Broadband Networks
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Lecture No. 25
MPLS and Traffic Engineering

So as we had discussed that in MPLS the packets are classified at the ingress of the MPLS domain into forwarding equivalence class and each FEC is bound to a label and the label bindings between the FEC and the labels and at the label bindings between the FEC at the labels are then distributed to the label switch routers through a separate protocol which is called as label distribution protocol.

Now let us see how the label allocation is done in the MPLS networks. Now as I have said in the previous lecture that label allocation can be done either based on downstream based label allocations or upstream based label allocations. So let us look at what are the various techniques.

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Now in downstream based label allocations, it could be of two types. Downstream Unsolicited: Now downstream in downstream unsolicited the label assignment is done by the downstream peers and then it is distributed to the neighboring LSRs. We had already discussed that we consider a node to be a downstream node with respect to another node if the packet flow is going to be in the opposite direction.

So essentially if there are two nodes in the networks and if the packet flow is going to be from one node to another node you know in one direction and the label allocation proceeds in the opposite direction, then we call it to be a downstream based label allocation. Now we are saying that downstream based label allocations could be unsolicited or it could be on demand basis. Now unsolicited label allocation the trigger for the unsolicited label allocations normally will be the new routing updates or you know any topological changes or routing information. On other hand on demand based label allocations can proceed when a node requests the allocation of a label. So as we have discussed here the downstream unsolicited label allocation the trigger is new routing information and for the downstream on demand it is the upstream labels which router which specifically request a label assignment and then the corresponding downstream routers will assign a label.

Now as we discussed that label distributions can be done either by piggy-backing the label bindings on to the existing control protocols like OSPFs or RSVP or some other routing protocols an alternate approach of course would be to come up with a separate new protocol which is called as label distribution protocol which has been standardized in the MPLS.

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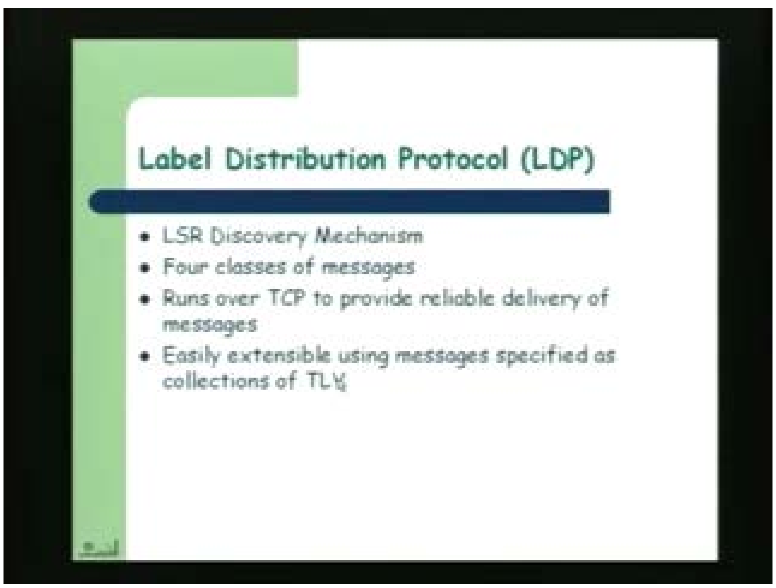

Now in the label distribution protocol first there is an LSR discovery mechanisms that means that protocol the LDP protocol first discovers the neighboring labels switch routers through an LSR discovery mechanisms, four classes of messages have been defined in the label distribution protocol for label allocations requesting a label, mapping a label and the label distribution protocol essentially runs over TCP to provide a reliable delivery of messages. Of course, this is an issue that you can build an inbuilt reliably you know reliable mechanism on to a label distribution protocol or you can make use of the existing transport protocol for the reliable delivery. Now, there are pros and cons again; see here Now, note that the TCP has its own congestion control and flow control mechanisms built into it which may not be required for the distribution of the labels in the label switch routers. So that also the TCP requires a three way hand shed mechanisms which introduces a further latency into the networks.

However it was decided in the MPLS standards that LDP will run over a TCP as a TCP application and make use of the TCP's capabilities for providing the reliable delivery of information, even though we may not need other features of TCP like congestion control or flow control mechanisms. The LDP is easily extensible using the messages which are specified as collections of type length and value as TLV encoding is done for these messages in the label distribution protocol.

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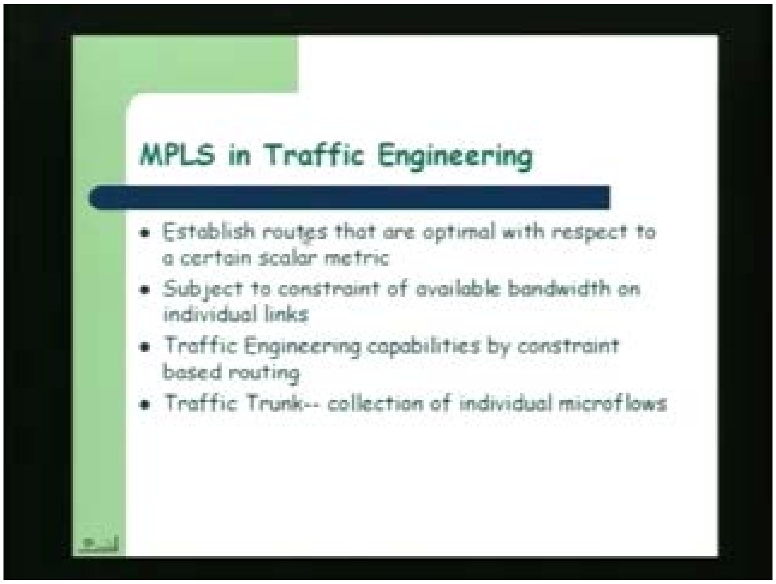

Now, we come to an… so as we were saying that what are the advantages of MPLS. There are two major advantages of two major driving factors for MPLS. One was the performance bottle neck in the IP routers due to the longest prefix match which no longer currently a driving factor for the MPLS, but the other important driving factor for the MPLS was that it can address the challenges of traffic engineering in the IP networks. So that is one of the major driving factors today for the deployment of the MPLS networks. Another important thing as you can see subsequently is that the MPLS traffic engineering mechanism also enables it to be as a control plane protocol for the DWDM based optical networks also. So for intelligent optical networks, the MPLS can serve as a unifying control plane mechanism.

So we will you know just see how MPLS is used for the traffic engineering purposes. Now in MPLS traffic engineering, you know the routes are established which are optimal with respect to a certain scalar metrics and which is subject to constraints on the available bandwidth on the individual links. So what does it do is that, it makes use of that constraint based routing algorithms.

These constraint based routing algorithms essentially are similar to quality of service based routing algorithms. Now, there is a slight difference between the QoS based routing and the traffic engineering algorithms. In QoS based routing also, you will choose a path which will be optimal with respect to a certain metric and it will be subject to availability of bandwidth on the link. So that is also done in the QoS based routing. But, the difference between the QoS based routing and the traffic engineering algorithm is that QoS based routing are typically greedy. So once they choose a path which satisfy the certain constrains and if another request comes and if that request can be accommodated by re-adjusting the load, that will typically be not done in a QoS based routing algorithm.

However, a traffic engineering algorithms may try to readjust the loads in such a manner that a new request can be accommodated. So that is really the difference between the quality of service based routing and the traffic engineering or a constraint based routing algorithms which are used in the traffic engineering.

So, the MPLS will make use of the capabilities of these constraint based routing algorithms to determine paths which are optimal with respect to a certain scalar matrix and which can choose a path subject to availability of bandwidths on a particular link or so now the traffic trunks are actually the collection of individual micro flows. The MPLS actually defines a concept of a traffic trunk which can be a collection of individual micro flows that means several micro flows are aggregated into traffic trunk and then these traffic trunks are routed in the MPLS domain in the form of labels switch paths and these labels switch paths are mapped on to the routes which satisfies certain constraints of available bandwidth or delays etcetera on the individual links and these links are actually chosen by some form of constraint based routing algorithms

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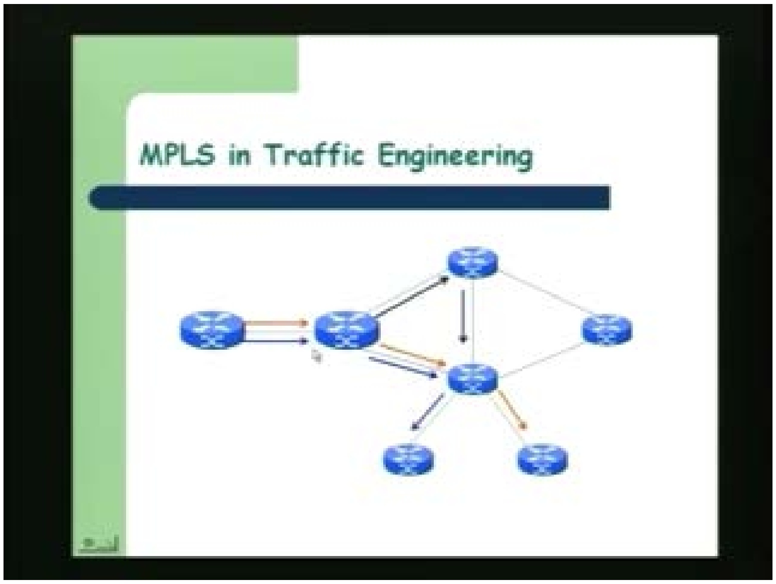

So here is an example of this that these are all you know labels which routers. So for example there may be um some traffic which may be going from this node to this node. So in a constraint based routing algorithms you know you may select some traffic to go on this link and that may be an optimal path for this but some traffic may get diverted onto this link.

So as a result, the constraint based routing algorithm may try to optimize the link capacity utilizations of this link, this link and this link. So, the three links link capacity utilizations you know the constraint based routing algorithms may try to optimize and then what can be done is that that labels switch path can be set up on these red line the labels which labels can be set up here and all the micro flows can be aggregated into this traffic trunk and this traffic trunk has been mapped on this LSP and it can be routed onto this you know labels switched path.

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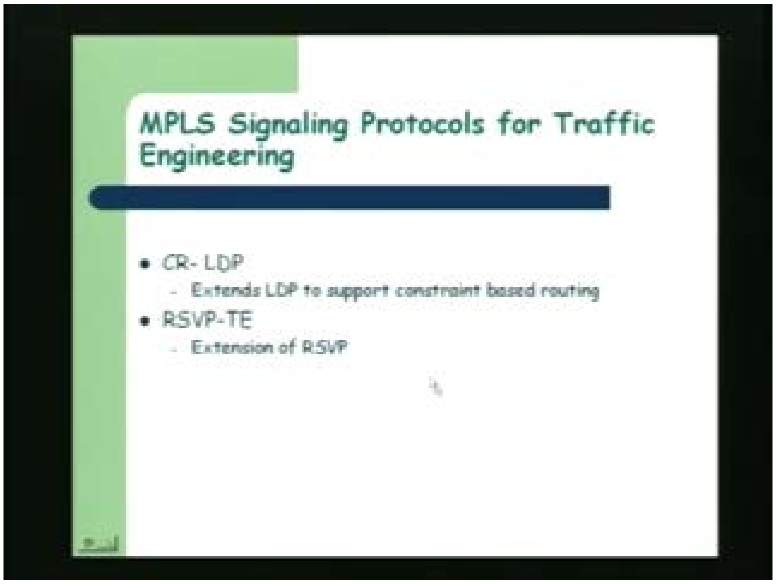

So of course to establish these labels switch path you require the signaling protocols for the traffic engineering and there are two approaches which were proposed. One is what is called as extension of the existing label distribution protocol to support the constraint based routing and that approach was called CR-LDP or constraint based routing label distribution protocol and another approach was the extension of RSVP-TE that is extensions of resource reservations signaling protocol for the traffic engineering purposes.

There were of course lots of debates: whether CR-LDP is better or RSVP-TE is better. Some people argued that RSVP-TE has a scalability problem. Note that RSVP was a signaling protocol which was proposed in the context of integrated services internet model of QoS and from that you know the people had this argument that RSVP-TE has a scalability problem, but actually speaking the scalability problem was more in the insure model rather than in the signaling protocols.

So it was then favored by many people that RSVP-TE could be a better signaling protocol for traffic engineering purposes in the MPLS networks. More over RSVP or extensions of RSVP have also been proposed for setting up a guaranteed bandwidth labels switch paths also. So even if you do not want to do the traffic engineering but if you want to provide the quality of service guarantees in the MPLS based networks, then extensions of RSVP also have been proposed to enable that.

So because of these two things, the RSVP-TE as a signaling protocol was favored for the traffic engineering purposes and that is the traffic engineering for the IP networks is as we have argued is a major driving factor for the MPLS networks and therefore RSVP-TE is going to be one of the dominant signaling protocol whenever the MPLS networks will be deployed in the networks.

Now, we will look into how the model of QoS, the quality of service the quality of the IP how IPLS actually extends the QoS model of the IP networks. In fact it was long believed that actually MPLS provides quality of service guarantees however actually that is not true MPLS really speaking extends the IP QoS model so therefore if in in an MPLS based networks if you really want the quality of service guarantees then actually you have to enable the IP QoS model only. So let us look at the MPLS and the quality of service.

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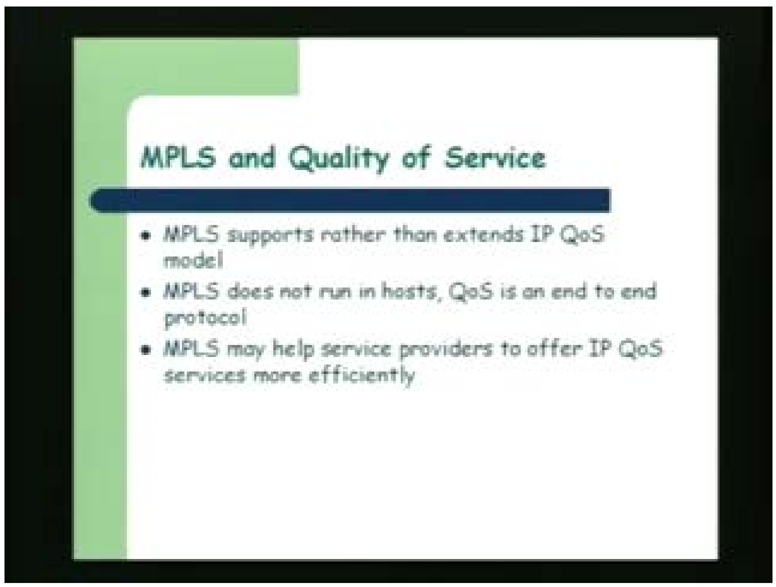

So MPLS actually supports you know rather than it extends the IP QoS model and the MPLS however does not run in the host. Typically you know the MPLS will be present in a label edge router. However, as you know that QoS is an end to end paradigm.

So what is really meant is that MPLS can be used to provide the quality of service guarantees to the traffic trunks or creating the label switched path which have guaranteed bandwidth or low delay qualities but really speaking the MPLS cannot enable an end to end quality of service guarantees essentially because the MPLS starts you know you starts seeing MPLS only from the label edge router kind of thing. The MPLS may actually help service providers to offer the IP QoS services more efficiently. So even though you know MPLS inherently does not have any inbuilt QoS mechanisms, it actually relies on the IP QoS model only. It extends actually the IP QoS model we will just see that how it can help you know the service provider to offer the IP based quality of service services you know in a more efficient manner.

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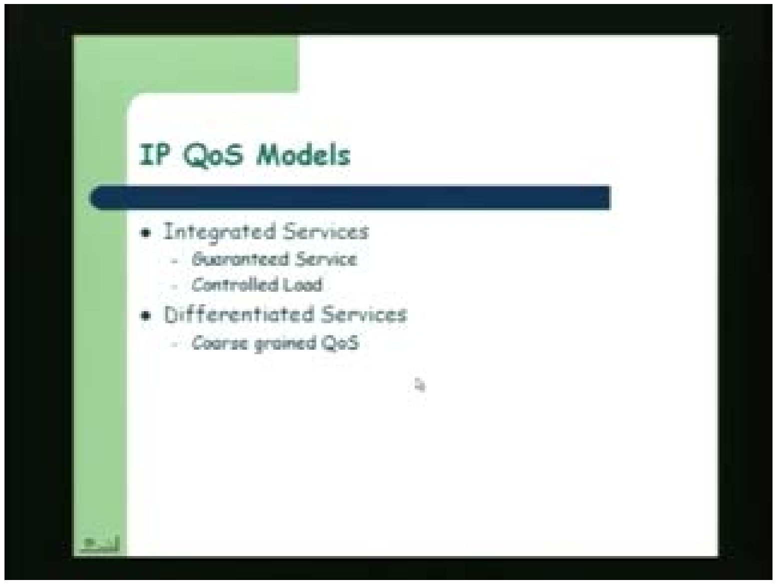

So as we had seen that the IP QoS model is of two types we have had extensive discussions on this. There are two major modules. One is the integrated services and another one is the differentiated services. The integrated services model also is of two types. One is that provides you know the guaranteed service one is provided the guaranteed service and another one is the controlled load service. Now as you know that in the guaranteed service the individual flows are given hard guarantees in terms of absolute quality of service attributes which is like bandwidth or end to end delay and so on.

So now what is done in the integrated services model is that, those individual packets are actually classified into several flows and then you know and the classification is done based on these application flows. So there may be as many you know virtual queues in the system as there are flows and then the scheduler will schedule these flows in such a manner that we can provide absolute quality of service guarantees or hard guarantees in terms of either the delay bounce or the minimum rate or the bandwidth.

Obviously, this model suffers from scalability problems in the sense that the scalability problems are that you have to classify the packets into individual flows and therefore the states corresponding to these individual flows will have to be maintained by the routers. So to address these problems of integrated services rather course grain QoS approach was proposed in the IP world and that was called as the differentiated services. Now in differentiated services instead of classifying the packets into individual flows you classify the packets into fewer numbers of classes only.

So basically you aggregate these flows into classes and then you know classify the packets into these three or four classes only. At maximum you know there will be it is widely believed that in the internet you know if we already have a best effort network class, if we have a better than best effort service model or a premium service model that will be more than sufficient for most service providers you know from the quality of service perspective.

So therefore a rather course grain approach that is the differentiated services approach was proposed you know which try to alleviate some of the scalability problems that were existent in the integrated services approach and you know the differentiated services based QoS model is likely to be more popular in the IP world, it is more scalable. It has less signaling overheads and it has less overhead in terms of statement analysis. So therefore you know it is scalable QoS model and likely to be more popular.

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So integrated services has a mechanism in terms of admission control, it has a classification engine. It classifies the packets into individual application flows the admission control decides how many number of such flows can be admitted, so that you know when you apply the queuing and scheduling mechanism you know you can provide the assured quality of service guarantees. Once the flows are admitted, then the flows are also policed to see that the corresponding flow is confirming to its advertised traffic descriptors or not and if it does not confirm to the advertised traffic descriptor, then the router may either drop the packets or it may mark the packets because it may affect the quality of service guarantees given to the other flows. The signaling protocol which is used in the integrated services is one of the most popular signaling protocol which is resource reservation based protocol or what is called as RSVP.

So this is a signaling protocol which is used to convey the information about the traffic descriptor that a source is going to have and the quality of service attributes which the source desires to have from the networks.

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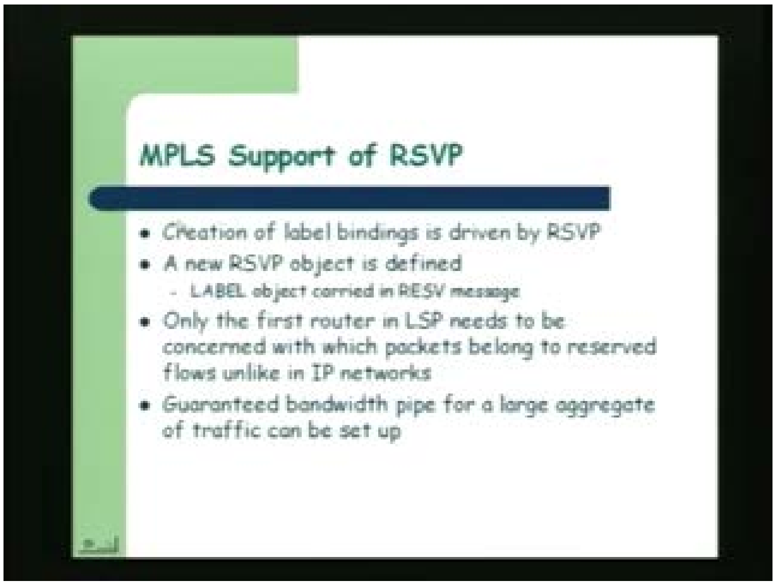

Now MPLS actually extends the RSVP protocol for signaling of the QoS. Now what we have to do really is that that if we have to extend the IP QoS model, then apart from you know conveying the quality of service attributes and the traffic descriptors, now the signaling protocol also has to convey the label bindings between this QoS state and the and the corresponding labels which path or the traffic trunk.

So what is done is that the creation of the label binding is driven by the RSVP and for that purposes, a new RSVP object is defined which is called as a label object which is carried in the reservation messages. Now, what is done here is that typically you know RSVP sends a path message from the sender to the receiver. So it will send a path message which will contain traffic descriptor and a request you know for a traffic descriptor and essentially you know it will go from the sender to the destination.

Now the destination will initiate the reservation request giving the quality of service attributes and along with that, it will also initiate you know a label request message. So a label object will also be carried in the reservation messages. You can see that only the first router in the LSP needs to be concerned with which packets belong to the reserved flows unlike in the IP networks because it is a first router which will do the packet classification of these IP packets into the corresponding FECs you know which is associated with a certain QoS state and later on you know once the labels switch path is setup really speaking you know the individual routers do not have to do the packet classification and associate them with the QoS state which has been which has been signaled by the RSVP which is normally done if the router was an in-serve router. So this you know post-date day as we have discussed a scalability problem in the INS serve router.

So that problem is addressed you know in the MPLS networks automatically, so typically you know in MPLS if you want to provide the quality of service guarantees you will be actually setting up a guaranteed bandwidth p IPE or a guaranteed bandwidth labels which path for a large aggregate of traffic. So that can be set up to provide quality of service guarantees. In MPLS typically you will not be setting up a labels switch path for individual application flows and associate them with QoS state because that as we have seen imposes a large scalability problem.

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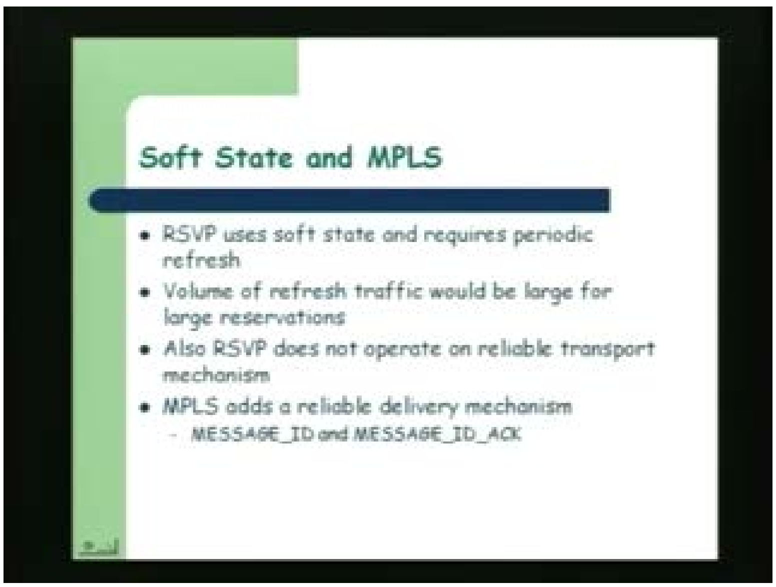

Now as we have seen actually, the RSVP is a soft reservation protocol in the sense that QoS state maintained by the RSVP are typically soft in the sense that they require periodic refresh mechanisms unlike in the atm world where the QoS signaling state could be a hard signaling state. In RSVP, the signaling state is typically soft and what is done is that it requires a periodic refresh mechanism. These QoS states need to be periodically refreshed.

Now if you do this in the MPLS, then the volume which will be generated by the refreshed traffic which will be very large you know for the large reservations so it would be prohibitively very large and moreover you know RSVP does not operate it on the you know reliable delivery mechanisms.

So therefore you know MPLS has added in the RSVP a reliable delivery mechanisms you know in which the message in which the signaling message will contain a message id and that message id will be periodically act you know and as a result what you can do is that you can increased you know the refresh timer interval, you do not have to send now the refresh states periodically for a shorter refresh interval now the refresh interval can be made a little larger and as a result, we can reduce the traffic that is there due to the refresh packets.

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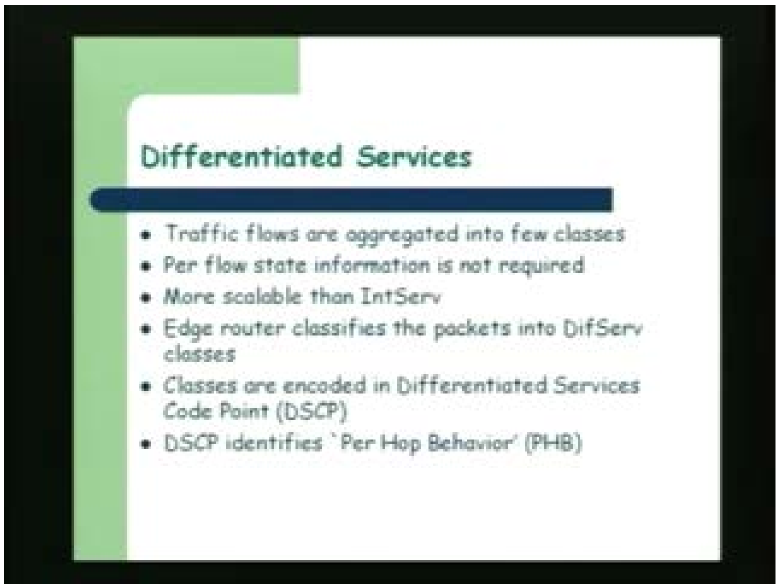

Now we see how the differentiated services paradigm can be integrated with the MPLS as we have already brought out that differentiated services is more a coarse grain approach for providing quality of service guarantees. In this approach, what is really done is that the packets at the ingress of the differentiated services domain are classified into few classes and once they are classified into few classes, this class is carried in the packet itself which is called as differentiated services code point or DSCP.

This DSCP bit actually was previously teapots field IP type of service field and that IP type of service field has been redefined in the differentiated services to be a DSCP code point, differentiated services code point. So as a result, what happens? Just like in the MPLS, so the paradigms are quite similar; just like in the MPLS where the packet classification is done at the edge of the network, packets are classified into forwarding equivalence class and FEC is bound to a label and then packet is attached with the label and then in the core of the networks, it is the label which is used to forward the packet to determine the next hop or the next label.

Similarly, in the IP differentiated services model also, packets are classified at the edge of the differentiated services domain into few classes. Now, corresponding to each class we have a differentiated services code point. So, that code point is then encoded into the packet and the packet is sent. Now, in the core of the differentiated services domain, no more packet classification is done on the IP header or on the TCP header etcetera. That has been already done at the ingress of the networks.

However, the core of the networks now will look only at the differentiated services code point, only they will look at the DSCP point and then this DSCP point will determine what treatment, what forwarding treatment the packet should get. So, this is the principle of differentiated services.

Now, as you can see the paradigms of the forwarding are very similar in the MPLS in the differentiated services; it would have been very good if there have been an alignment of the DSCP or a differentiated services field along with the MPLS label field. But since the two we are defined separately, as a matter of fact, the differentiated services were defined much earlier to the definition of the MPLS label. So, when we need to extend the differentiated services paradigm to the MPLS world, the problem was how do we map these differentiated services classes to the in the MPLS.

Now, one way could have been that in the MPLS, as we had seen that in the label there is a 3 bit EXP field - Experimental field which was put. Now, we can map therefore the differentiated services classes by using this 3 bit of the EXP field, we can use that. Unfortunately, however, that in the differentiated services model, there are 6 bits which have been used to define the differentiated services classes.

So therefore theoretically, there are 2 raised to the power 6 or 64 differentiated services classes are possible. Now, in the MPLS we only have 3 bits; so therefore, only 8 bits are possible. So, now the question is how do we map these 64 classes into these 8 classes which are possible in the MPLS network.

It was argued that in many cases actually, in most IP Qos network, 64 classes are not going to be implemented, mostly. Mostly, in the differentiated seven, the differentiated services is deployed in the IP world more than 8 classes are unlikely to be there. Now, this solves the problem to a large extent. If in a particular network, if not more than 8 differentiated services classes are to be deployed; then the EXP bit, the 3 bit EXP bit can be used to determine the differentiated services class in the MPLS network and that in turn can determine the forwarding treatment which corresponding label packets will get in the networks.

Now, when we use, when we set up LSPs in this manner, then they are called ELSP. ELSP - E stands for that we are using essentially the EXP bit, the 3 bit EXP bit to denote the corresponding differentiated services class. However, in cases where more than 8 classes are to be deployed, then obviously some portions of the labels must be used. So, some part of the 20 bit label that needs to be used and that is what is called as LLSP.

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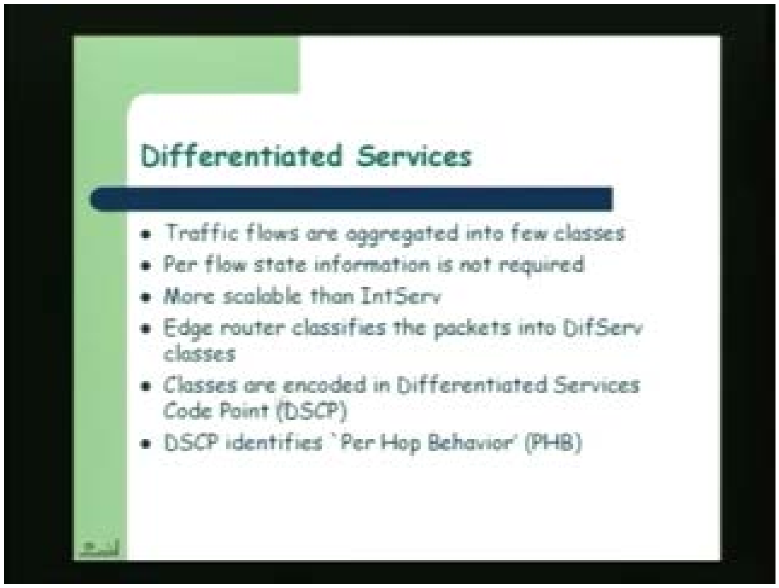

Now, let us see how that is done in MPLS. As we have already seen that the differentiated services, we do not require a per flow state information. Edge router will classify the packets into DifServ and classes are encoded in the differentiated services code point and the differentiated services code point essentially identifies a per hop behavior. Now, one more thing which I would like to point out here is that in the integrated services model, the paradigm was more an end to end QoS model. In the differentiated service model, it does not define actually the services but it actually defines the forwarding treatment.

Now, the value of the class which is carried in each packet through the form of differentiated services code point will determine what is the forwarding treatment that a packet will get and it will not determine what is the service that the packet is getting. The services, the end to end services needs to be created by a combination of the forwarding treatment which each router has to give in conjunction with some other mechanisms like admission control or policing at the edge of the router. So, services by the services provider need to be created out of these legos or out of these components of the differentiated services.

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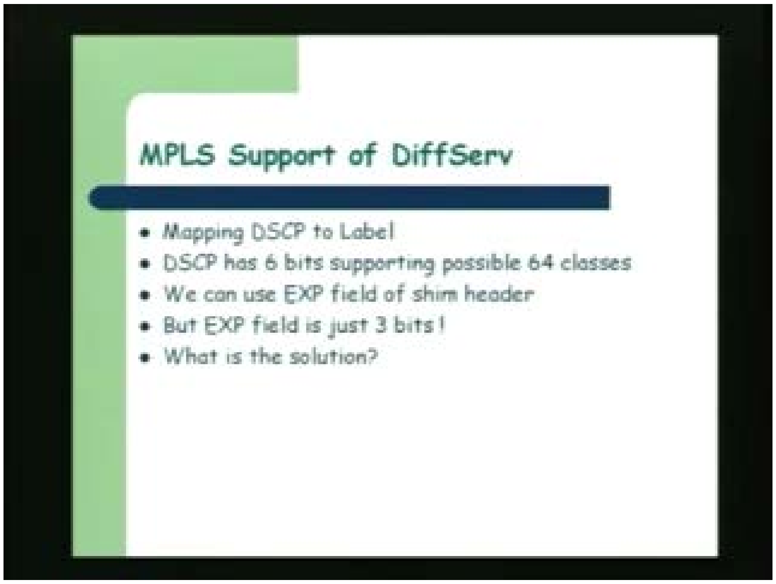

So, as we were discussing that we need to then map the DSCP field to the label.

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So, since the DSCP has 6 bit supporting possible 64 classes, we can use the EXP field of the shim header but since EXP field has just 3 bit; so what is the solution?

Now, one observation as we have seen that if the network support fewer than 8 PHBs, then we can use the EXP bits and LSP set up under these conditions is called ELSP. But what if we need more than 8 PHBs; then obviously as we are just discussing, we need to provide information inside the label. So, we need to provide information inside a label and this requires now enhancing the label distribution protocol also because labels are now need to be bound to both FEC and the per hop behaviors.

So, this binding needs to be done and therefore that requires an extension of the label distribution protocol and actually such LSPs are called LLSP as opposed to the ELSP where we are using that 3 bit of the experimental field of the MPLS.

Now, in LLSP actually, the packet which belongs to the different PHBs; now, it may so happen actually that packets may belong to the different per hop forwarding behavior but you want that this packet should not be re-ordered. So therefore, all those packets which belong to the different PHBs but these packets should not be re-ordered; they form one PHB scheduling class and it is therefore mandatory that packets belonging to the same schedule PHB scheduling class must travel on the same LSP.

So, this point needs to be taken into account while setting up an LLSP in the MPLS network.

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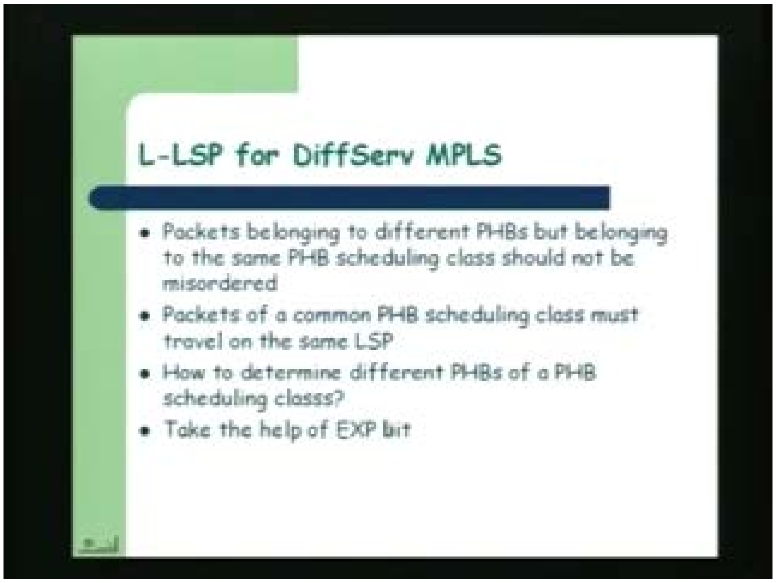

Now obviously, the question then arises is that if we have bound a PHB scheduling class to a label because what we are now saying is that the packets which belong to the same scheduling class, they are bound to now an LSP and therefore the label now identifies the PHB scheduling class.

But now how to determine the different PHBs of a PHB scheduling class? Then in that case, we can take the help of the 3 bits of the experimental EXP bits. We can take the help of EXP bits to determine that from this PHB scheduling class, how the different PHBs, what are the different PHBs which are present. So, this way one can determine the different PHBs of a PHB scheduling class also.

So, what really we have seen is that so in conclusions, what we have really seen is that the MPLS extends the Qos model of the IP networks. So, first of all it needs to extend the signaling protocol the Qos model like RSVP because now you have to not only bind the labels to FEC but you have to also bind the labels to corresponding Qos state. So, when we want to Bind the LSP to the corresponding Qos states like in the differentiated services, obviously the question then is that how do we identify the different Qos states?

So, we can identify the different Qos states by using those 3 bits which are present in the label in the form of EXP. But then the problem is that there are only 3 bits, so therefore only 8 possible Qos states will be available. Now, if we want more than 8 possible Qos states, then we can use the label, the part of the label themselves to identify the corresponding Qos states. So, this way we can extend the IP Qos model to the MPLS networks.

Now, this essentially completes our discussion of how MPLS can be used to alleviate the problem of longest prefix match in the IP networks which is very simple because instead of using forwarding based on IP addresses, we are using based on labels which can be and the label look up can be simply done in the form of an index look up. The second problem is that the MPLS enables the that traffic engineering in the IP networks and that is done essentially by using the capabilities of constraint based routing algorithms and extending the MPLS signaling protocol to establish routes which are optimal with respect to load balancing in the IP world.

And, the third thing is that the MPLS extends the IP Qos model; either the integrated services or the differentiated services model. So, these are the 3 features on enabling the applications of MPLS that we just discussed as a part of this lecture. Now, what we will discuss further in this lecture is that MPLS can also has a novel application and that is that MPLS can also be used as a control plane for next the generation intelligent IP networks, IP optical networks.

So, in the next few minutes will see that how MPLS can be used as a novel signaling or a control plane protocol for the intelligent optical networks. So, let us see how MPLS has a control plane which be used for in intelligent optical networks. Now, before really we go into this, let us see how today's optical networks are built. So, here is the slide which shows how a multi-layer optical network is built.

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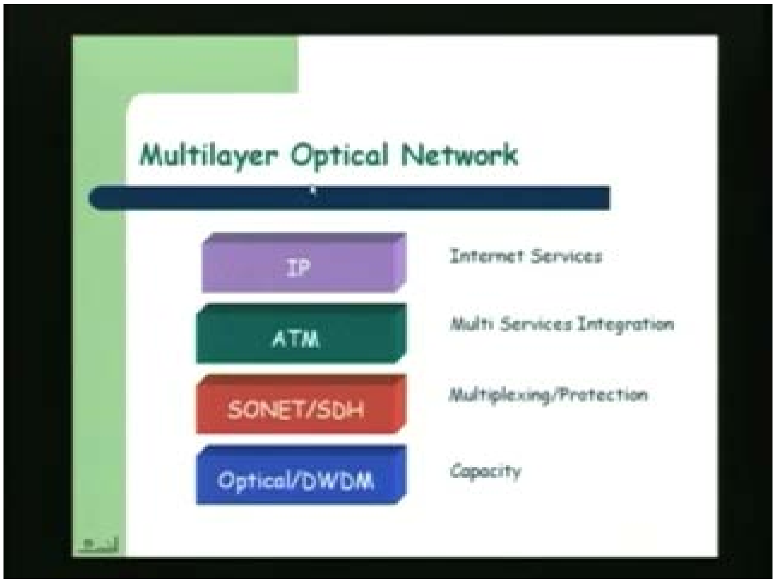

Now, you can see the physical layer could be based on an optical DWDM network - dense division multiple networks and which can be used essentially to increase the capacity of optical networks. Today, we can build a DWDM based networks for 40 giga bit per second kind of capability. Then, we have this sonnet SDH kind of networks. So, essentially we can have a DWDM ring, then we can have a ring of SDH and SDH basically provides both - the multiplexing as well as protection and restoration capabilities, the protection of the restorations capabilities are inherent in an SDH based networks.

And then, we have the atms which runs over the SDH. An atm is the primary transport protocol which is used for the various services integration and provides an information transport mechanism over the fiber based SDH or the DWDM networks. And then, we get those IP or internet services by running IP over all these protocols.

So, as we had seen here, in our previous discussions also that at the physical layer you can have these sonnet as SDH sonnet SDH ring or DWDM ring as the physical layer and atm is actually used as a transport mechanisms which provides the traffic engineering capabilities and which provides a multi services integration, which provides basically an information transport protocol and over which the IP network is run. And, this is what is what we had discussed earlier is like an overlay model where IP is being run over an atm.

Now, we see how the next generation network is evolving and as you can see here there are next generation network is rapidly evolving from IP atm sonnet DWDM networks TO IMPLs over sonnet DWDM.

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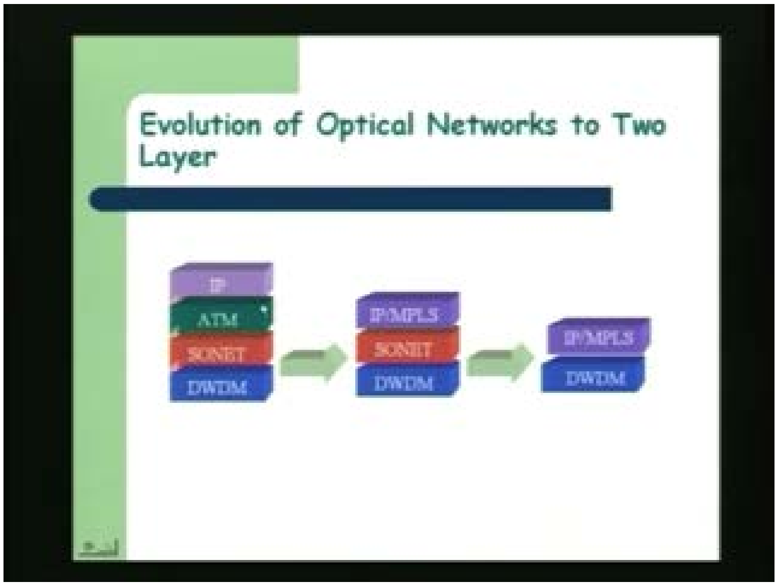

So, you can as you can see here that this atm layer has been completely removed. Atm layer was basically used for providing traffic engineering capabilities, for providing Qos capabilities, for providing transport capabilities; all that jobs is now done by the MPLS networks. The sonnet or SDH is still present for providing the multiplexing or protection capabilities and as we are gradually moving to the next generation networks, as you can see that some networks are now been being built where we no longer have a sonnet or SDH ring but we have a pure fiber ring as well where the IP MPLS protocol is native run in a native mode over this fiber ring.

In fact, as we will see that in the next generation optical networks, we are going to have a fiber based Ethernet rings also where the metro Ethernet based services are going to be provided and MPLS actually provides a mechanism; by running MPLS over Ethernet, it provides a mechanism for multi services integration and for providing traffic engineering capabilities. Alternatively, if you are not using the 1 gig or 10 gig Ethernet ring, we can use a DWDM based ring also to provide more capacity like 40 gbps and so on and then MPLS can be run over that networks for multi services integration.

So, this now going to be an evolution to a next generation optical networks where sonnet and SDH may be replaced by a MPLS DWDM or MPLS 10 gig Ethernet combinations. So, this is an evolution to basically a next generation network. And, we will see here what the role of an MPLS networks.

Now, as we can see here that sonnet and SDH basically provides an important protection on the restoration capabilities what is called as 50 millisecond restoration times and this is historically this was historically very important for providing certain time critical services like voice - the public switched telephone network quality voice, the pspn or TDM quality voice.

The sonnet SDH was providing an important function of having a sub 50 millisecond protection at the restoration capabilities and when we chop of these sonnet SDH ring and come up with the MPLS Ethernet or the MPLS DWDM ring; then we need to see that those kinds of protection and the restorations capabilities are being enabled by these networks.

So, that is how we will see whether it is possible to enable that in the IP IMPLs based network, how that gets enabled and how we will evolve to a next generation optical networks. And, the key there is that since MPLS has this traffic engineering capabilities; that can be used as the corner stone or the starting point to enable an MPLS as a control plane protocol for configuring this next generation DWDM based optical networks.

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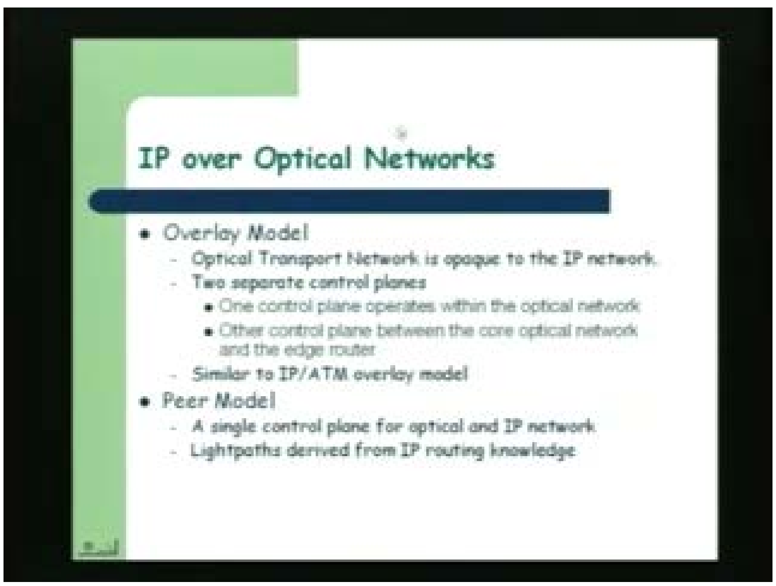

So, what we are now saying therefore is that how IP can be how IP directly can be run over optical networks. So, first let us see that we are having directly IP over DWDM and what are the challenges there and how MPLS actually will be used to address those challenges. So, there are 2 models quite similar to when we were discussing IP over atm networks.

So, one is the overlay model and another one is the peer model. Now, in the overlay model - the OTN that is the optical transport network and which could be based on DWDM is completely opaque to the IP networks. So therefore, we have 2 separate control planes; very similar to the discussions what we had for IP over atm. So, one control plane will operate within the optical networks and other optical networks operate between the core optical networks edge routers. So, there are 2 separate control planes: IP routing is separate, the wavelength routing or optical routing is separate. So, this is very similar to the IP atm overlay model.

But then we have a peer model where there is a single control plane for optical and IP networks and optical routes or what are called as light paths, they are derived from the IP routing knowledge. So, they are actually derived from the IP routing knowledge, there are no two separate control planes.

Now, here there is an important point to make. Now, as we have seen when we discussed this overlay model in the context of IP over atm; to address the problems of IP over atm, we said that in a peer kind of a model an MPLS based networks actually provides a peer model. Now, in this context, we will see that MPLS can also be used as single control plane protocol even for the integration of optical and IP networks. So that is really an advantage of that.

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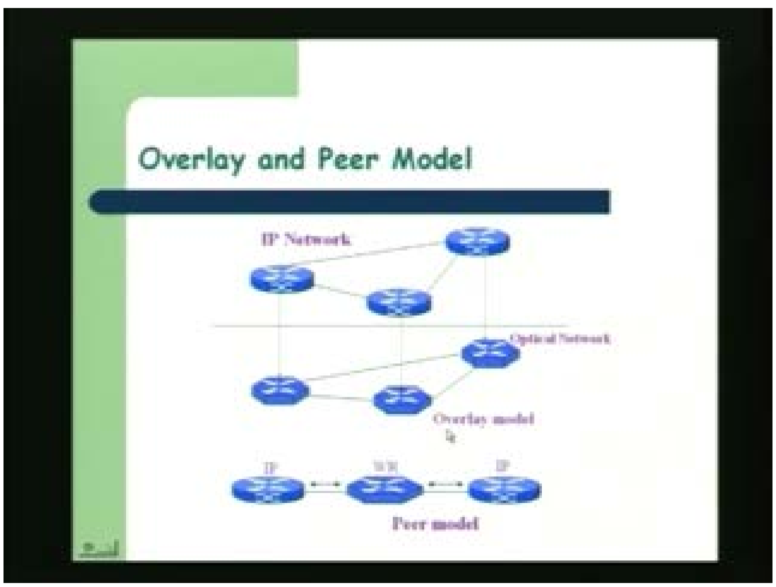

So, this is how an overlay and peer model look like. This is an underlying optical network which is there in the core of the network which is essentially a wavelength routed network and these are IP routers at edges of the network and the entire network has been over layer over a wavelength based a wavelength routed based network.

Now, these optical routes are derived by using a separate wavelength based routing and the IP routes are derived using the IP routing protocol. But this is here a peer model where the optical routes or the light paths, they themselves have been derived from the knowledge of IP routing. So essentially, these wavelengths routing protocol is also participating in some form of IP routing.

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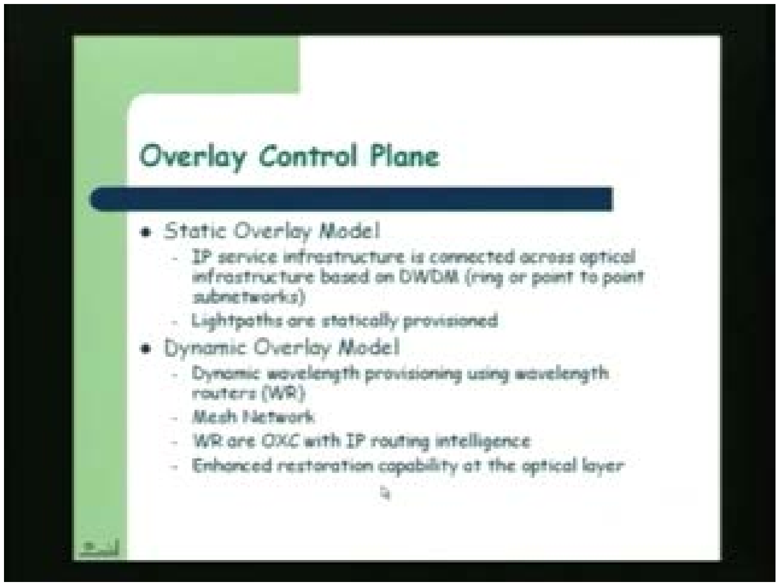

Now let us look at the overlay model. There are 2 possibilities in the overlay model; either you can have a static overlay model or you can have a dynamic overlay model. Now, essentially what happens is that in the static overlay model, the light paths have been statically provisioned. So, the light paths are essentially, basically, statically provisioned and in the dynamic overlay model, the wavelength provisioning using wavelength routers is used and wavelength based routers are essentially nothing but optical cross connects and they may have a IP routing intelligence.

So, the two separate distinctions are there; one is the static overlay model and another one is the dynamic overlay model. Both are overlay model, they are not peer to peer model in the sense that light paths are not derived from the knowledge of the IP routing. But in the static overlay model, the light paths are statically provisioned and in dynamic overlay model the light paths are provisioned using wavelength based routing. Using wavelength based protocol, the light paths are provisioned in the dynamic overlay model. And basically, what we are saying is that these are optical cross connects with some intelligence routing.

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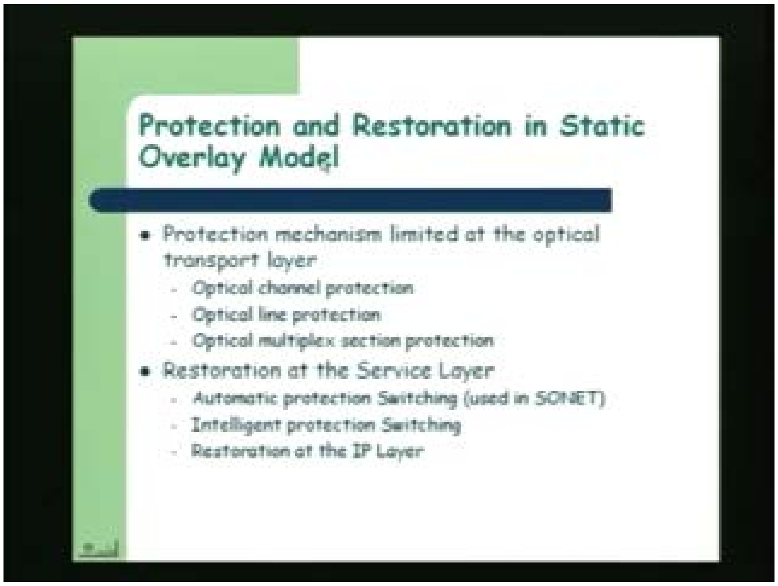

Now, if you consider the protection and restoration which is available in the static overlay model, then the protection mechanism is basically limited at the optical transport layer only if you see the static overlay model and there may be some restorations capabilities which may be available at service layer.

For example, if we are using an SDH networks, you may exploit the automatic protection switching capabilities which are there in the sonnet including the intelligent protection switching or we may exploit the restoration at the IP layer. But as you will see subsequently that the restoration at the IP layer is extremely slow and it does not confirm to the sub 50 millisecond restoration capabilities which are typically required at the by the optical networks.

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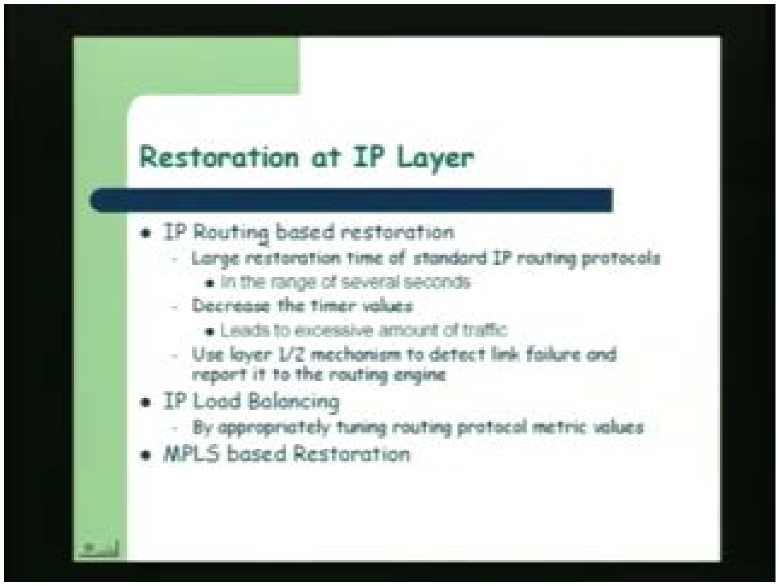

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So, if you see restoration at the IP layer, then we have really a large restoration times. So, when by the time IP routing protocol discovers that some node or link has failed and then try to recover from this and try to establish or restore a new path; you may take several seconds. Of course, you can alleviate this problem by decreasing the timer values in which we have to send the routing updates because typically will send the routing updates only after the expiry of the timer and you can decrease this timer value.

However, the disadvantage is that it leads to excessive amount of traffic. And, we can use a combination of layer 1 and 2 mechanism to detect the link failure and report it to routing engine and this can be used by the IP routing protocols. Now, the thing is that if we are just using the IP routing, then we have the same problem that protection and restoration is very difficult by just using the IP layer. Now, what therefore one can use is that instead of IP routing, we can use MPLS based restoration mechanisms. That may be little faster than simple IP routing.

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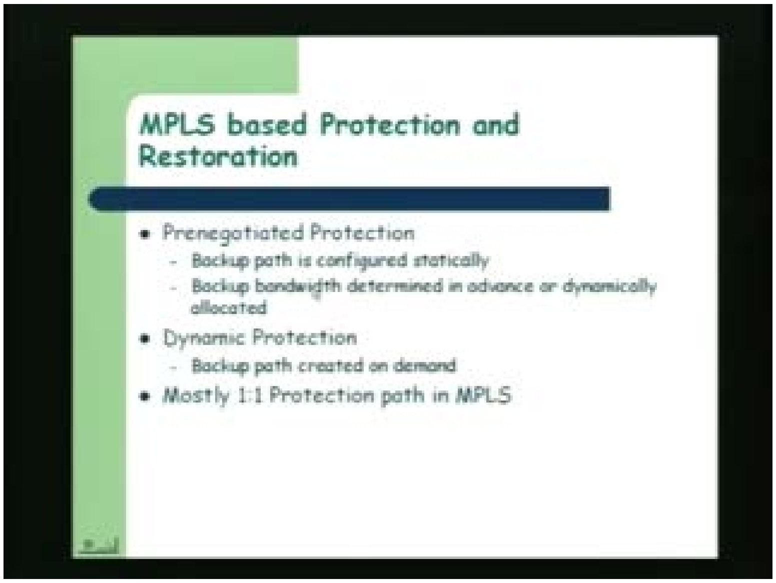

Now, how does this MPLS does these protections and the restoration will work? So, we are still talking in the context of overlay model only. So, we have at the edges those IP routers which are over layer over this optical cross connect or wavelength based routers. But now we are actually talking of restoration which will be available at the IP layer.

So, may be these IP routers now may be are the MPLS routers. So, they are not, so what we are saying now is this MPLS network is over layer over the optical networks and try to use the MPLS based protection and restoration capabilities. So, in MPLS you can do a pre negotiated protection that is in the sense that back up path can be configured statically.

So, there is a primary labels what is called as primary labeled switched paths where you will be sending your data in the normal course. But whenever that primary labels switch path breaks down, then you will start forwarding the data on the alternate paths. So, you can determine the bandwidth of the backup path either in advance or you can dynamically allocate it.

So this is like a pre negotiated protection: you have already set up a backup path. A dynamic protection would mean that a back up path can be created on demand. So obviously, this is will have some set up time. Mostly in the MPLS, we can use 1 is to 1 protection mechanism in MPLS, in the sense that for every primary LSP you can have a secondary LSP as the backup path.

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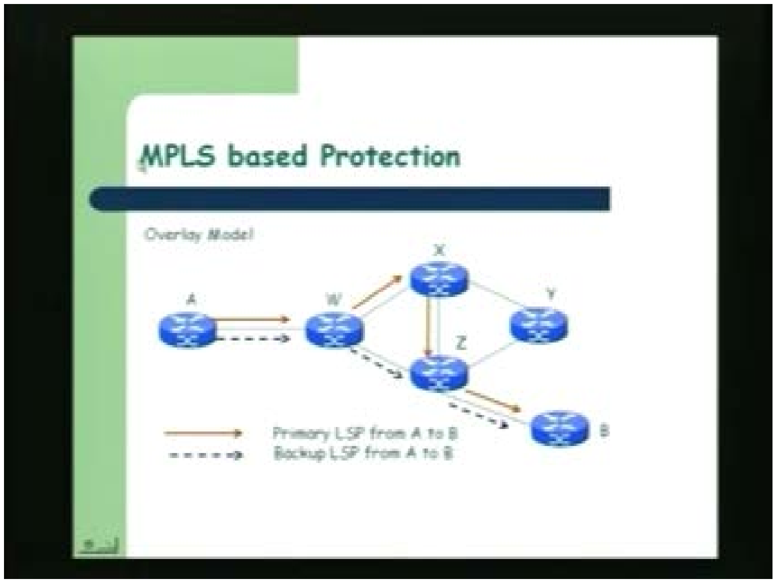

So, this is how MPLS based protection will operate. So, these are all, so here is the primer LSP from a to b which is shown in the red color here and here is a backup LSP which is shown from here. Now, in the normal course, the packets will be forwarded on this primary LSP that is this red line but let us say any of this links breaks down, then when this is discovered by this label edge router; then the packets will actually start forwarding on the back up LSP .

So, this way we can provide a protection mechanism in the overlay model itself. Now, the next step of course would be to see how the MPLS with its traffic engineering capacities can be used as an integrated control plane for a peer to peer model as well. And that is like an extension of MPLS to optical network which is called as gmpls or generalized multi protocol label switching protocol, generalized multi-protocol label switching. So, we will discuss this in subsequent lectures that how MPLS with its traffic engineering capabilities and protection of the restoration capabilities can be used to provide an intelligent peer to peer optical networks.