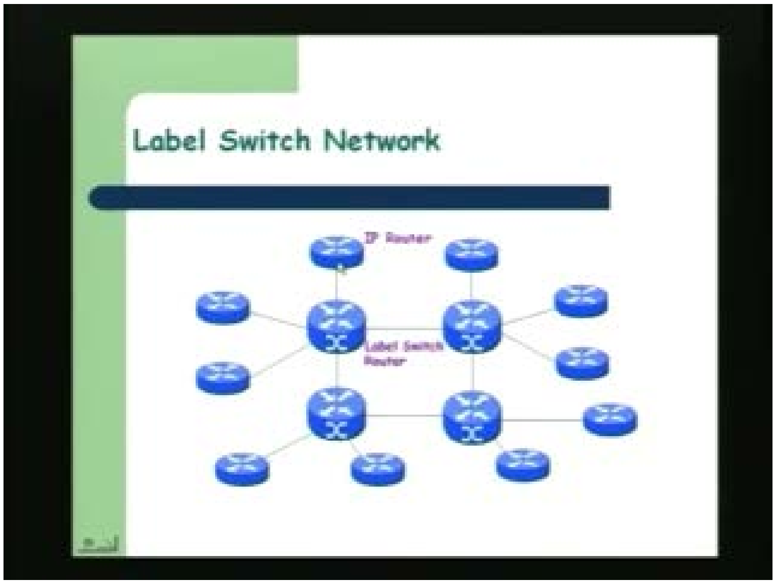

So now this is how a label switch networks will look like. So these are all IP routers. So you know as we had considered earlier also and these are all you know label switch routers what they call as LSR. Now, as you can see that these label switch routers have the capability of IP routing as well as the label switching. So, they understand IP routing protocols. They understand the label switch label switch paradigm also and all these routers actually work on the IP packets only. So as a result you can see that in our previous discussion where we are saying that an ATM based network will be used as the overlay network. Earlier instead of these label switch routers these were you know the ATM based switches.

So instead of these being ATM based switches, now what we are saying that they are the label switch router. So, all these are the label switch routers. If they were the ATM switches, then these were working on the ATM cells. So there was the problem of as we had discussed segmentation and reassembly overheads and other thing. Now as you can see that these label switch routers are working on the IP packets only.

So therefore these IP packets need not be fragmented into smaller length packets and so on so you know your label switch routes can handle the IP packets themselves. So the problem of the segmentation and reassembly is alleviated. Moreover you know these label switch routes are establishing the label switch path based on IP routing only. So they understand the IP routing protocols also, so therefore the complexity of having to deal with two separate routing paradigms which was there when we are using ATM as the backbone network like the ATM based virtual circuit routing and the IP routing that problem also gets addressed.

So as a result we get a very integrated and uniform paradigm for addressing the traffic engineering challenges of the IP networks. Now as we can see here in this network, as for as the label switch routers are concerned, we now need two components. Really is the can so this label switch router has two components. One is the control component and another one is the data component or the data plane of the label switch router. As for as the data plane of the label switch router is concerned the label switch router will act only on the labels. They do not act on the IP address. So they will look up the label in the label information base which will be there and do an index-look up because typically this label will be much smaller than 32 bit IP address infact in MPLS, it is 20 bit.

So therefore the number of entries which will be required in the label information base will be much less it will be 2 raise to power 20 which is of the order of one million. So, you will require only one million entries and as a result you can comfortably do an index look up. So once a packet come you look up the label in the label information base and then determine where the packet needs to be forwarded to the next hop and also the label information base will tell you what is the next label that needs to be swapped with the present label, now as for as the edge routers are concerned at the edge the edge router participate in in both IP forwarding as well as the label switching.

So when the packet comes at the label edge routers which are untagged, the label edge router needs to classify those packets into forwarding equivalence class and then attach the packet with a label. Now once the packets are attached with a label and FEC is mapped to a label, these bindings between the FEC and label must be communicated to the other label switch routers which are going to be there in the label switch path. So as a result you need some kind of a control protocol. Now this control protocol which is we call it to a label switching control protocol.

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Now this control protocol will create the bindings between the labels and the FEC and then inform the other label switch routers of the bindings that it has created and then utilize the above two to construct the forwarding table used by the label switching.

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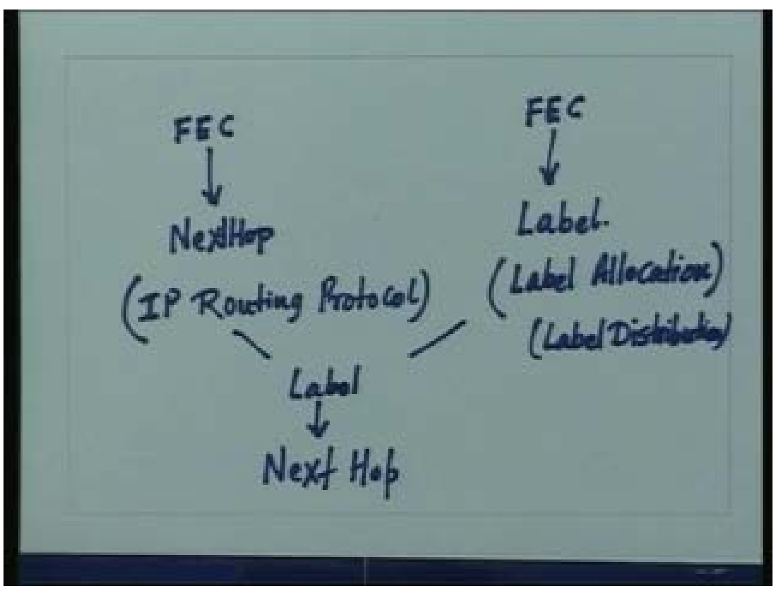

Now something like this we have FEC to next hop. This we may know from standard IP routing protocol from FEC to next hop, then we have bindings you know from FEC to label. Now, this is like our label allocation or label allocation mechanism and this will be communicated by a label distribution protocol and from these two, we will create a binding from label to next hop. So this is how you know you will label switch router knows that when these labels are there how to determine the next hop. Now, the question really is that how do we inform the other label switch routers of the bindings that is being created between the FEC and the labels.

So, there are two separate ways to do this either you piggy bag it on to the existing routing protocols like BGP or OSPF essentially OSPF. So you piggy bag or RSVP. So you piggy bag so you extend these routing protocol. Another approach is to suggest with a separate routing protocol with the separate label distribution protocol. So, there are both pros and cons of these approaches. Of course, the disadvantage the advantage of using the existing routing protocols and piggy bag it on to the routing protocol is that the routing information the forwarding information base will be consistent. It will be consistent with the any routing changes etcetera, because what happens when the routing protocol sends the routing update messages if there are any topology changes and along with that also you know if the label distribution is carried out, then the label information will be most recent.

It will be consistent with the you know with the with the routing update mechanism also but of course there are disadvantages in the sense that you have to extend the existing routing protocols and sometimes extension may not be so easy unless to modify you know several of the messages of the protocols. So the advantage of the separate label distribution protocol is that that you can come up with the clean protocol in the beginning itself you know to distribute the binding between the FECs and the labels and you do not have live with a legacy of the existing routing protocols but the disadvantage is that sometimes the label information base may not be consistent with the routing information base.

So the MPLS earlier chose to define separate label distribution protocol which is called as LDP or label distribution protocol. Of course, later on when extensions to the traffic engineering issues and quality of service issues were concerned, there was again this debate whether we should have a label distribution, separate label distribution protocol along the lines of LDP that was already proposed. So that was cause called as constraint based routing or CR-LDP protocol or else the option was to extend the existing reservation based or traffic engineering based mechanism and it was it was found that RSVP, the extension to RSVP were considered more favorable candidate but we come that discussion later.

So what we are now saying is that at the label edge router once the packets are classified into FEC and the FECs are bound to a label, you have to distribute these label bindings to all the nodes you know which were which are going to participate in this label switching and this binding is done by protocol which we call it to be a label distribution protocol.

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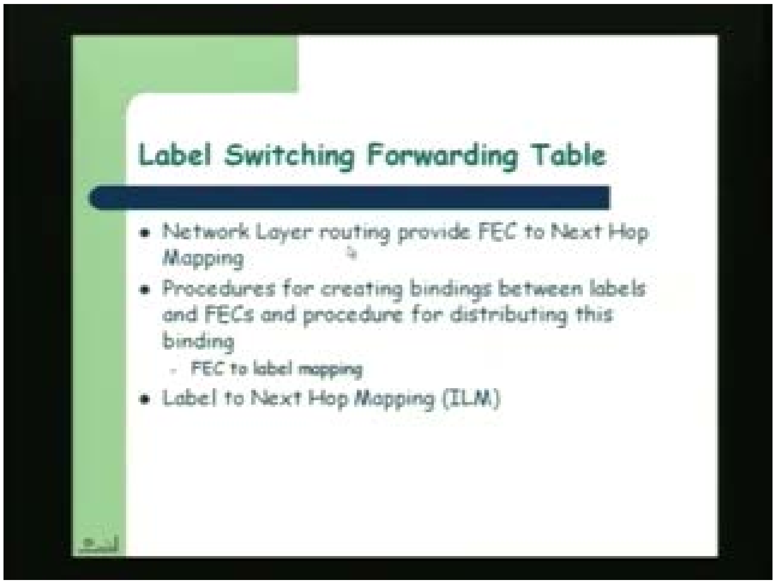

Now as we are saying that as i was just discussing that the network layer routing will provide FEC to the next hop mapping and as i was saying that you can have a definition of FEC to be associated with the destination IP address prefix. So, for example you know what is now done is that that a network layer routing in the core of the networks will determine the path from one node to another node through the standard routing mechanisms. Now if we associate an FEC to with a IP address prefix then what will happen is that that the route which exist to forward that IP address prefix there we would be creating a label switch path.

So what happens is the network layer routing will provide the information about the FEC to the next hop mapping, then procedures for creating the binding between labels and FECs and then procedures for distributing this binding that is the label distribution protocol that will enable the FEC to the label mappings and once now we have FEC to the next hop mapping, we have FEC to the label mapping from these two we will create what we call as the label to next hop mapping which is called as ilm table. So, this is how you know a label switch forwarding table will be created.

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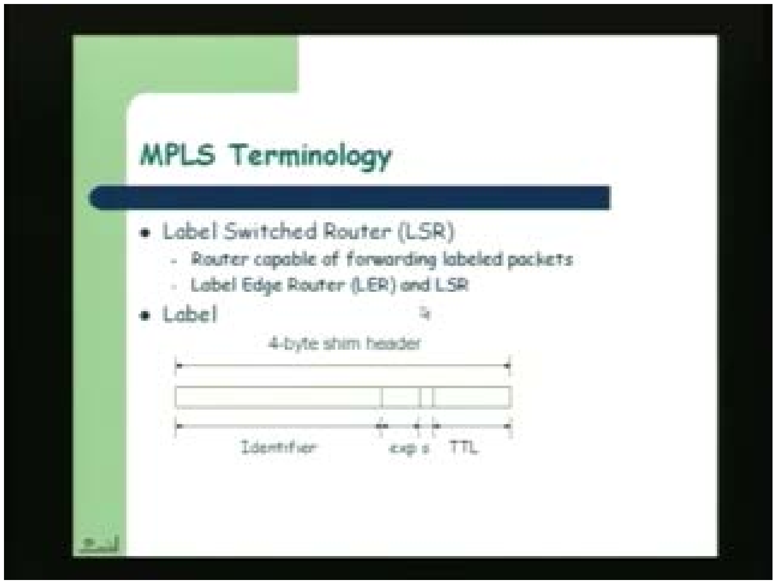

Now let us see how and MPLS has defined several of these protocols. Now here i would like to mention one thing is that this was also a question that when do we when do we create the bindings between the FECS and the labels? So there were two approaches. One is data driven. Now what is data driven? The data in the data driven approach when the packet of a particular flow are belonging to some IP address prefix comes for the first time comes for the first time at the label edge router at the edge of the MPLS node, then the packet is classified into an FEC and a label is tagged. So when the first packet of the flow comes, then only you start the classification process and mapping the FEC to the label.

Otherwise you know you do not create the label binding. Now, this was an approach. For example: it was followed in IP switching approach which was a precursor to the MPLS networks there are several disadvantages associated with this the disadvantages that that for short lived. So essentially you know here you are doing the bindings based on flows and for short lived flows like http flows etcetera you know even before the label switch path is created, the flow may actually die down.

So, therefore the most favored approach taken by the internet engineering task force which was a standardizing body for MPLS was that we should go ahead for the control driven approach. Now in the control driven approach, the philosophy really is that say for example if the FECS are associated with IP address prefixes. So if the FECS are to be associated with the IP address prefixes, then by utilizing the information from the network layer routing, we can already create the label switch path corresponding to the IP address prefixes. So, we have already created the label switch path in the core of the networks and the bindings between FECS and labels have been distributed using label distribution protocol.

So whether or not a packet bound to a particular IP address prefix appears at the edge of the network that is not of concern. So the path would already would have been created and the binding between FECS and labels were already been distributed to the label switch routers.Now this kind of approach is called a control driven approach and whenever changes in the topology occurs or a routing update occurs and the path changes then again you know new label switch path maybe created and the old label switch path maybe torn down.

So, this approach actually follows a control driven approach and it does not rely on whether or not a packet destined to go on a particular label switch path is present or not present. Now in MPLS essentially we say that the label is a 4 byte of shim header. It is 32 bit and in this 32 bit actually the 20 bit is what is a label identifier or an index and there is a 3 bit exp field which for the experimental purposes and one is a field s which indicates whether there is a label stack followed by it.

So i will just explain the meaning of the label stack and after that there is this field which is called as TTL. Now the importance of having this TTL field is remember that the label switch routers that is the router which are in the core of the networks. They are not going to now work on the IP address header. So, they are mostly going to do the forwarding based only on the MPLS labels. Now, recall the IP forwarding paradigm, whenever an IP packet comes the TTL field is decremented by one and when the TTL field reaches zero actually the IP packet is discarded because it indicates that there may be a loop in the networks.

So, therefore you know what is done and also you know when the packet reaches at the ingress of the network. So basically in the MPLS network, what is done is that the ingress of the network the value of the TTL field which was present in the IP header is copied to this MPLS label and then the packet gets forwarded in the label switch router. Now when this packet reaches at the egress of the network, this TTL field is copied back into the IP header again and then the packet so as far as the IP is concerned. It will appear as if the IP packet has passed through you know so many of IP routers only. So on the other hand and if the MPLS label switch network also if the TTL field reaches zero then the packet is actually dropped because it indicates that the packet basically is loopy. So this may also be used to you know perform loop preventions as well.

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So this is a 20 bits identifier that i have already said, then there is a 3 bit-exp field which is similar to the type of service field which is used in the IP header one bit which is called the bottom of the stack field whether it is the bottom of the stack, eight bit is of TTL value. So this adds up to the 32 bits, then as you already discussed the forwarding equivalence class label switch patch is called LSP. Next hop label forwarding entry which is nhlfe which indicates the mapping between the FEC to the next hop and typically sorry this is the next hop level forwarding entry this gives the next hop and FEC to nhlfe map which is ftn. These two available from the net, this two information is available from the network layer routing and then we have incoming label map which will give the bindings between you know the label and the next hop.

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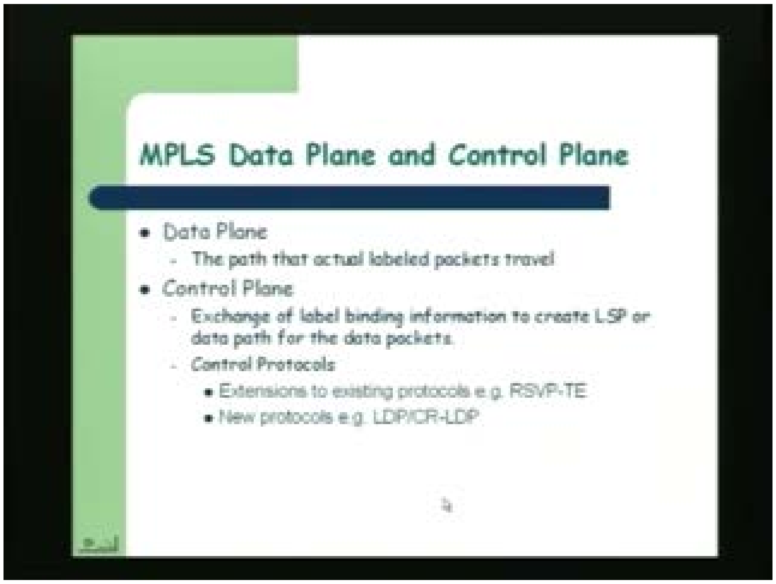

Now as i said the MPLS data plane is that the path that actual labeled packets travel which is actually also called as label switch path and then there is a control plane which is involved in exchange of label binding information to create label switch path or data path for the data packets. Now there are control protocols as i already discussed that we can either have extensions to existing protocols like there are RSVP-TE or we can have a completely new protocols which is label distribution protocol or CR-LDP, about CR-LDP and RSVP-TE we will discuss later.

Now the forwarding equivalence class is basically a set of classification rules and so forwarding granularity it is the forwarding granularity essentially which determines the scalability of the network also. Now look at what kind of forwarding granularity which can be there in the MPLS network.

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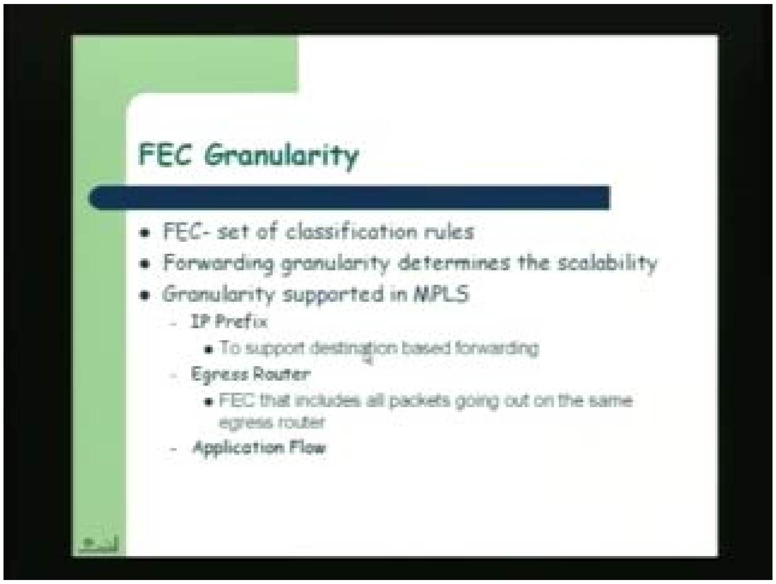

Let us look at this as i said at the courses level we can have the granularities which is IP prefix and this can be used to support destination based forwarding. So, we can have one to one mapping between an IP address prefix in the routing database within a pc and a labels which path may be created for every route that goes to a particular destination IP address prefix. So, this is at the very cores level and of course as we have seen that an IP address prefix is a quite scalable mechanism. So this approach is very scalable and the other intermediate granularities could be that FEC is associated with the egress router that is FEC that includes all packets which are going on going out on the same egress routers.

So not based on destination based forwarding but it is based really on the packets which are going out on to the same egress router and at a very fine level, you can have an FEC associated with a particular application flow also. So, as we can see that since there will be large number of flows in the network, the number of label switch path required if we are associating a label switch path with an application flow will be very large and therefore this approach is clearly not so scalable. But, in other hand if we are having FEC associated with an IP address prefix and labels which path based on the destination based forwarding, then this approach is actually quite scalable.

So, this is now a decision that one needs to take into an account what kind of you know scalability one is needed in the MPLS based network. Now, let us look at the little bit of the MPLS label as i said, it is a 32 bit shim header which is there between which will be attached between the IP header and the link layer header. So, essentially you know the label will look something like it will be as it will be it is called as a shim header.

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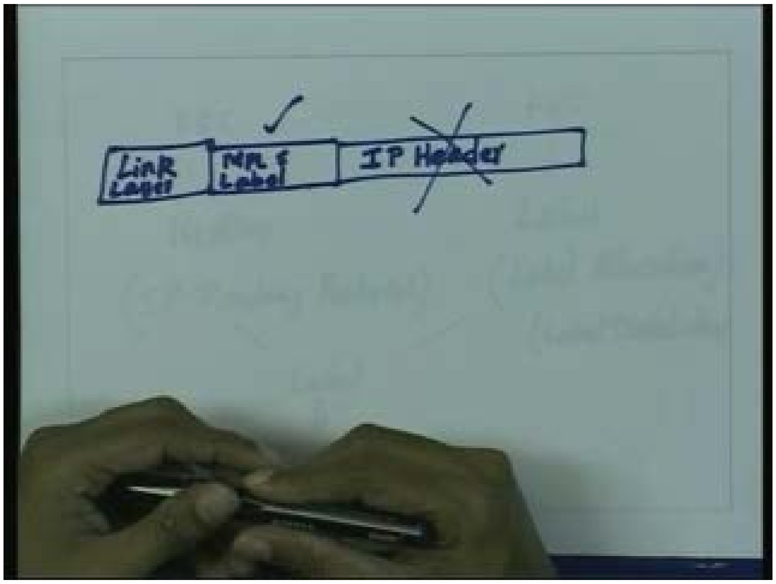

So here you may have an IP header and here you may have a link layer header. So the label is attached an MPLS label is attached here. So, the labels which routers essentially they do not work on the IP header they will work only on the MPLS label. So that is the reason as i had discussed that the TTL field is also copied from the IP header into the MPLS label. Now out of this 32 bit that 20 bit is actually the label or the label identifier which as i was saying will determine what is the next hop and so on.

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So now what are the basic operations which a label switch router will do? The label switch routers will do a basic operation on the label is push, pop and swap. So as you can see the swap as we have already discussed whenever labeled packet comes at a label switch router, the label is used to determine the next hop and the packet is then forwarded but at the same time, this incoming label is swapped with an outgoing label also. So every time an incoming label is swapped with an outgoing label and we have already discussed that the push and the pop operations are required only when you are using a stack of labels. Now the thing is, as we had seen in the MPLS as we had seen in the ATM based networks several virtual circuits can be aggregated or can be bundled into one virtual path.

For example: what you can do in the ATM networks if there are some virtual circuits which have the same end points that is there are some virtual circuits which are there between a pair of origin and destination between the same origin and destination, then all these virtual circuits can be bundled into virtual path and the intermediate ATM switches can then do the switching based only on the virtual path identifier that is what you can do. MPLS actually allows these bundling at an arbitrary level. What does it mean that some label switch path can be bundled or you know nested into one bigger LSP. This bigger LSPs can be nested into another you know one big fat pipe or a trap or a trunk or a trunk LSP and so on.

Now suppose you know, let us say that only two level of bundling has been done that means a set of LSPs was quite similar to the ATM networks, a set of LSPs which were there between a pair of source and destination they have been bundled into one bigger LSP. Now the intermediate nodes they will do the switching based only on these bigger LSPs identifier. Now these bigger LSP will be identified by a label which will be called as an outer label. So, now this label will be then followed by another inner label. Now this inner label will be different for the different LSPs which are part of these big fat LSPs or the bundled LSP and the outer label will be identifying this you know bigger LSP.

So basically we can have a stack of labels and while in the ATM we are having only two levels of stacking that is either virtual circuit or virtual path. In MPLS you can have any arbitrary level of stacking by making the label stack as big as possible as only thing you need to indicate is that said s bit where it will indicate that it is the bottom of the stack or not and then the labels which routers can also perform the operations of pushing the label or popping the label. Now let us look at that these two levels of bundled LSP reaches at the ingress. Now at the egress when that the router knows that it is the egress for this bigger if big fat LSP then what it will do it is that it will pop the outer label and then forward the packets you know based actually on the inner label.

So as a result you know what is done is that pop operation can be done at the egress and similarly at a point where these aggression is taking or the nesting of this LSPs into this bigger LSPs is taking place there when we want to create a stack of labels you can do a push operation. So that is why you know we have written here that the basic label operations that a label switch router needs to perform is push pop and swap. So these are the three basic operations that you know a label switch router needs to perform. Multiple control planes can actually manipulate labels on a single packet what does it mean is? For example: we can have a label associated with a label switch path and the label can also be used to identify the forwarding treatment that the packet needs to be given. for example: it can identify which on which queue the packet needs to be queued, so that it can get a you know appropriate scheduling treatment for the quality of service and so on.

So therefore, you know it is written multiple control planes can actually manipulate labels on a single packet. For example: the exp bit can actually indicate the quality of service guarantees as well. The label distribution as we have already discussed is done by label distribution protocol. Now these label distribution mechanism actually can be of two types. One is independent and another one is ordered. Now, let me just tell you the difference between the independent and the ordered?

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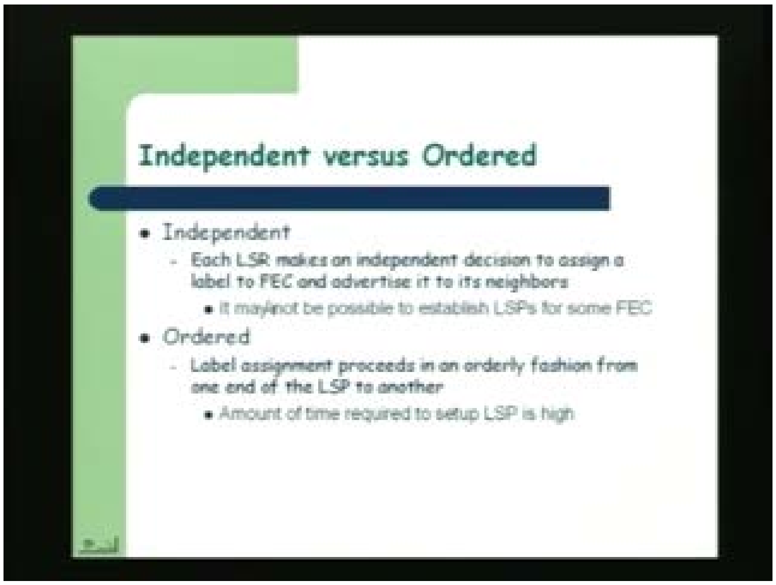

Now in independent, each label switch router will make an independent decision to assign a label to FEC and advertise it to its neighbors. Now since, each LSR is making an independent decision to assign a label it may not be possible to establish the LSPs for some forwarding equivalence classes. Now, it is saying something like this that the network of the label switch router each individual LSR you know takes a decision that what is its definition of FECS and then it assigns the FEC to a label and then it distributes these bindings to its neighbors. Now obviously, this may create two problems. One is think that the definition of the FEC may not be consistent with all the label switch routers in the network.

So, as a result you know for some FECs, it may not be possible to establish label switch path. Now what is the advantage of independent label distribution protocol? The label distribution mechanism is very fast. So therefore, a particular label switch path can be created very easily. Now, therefore an independent approach works only in a situation where you know the network has stabilized and the definitions of FECs etcetera are understood by all the routers to be the same and there is some agreement earlier that whatever maybe by the network administrate at by the network administrative mechanisms or network provisioning mechanisms. If these definitions are understood, then independent approach can be really good. But, otherwise you know an ordered approach will work and in ordered approach essentially label assignment will proceed in an orderly fashion from one end of the LSP to another. I mean in the sense that, if this is the label switch router and so ‘A’ is a label switch router then ‘B’ and then C.

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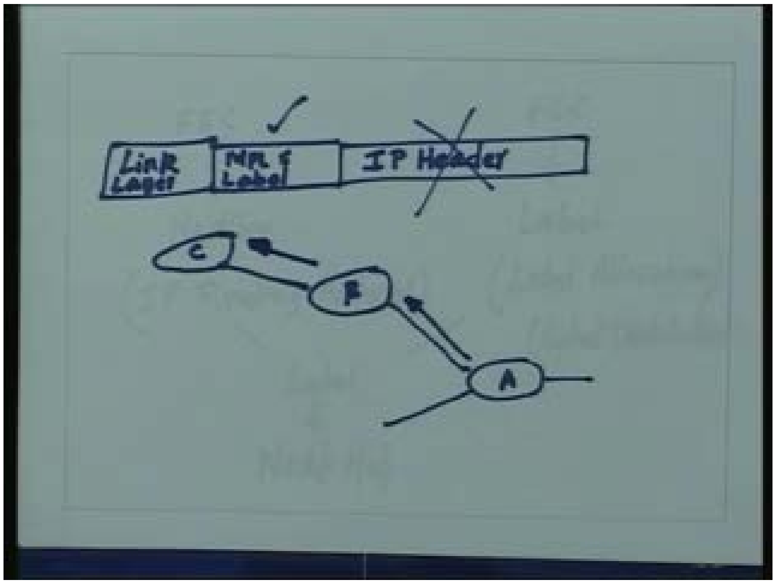

So let us say that you know if knows that it is the egress of some LSP and then LSP is going to be on a destination based IP forwarding, then it knows that the next hop is for that LSP is going to be 'B' then it will send. It will assign, so it assigns the label and then it distributes the binding to 'B' and then the 'B' then again assigns the label and then distributes the bindings to 'C' and so on. So, this way it will proceed in an orderly fashion. Of course, the disadvantage is that that the amount of time required to set up a label switch path in an orderly fashion is very high.

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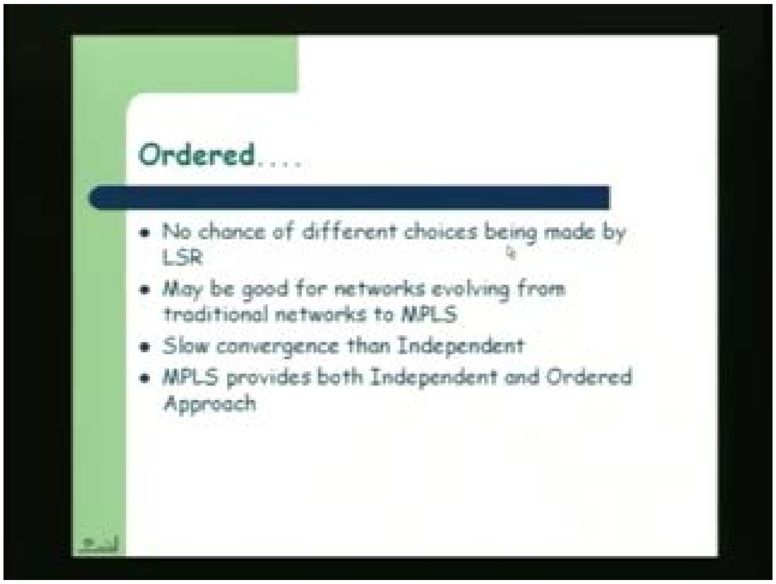

However the advantage is that there is no chance of different choices being made by LSRs and really speaking as i was mentioning that it may be good for networks which are evolving from traditional networks to MPLS based networks. However the main disadvantage of an ordered approach is that that it has a little slow convergence than independent based approach. So the convergence time is really very high the MPLS by the way has standardized both approaches independent as well as you know ordered approaches. So that it has standardized actually both approaches and also you know we can see as we are seeing the hierarchy in the label stacking.

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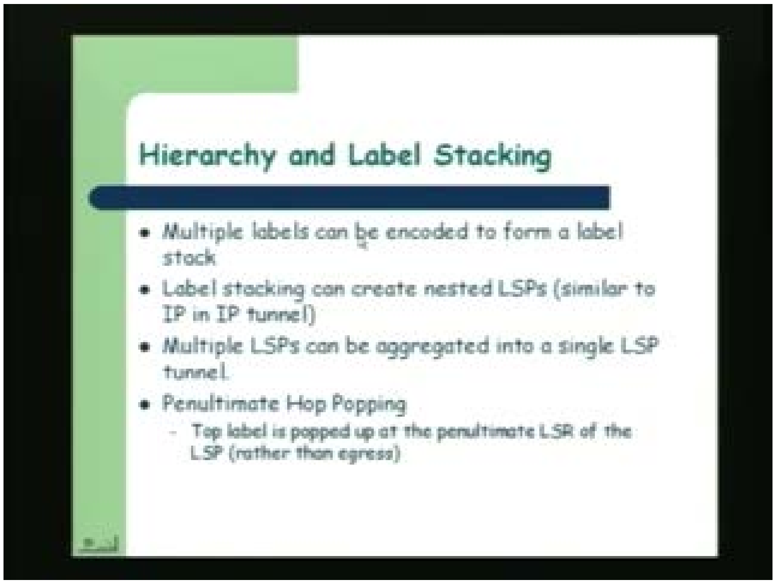

Multiple labels can be encoded to form a label stack, as we have just discussed the labels stacking can create the nest nested LSPs just like virtual circuit to virtual path or similar to IP in IP tunnel also and multiple LSPs can also be aggregated into a single LSP tunnel and by using the push and pop operations. For example: the outer level or the top level can be popped up at the penultimate LSR of the LSP and then you know the forwarding can be done based on the inner labels. So each label switch operator each label switch router will essentially perform the push and pop operations. Now as another thing is, we wanted to say that the label allocation is either you know could be downstream based or also it could be upstream based label allocations.

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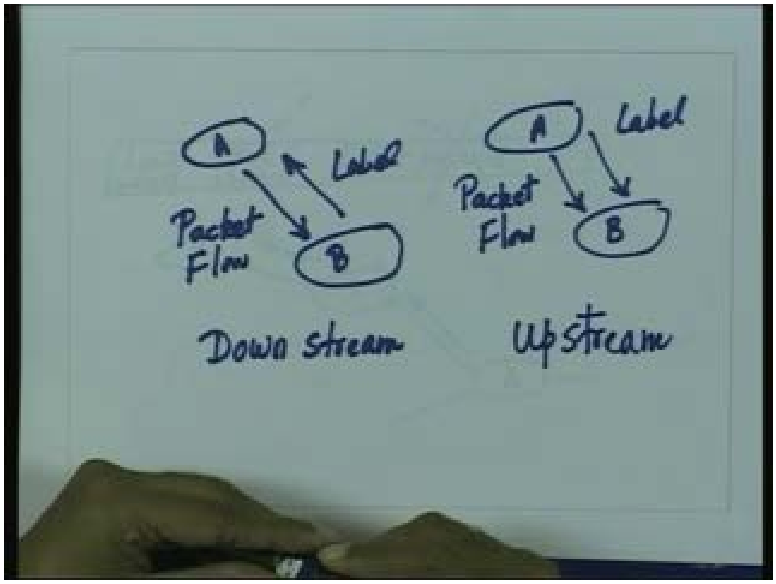

Now in the downstream based label allocation essentially what happens is that, if the packet is going to flow from A to B you know then label allocation will proceed basically from you know B to A. So this is like downstream based label allocation. So this is a packet flow and this is label allocation. So if ‘B’ will assign actually the label which should be incoming and will assign that label to ‘A’ and then a will use the label which has been assigned by ‘B’ to forward into its packet, the upstream based label allocation is in the same direction of the packet flow.

So the packet flow is from A to B and label. Essentially what the A will do is the A will be sending the outgoing label. Essentially A will be sending the label which will be used in this packet flow and B will put that label which has been assigned by A in its outgoing label entry. So, this is what is called as the upstream label allocations. Now just to summarize the MPLS i mean then we will go to how we can do the loop prevention and detection in the MPLS based networks and how the traffic engineering issues are addressed in the MPLS based networks.

Just to summarize now what is done in the MPLS based networks is, at the ingress of the network, the packets at the edge or at the egress the router has the capability of working on both IP forwarding as well as based on the label switching. At the edge, the packets are classified into forwarding equivalence classes, the FEC may be associated with destination IP based forwarding or it can be associated with any classification rules. Once packets are classified into FECS, label is bound to an FEC and then label distribution protocol advertises these bindings between the labels and the FECS to all other label switch routers.

They can follow various mechanisms of label assignment like independent or ordered. We can have downstream based label allocations or upstream based label allocations. We can have downstream on demand based label allocations. So there are different approaches of distributing these label bindings. There are different protocols also for distributing the label bindings either piggy bagging on the existing routing protocols or having a separate label distribution protocols

So once the label switch paths are created, then the intermediate nodes in the MPLS domain or in the MPLS network that is the label switch routers, they will do the forwarding based only on the labels which may be used to identify not only the next hop and the next label. But sometimes also the quality of service attributes. So, this is the basic paradigm or the basic working structure over which an MPLS network is formed. Now let us see the mechanisms which have been used in the MPLS networks for preventing the loop formations.

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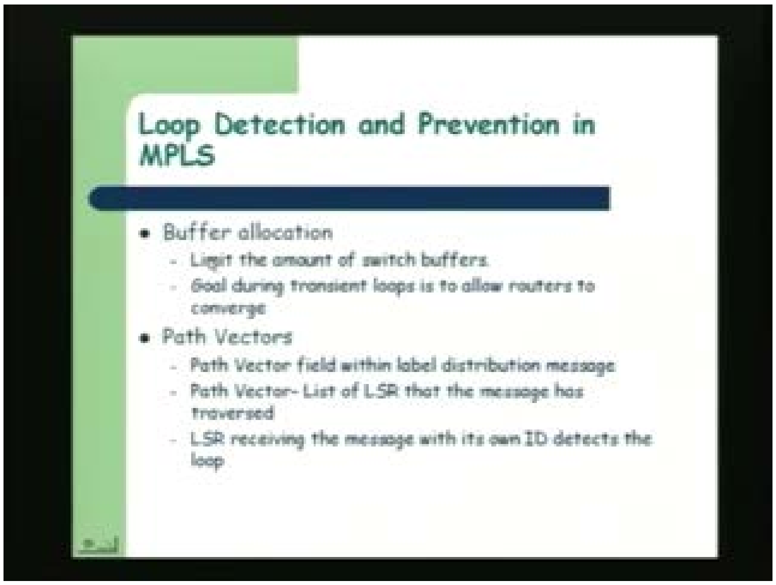

As you can see that the looping in the IP based network is a serious problem and two approaches can be done to alleviate this problem either we detect the loops before actually they are formed or the other approach is that we mitigate the problems after the loops have been formed. So to mitigate the problem in the IP world, the TTL field is used. Each router decrements the TTL field and when the TTL field reaches actually zero, the packet is actually discarded because it is assumed that the packet must be looping it in the network. So this is like loop mitigation. Now what can be done in the loop prevention is that for you know which is used can be used by the ATM also like you know to limit the amount of switch buffers.

Basically you know what you can do is that you do not allocate lot of buffer space to these data packets if the loops have been formed because the objective really when the loops have been formed is that the switches and the routers should not consume their energy in forwarding the packets. Energy means their resources essentially both the computer resources as well as you know the buffer resources. They should not consume their compute and the buffer resources you know in forwarding the packets etcetera. So, we can limit you know the amount of switch buffers that is required and what will happen is that you allow basically the control packets to pass through because during the transient condition, when the loops have been formed then the control packets you know should be allow to pass through with the higher priority so that the routing protocol convergence takes place and these loops are actually removed.

So therefore the objective should be that to limit the amount of resources to the actual data packet which are there in the networks. The other thing you know which can be which is done in the MPLS is that we can follow the approach of the path vector, if you know you can have a path vector field within the label distribution message. So what is happening is that when you are distributing the labels, now each node what it will do is that each node will assign will attach its IP address in that path vector field. So, basically you know the path vector field is that whenever label distribution message is passing up, each LSR will attach its IP address. Now, if the packet has looped back then a particular LSR will see its own IP address in the path vector field.

So when the LSR receives the message with its own id in that path vector field then it immediately detects that you know the packet or this label distribution message essentially as looped. So when it detects that you know then it discards this label allocation procedure.

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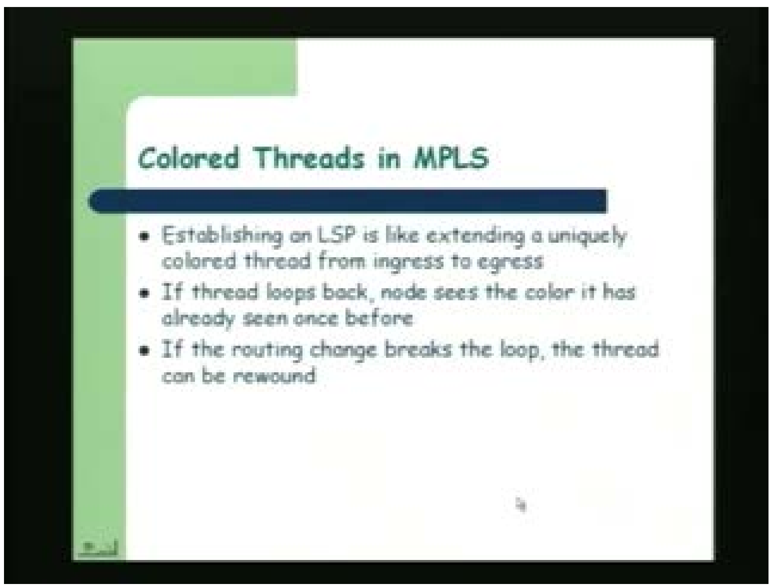

The other thing is quite similar to the path vector. Now in path vector what you are doing is that each LSR when it forwards the label allocation message, it attaches its own id and then and when the LSR receives label allocation or label distribution message, then it checks whether its id is present in that label distribution message or not and if its id is present then of course you know it concludes that the packet must have looped. The similar technique in fact better and powerful technique is what is called as colored threads in MPLS. Now this based on the premise that establishing here a label switch path is like extending a uniquely colored thread from egress to the ingress.

Now uniquely now this colored thread is basically one number some number, now when a particular when a particular LSR passes a label distribution message, it will it will attach one particular number. Now the second LSR actually will copy back that number into its own label distribution message and so on.

So when the packet comes back to a particular node with the same you know color or with the same number that it has earlier passed on then it concludes that actually the packet has basically looped. So what really it call is that, if the thread actually loops back then the node actually sees the color it has already seen once before and if the routing change actually breaks the loop then the actually this thread can be rewound or what is called as rewinding the thread. So this way if the loops have been formed you know they can be their effects can be sort of mitigated. So this is like a loop detection and mitigation techniques.

So what we have seen really is that the basic features or the basic properties of a MPLS networks. What will now do in out next lecture we will address how MPLS can be used to address the challenges of traffic engineering and how MPLS can work with the IP QoS issues?

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