Broadband Networks
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Lecture No. 23
I P Over ATM

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So far you know we have addressed the issues of IP addresses look up and packet classification and we will now see the issues in implementing I P over ATM and then the proposal of a new technology called multi-protocol label switching as the layer three forwarding and routing paradigm. So, MPLS is poised to address the traffic engineering challenges which are present in the IP networks and we will just see what are the difficulties of traffic engineering in an IP networks, how that can be addressed by virtual circuit networks like ATM, then what are the challenges of implementing IP over ATM and how those challenges have been overcome or addressed by multi-protocol label switching technology.
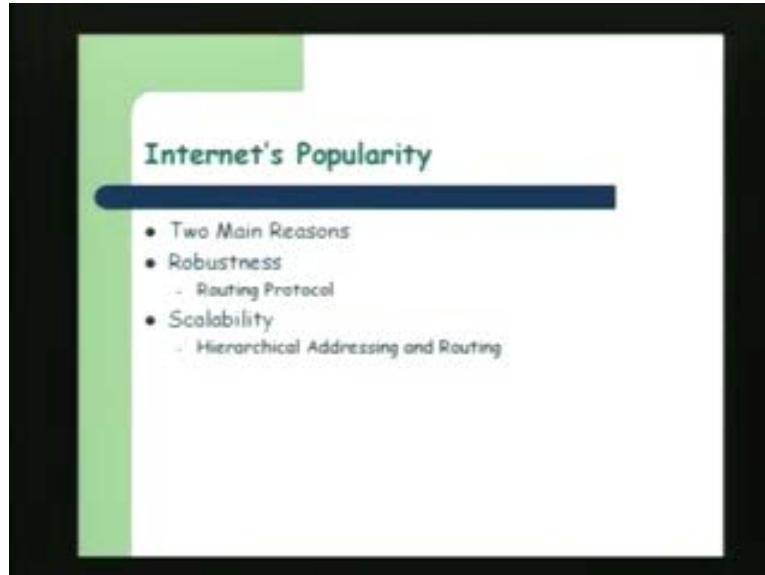
So before actually we look at it, let us look at you know why internet is so popular? So if you look at this, the internet is popular because of two main reasons: One is the robustness of the routing protocol and another one is the scalability in the addressing mechanisms. Now what do we mean by robustness of the routing protocol? Now robustness of the routing protocol we mean that if a node or a link fails in an IP network, then you know the packets can get so the essentially you know the routing protocol will discover this topology change and will discover an alternate path and then the packets can get forwarded on to an alternate link or an alternate path. So in that sense you know the internet is robust with respect to the node failures or you know link failures.

The routing protocols adapt to the changes in the topology of the networks. Also one important thing is that that the addressing mechanism that have been used in the internet is not flat addressing as we have just seen in the previous lectures, that it is an hierarchical addressing in the sense that an IP address comprises of a network part and a host part and therefore the intermediate routers or the core routers need to store the entries corresponding to the network part only and as a result, you know the internet becomes a scalable. By scalable, you know we mean that the node can come up anywhere in the networks without having it to register with all the nodes in the networks and as you have seen you know that this addressing mechanisms is quite similar to the addressing mechanism that is used for the postal addresses right.

So you know a for example: a house can come up anywhere in the city or in the locality without having it to register with all the post offices in the world and yet it can receive letters from anywhere in the world. So that is possible because the forwarding of those letters is done first based upon the city and letters come to the city, then you look at the next level which is the nearest post office where the letter goes and after that the letter gets delivered to the to the respective destinations. So, a similar philosophy is also followed in the IP forwarding and that has led to scalability in the network.

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However you know and that is the reason why technologically you know the internet is so popular. Of course, internet has become also popular because of various applications that it has enabled but from the technological point of view also the internet is popular because of the robustness of the routing protocol and the scalability of the IP addressing mechanisms. So what are the problems?

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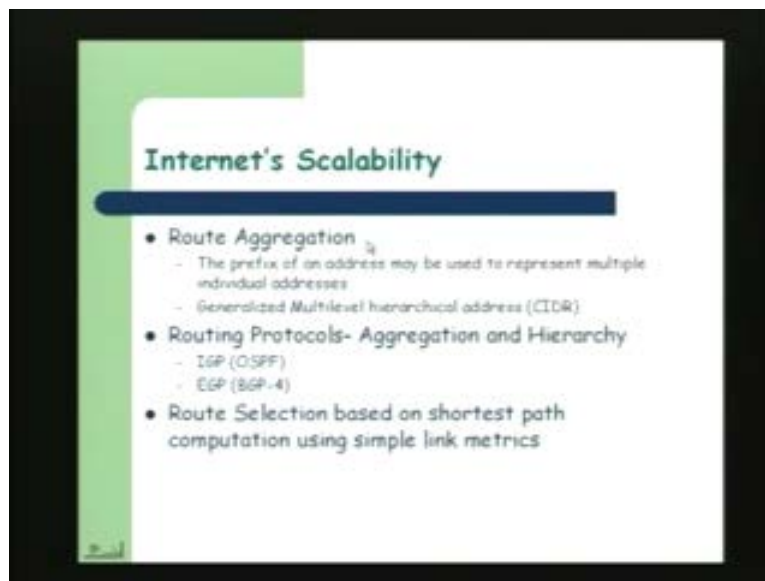
So first you know as i was talking of internet scalability, in internet you know we do the route aggregations and so the prefix of an address may be used to represent the multiple individual addresses number 1. Number 2; We are also using as we had seen the class less inter domain routing which is generalized multilevel hierarchical address CIDR that we had already discussed and routing protocols like OSPF or you know BGP four they also enable these aggregations and hierarchy. Now the routing in the internet is done based on a simple link metric and which is like the shortest path.

So between a source node and a destination node, the routing protocol determines you know what is the shortest path between the source and the destination? Based on very simple link metrics, which is the hop count. So the path which is shortest in terms of the number of hops was selected as the best possible path. You know while so what is what is it what is important thing here is that while you know determining the best possible route from the source to the destination the congestion conditions on the links or the bandwidths on the link or the available bandwidth on the link is not taken into account. So, while you know this leads to the simplicity but as we will see that you know and scalability but as we will see shortly that this also leads to some of the problems or challenges in terms of traffic engineering. So, what are the bottlenecks that we are looking up?

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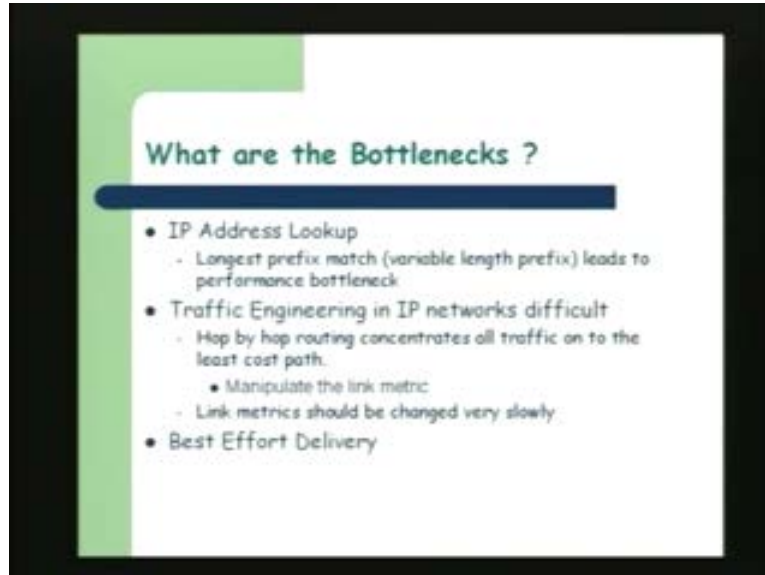
Now because of these hierarchical addresses, you know because of the hierarchical addresses that have been used in the internet the IP address lookup is done using what is called as the longest prefix match. By longest prefix match, we mean that in the forwarding database we have actually a lot of address prefixes and a given IP packet may match several of these several of these prefixes. So we have to select the entry corresponding to the longest match that this destination IP address gets. So we have to select the entry corresponding to that.

Now if we have had followed the class full IP addressing scheme that is class A class B or class C IP addressing scheme, then forwarding was very simple. You need to first determine whether the destination IP address is a class A IP address or a class B IP address or class C IP address but because of these classless inter domain routing, the forwarding is made little complex in terms of the longest prefix match and as we had already discussed that this is one of the performance bottleneck in today's internet. So that was a challenge. So although it leads to lot of scalability in terms of allowing aggregation at arbitrary levels, it also leads to performance bottlenecks in terms of the look up, then what is the second problem the second problem is that the traffic engineering in IP networks is very difficult essentially we are following a hop by hop routing and that concentrates all the traffic onto the least cost path. So what does it mean? It means that you know this is a typical phish problem and the situation is something like this.
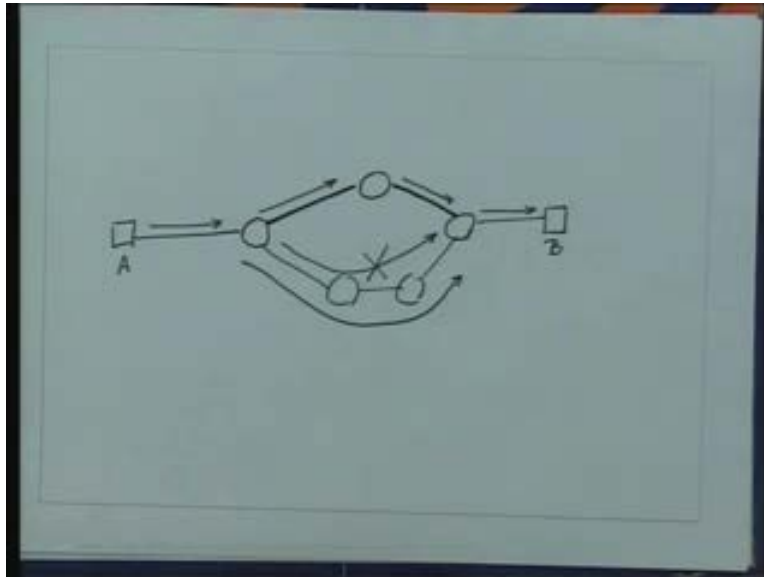
that if we have a network like this, where the packets have to go from A to B. Now you can determine that since this has more number of hops this route, so the packets will get forwarded on this route only. Packet will not be forwarded onto this route because this is considered as the shortest path in terms of the number of hops. So therefore if we follow the routing protocol which is determining the route based on the shortest number of hops, then all the packets will get forwarded on to this. This link will remain under-utilized. So as a result you know as i said that a traffic engineering in I networks becomes difficult.

Essentially, you know what we are saying that we can, if a net service provider has alternate routes or paths then what ideally he wants is that in that core network all these links are properly utilized. So none of the links is underutilized and none of the links should be over utilized or should be congested. So your traffic should be evenly balanced on all the links leading to a higher utilization. However, if you are following a routing protocol which forwards the packet which selects the route which selects the route based on the shortest number of hops, then you know you may end up concentrating all the traffic on the shortest path in terms of the number of hops leading to difficulties in the traffic engineering.

Of course, you know you can avoid this by making a slight modification to a routing protocol in the sense that you can change the metric and you can say that the metric is proportional to the conjunction conditions in the networks. So, as a result you know what may become is that even though you know this path. Earlier may be shortest but as you start forwarding more and more packets onto this path you know the links may become congested and therefore if we define a link metric proportional to the conjunction condition in the network, then this path may slowly become congested and then the packets may start getting forwarded onto this path also.

Now, the difficulty here is that that once a particular path becomes congested and you start forwarding the packets onto the other path, then as the time elapses, the path which was earlier

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congested you will find it will slowly becoming it is slowly getting uncongested and the path which was you know were now you are the new path where you are now forwarding the packet, that will slowly start becoming congested.

Now as it starts becoming congested, because of your link metric being proportional to the congestion conditions in the network, now the packets will again start getting forwarded onto the other link. So, as a result you know what will happen is that that this will lead to oscillations in the routes or what is called as route flapping. So, one time you know this particular route will be declared as a best path. After some time when it becomes congested, then the other route will be declared as the best path leading to oscillations in the routing.

So ideally, we do not want oscillations in the routing. What we really want is that that all the links should be properly utilized. So what we ideally want is that, some traffic you know if there is some amount of traffic between A to B some traffic should get forwarded on this link and some other traffic should get forwarded onto this link. Such that you know both these paths are evenly balanced. So that is what you know our objective is. The third problem is as we have seen that best effort delivery.

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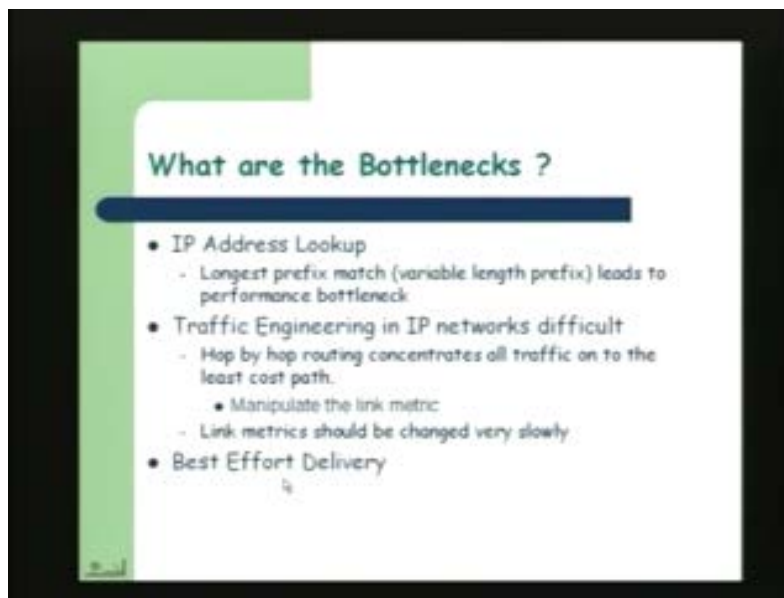
Of course, an internet is a best effort network. The network makes every attempt to transmit the packets but it does not offer any explicit quality of service guarantee. So, this is you know one of the issues in the best effort internet and we had seen that we can address this issue by incorporating the QoS mechanisms in the internet. So now what is the solution that a service provider has and the solution that a service provider has is, that it can use ATM as the backbone solutions.

So, it can deploy ATM or frame relay as the core networks. So, what are the advantages of having ATM as the backbone or the core networks? So, first of all as you know that ATM uses short fixed length packets which we called them as cells. We have already studied this and the ATM is based on two fundamental paradigms: One is what is called as label swapping paradigm and another one is a virtual circuit based switching actually simplifies the forwarding mechanisms. So in the ATM what you do in the ATM routing? What you do is that, before the data transfer begins, you setup a virtual circuit between the source and destination using virtual circuit routing and after that only the data transfer can become. Of course, this circuit is virtual in the sense that one physical link will be statistically multiplexed with several other traffics and each of the virtual circuits may be given certain quality of service attributes.

So that is essentially the paradigm of the ATM. Now, we also as you know as we already seen that the vci and vpi labels can be swapped at the intermediate nodes. We have seen that in our lecture on ATM because this leads to an efficient use of the VCI and the VPI's number space. So that is why you know they it follows a label swapping paradigm also. So, by using this ATM as the backbone networks, we get several advantages and one of the biggest advantages is that,

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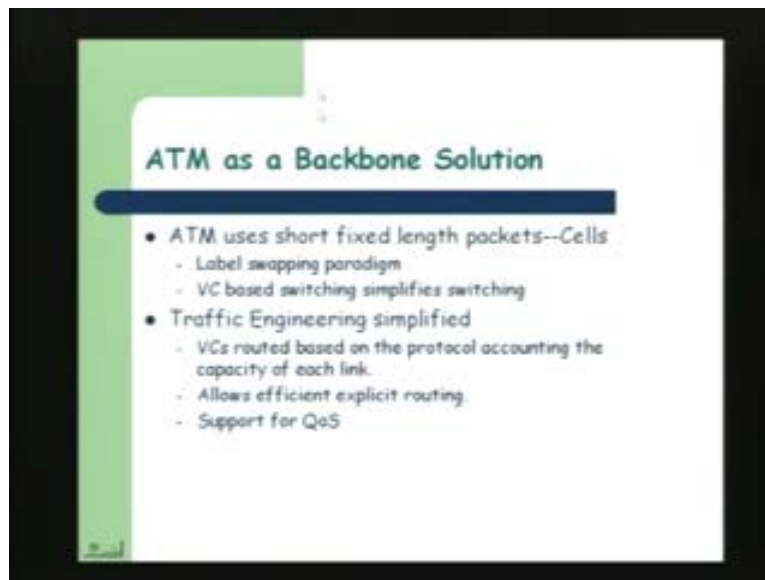
The traffic engineering is considerably simplified. he traffic engineering is considerably simplified the reason being that these virtual circuits they are routed you know based on a routing protocol which can take into account the capacity of each link and as a result it allows you know explicit routing. So what we are saying is that when we select the virtual circuit between the source and the destination when we are selecting the virtual circuits between the source and the destination then you know we can take into account, what are the bandwidth available on each link? What is the buffer capacity available on each link?

What are the congestion conditions available on each link and then setup a virtual circuit between some source and destination or between one node and other node. So, as a result you

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know the virtual circuit routing protocol can take into account the capacities of each link and then can decide to route you know various traffics in such a manner that the entire network is sort of evenly balanced or you know is balanced as much as it is possible. Also, the advantage of ATM is that it enables the quality of service guarantees. So these virtual circuits have quality of service attributes and therefore you know you can also give the quality of service guarantees in the ATM networks. So as a result you know we have

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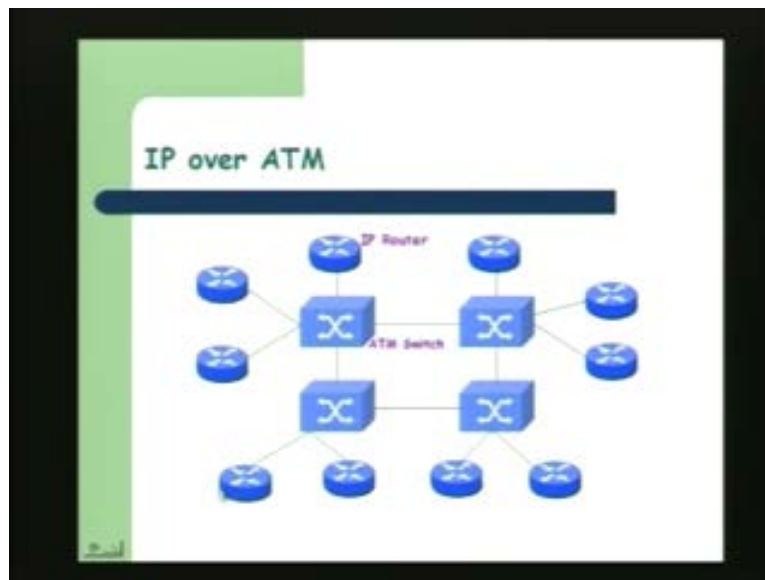
Something like IP over ATM. So these are all IP routers. They are all you know situated at the edge of the networks and you can see the core the core actually comprises of all these ATM switches. So, obviously this is a natural question to ask that why we are not extending ATM to the desktop. You know why at all has an IP world or an internet world? The answer to that question is that if i extend the ATM to the desktop then i have to {maint} (00:17:57) since ATM gives quality of service guarantees and virtual circuits based routing i have to then setup a virtual circuit right from you know the users' desktop up to the destination users server or his desktop.

So, as a result the number of states that would be required to maintain in the networks would be extremely large and the complexity of the protocol from the source to the destination will increase sort of enormously. So, therefore because of these reasons also you know the ATM did not become popular in the local area networks or as an enterprise wide networks you know. Also the another reason was that the ATM was earlier you know touted as one of the high speed networks because when the ATM switch was designed, it started from 155 megabits per second, then it grew to 622 megabits per second, but then soon Ethernet caught up with the speed Ethernet was already having 100 megabits per second and now we have 1 gigabit Ethernet and we also have 10 gigabit Ethernet.

So as a result relevance of the ATM network as a high speed network drop down considerably the relevance of the ATM network as a QoS based networks. Also drop down because of

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practical considerations in terms of required to maintain the large number of states. So, therefore ATM had this Nish applications where it is been used as the core networks. So, the idea essentially is that these packets. So you setup a virtual circuit you know between one to another ATM switch and you aggregate the traffic at this ATM switch and these virtual circuits are essentially used as a trunk path between one ATM switch to another ATM switch. So in the backbone you are having ATM based networks. You setup virtual trunks or using you know some of the explicit routing algorithms or traffic engineering algorithms so that, the service provider can see that the links are evenly balanced and the network is efficiently utilized and you have these IP routers at the edge of the network.

So basically what we are saying the core of the network comprises of a virtual circuit based networks which is an ATM switch and the edge sort of comprises of an IP based networks. So as a result, we get the best of both worlds because of IP routing having in the edge of the networks we can link with the scalability of you know the IP world and because of its hierarchal addressing and routing and at the same time, the core routing being done based on the virtual circuit, we can enable the traffic engineering you know solutions also.

So now so so now you know when we say that we are running an IP networks over this ATM networks, this is what is called as an overlay model and we need to then address some of the issues that arise in running an IP protocol over an ATM protocols. So now in this overlay over lay model there are three solutions that has been proposed.

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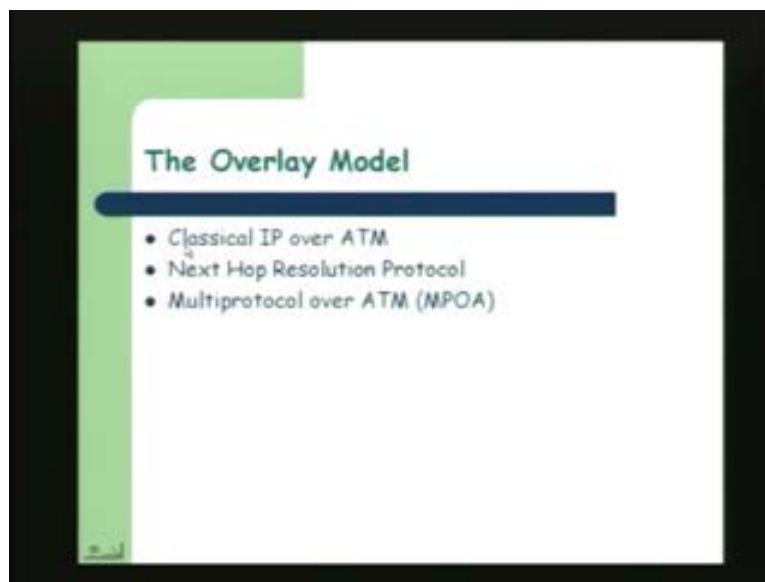
One is of course, the classical IP over ATM. Another one is what is called as NHRP or next hop resolution protocol and the third one is multi-protocol over ATM or what is called as MPOA. So, we will discuss each of them. Each of these overlay model. We will see that what are the difficulties or challenges that arise in implementing IP over ATM and how they have been addressed or overcome by the individual protocols and what are the challenges that are still

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remaining and how this new technology that is the multi-protocol label switching or MTLS is sought of trying to address these problem or difficulties. Now, in classical IP over ATM what is done is, you have an address resolution mechanism.

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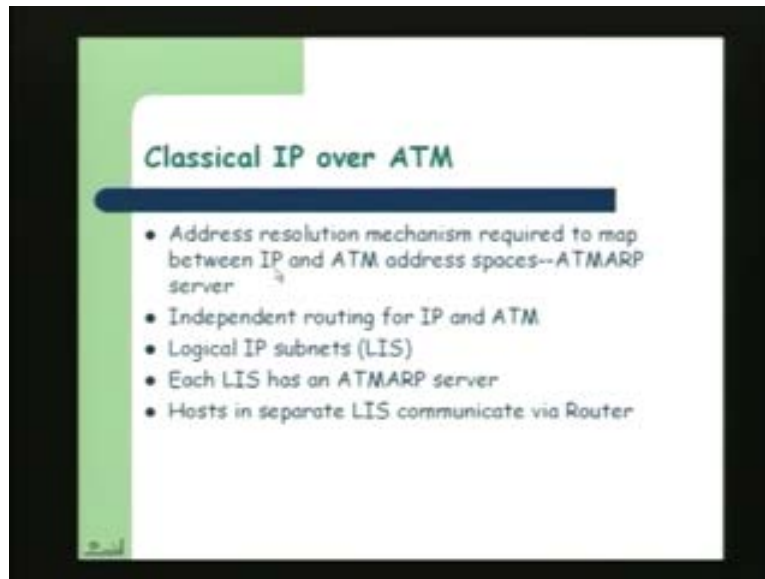
So basically in classical IP over ATM address resolution mechanism is required to map between the IP and the ATM address space. So, this is very similar to the address reservation protocol ARP protocol that we use it in the Ethernet. So, the approach of classical IP over ATM is to treat ATM as a link layer, just like you know Ethernet is a link layer or as a Mac layer. The classical IP over ATM takes an approach that you treat ATM as the link layer. So, if there is an ATM cloud and if you want to forward IP packets, if you determine path in that then you treat ATM as a link layer. Now the ATM cloud that will determine the route or that will forward the packets based on the VCI VPI number but over this network an IP network has been overlaid.

Very similar to when we have an Ethernet network over which you know the IP network has been overlaid. In the Ethernet network, the forwarding is essentially done based on Mac addresses or if there are Ethernet switches, then the switching is done by looking at the Mac addressor. So the same concept here: In the ATM cloud the switching will be done based on VCI or VPI addresses but over which the IP network has been overlaid. Now, in Ethernet if you want to do the forwarding, since the forwarding is done based on Mac addresses you need a mechanism to resolve the IP addresses to the Mac addresses which is what is called as address resolution protocol or ARP.

So in ARP, the IP addresses are resolved to the Mac addresses. Now, Ethernet since Ethernet is a broadcast medium, so the ARP works something like this that if a particular node wants to know the Mac address of the destination node, then what it will do is that, it will broadcast an ARP request. Ask you know asking essentially that am looking for the Mac address of this destination IP address. Now since it is a broadcast medium, all the users will receive this request and the

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user for whom this query is meant will respond by an ARP response stating his Mac address to the originating node. So as a result the originating node you know will come to know of the destination Mac address and after that you know it can start sending packets using that destination Mac address.

So similar thing is required here when we want to resolve the IP addresses to the ATM addresses. However only the problems is that, in the ATM switch it is not a broadcast medium like in the Ethernet. So therefore you require some kind of an ATM ARP server. So, here is there is an ATM ARP server. This ATM ARP server is used to resolve the IP addresses to the ATM addresses. So, instead of using a, instead of broadcasting ARP request which is done in the internet here what you do is that you have a separate server. Now, you then have essentially independent routing for IP and ATM and we create what is called as logical IP subnets. You know logical IP subnets which are called as LIS and each logical IP subnet will have an ATM ARP server and hosts in separate logical IP subnet. They will communicate with routers. So situation is something like this that you may have,

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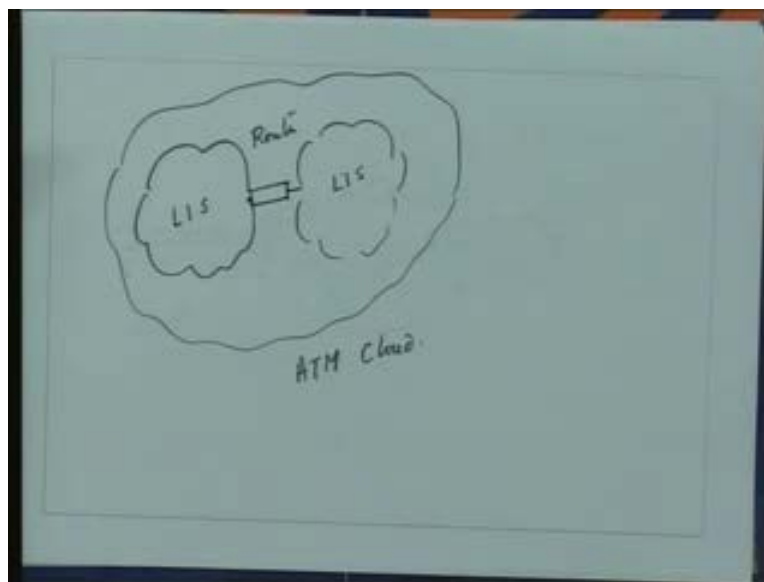
You know you may have an IP cloud and this is a router and you may have a separate logical. So this is a separate logical IP subnet. This is a separate logical IP subnet and this is a router and of course, it may be a same ATM cloud but so this has been identified as separate logical IP subnet and this has been identified as another logical IP subnet. The host in logical IP subnet they will communicate via separate router. Now the disadvantages of these classical IP over ATM approach were that the direct ATM connection you know the direct ATM connection between the hosts.

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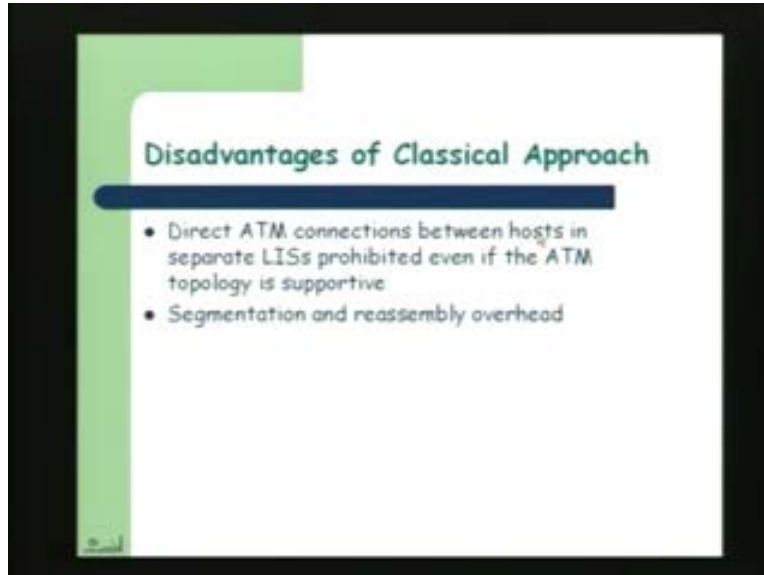
in separate logical IP subnets are prohibited even if the ATM topology is supportive. So something like this can happen that let us say,

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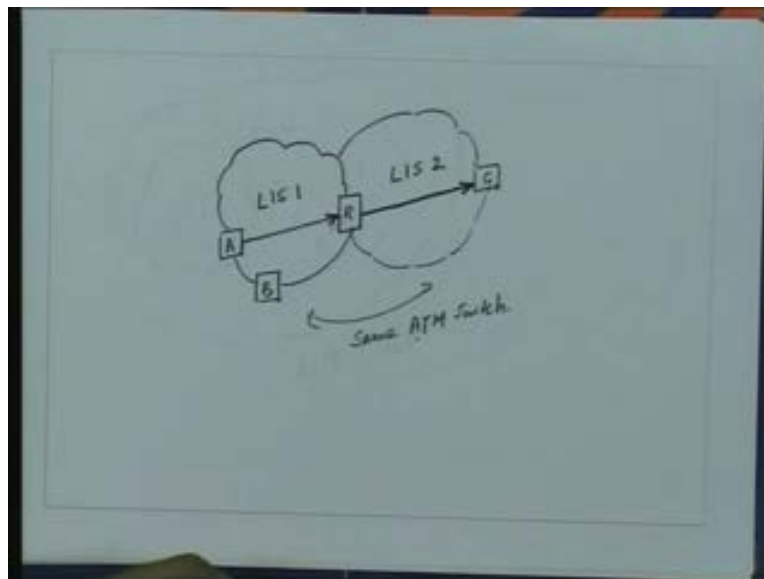
that here is a here is a router 1 and here is a host you know, this is C and this is router R. Now suppose you know that these are in the same ATM cloud, that is if you assume that the host A B and C and this router R, they are on the same ATM switch but A and B are one logical IP subnets. So this is LIS 1 and C is on different logical IP subnet this is LIS 2. Now, since we are using independent routing for IP and the ATM. Now host A wants to communicate with host C, then it

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has to first setup a virtual circuit with the router R and then this router R sets up another virtual circuits with the host c and then you know the data transfer can begin can begin from host A to C.

So you need to setup first a virtual circuit from A to R and then you need to setup a virtual circuit from you know R to C and then only the data transfer can begin. Now, actually since A and C they are in the same ATM switch, you could have established a direct virtual circuit from A to C also but A does not know that C is situated on the same ATM switch. A is talking to C based on the IP address. Now when it discovers that this IP address is on a different IP subnet then as per the IP routing it needs to communicate through a router only.

So this is the sort of disadvantage that you know it is like an overlay model where in the underlined data link, the routing is done based on the ATM virtual circuit and the upper layer the routing is being done on the IP addresses. Now, when there are two IP address host which wants to communicate with each other, the link layer is comprising of the ATM. So, therefore they know they can communicate between themselves by setting up virtual circuits. Now since they are on different IP subnets, they need to communicate through the router as per the you know IP routing.

Therefore they need to first setup a virtual circuit between you know these routers. So this is one of the disadvantage that you know the direct connections is not possible its leads to setting up of several virtual circuits even though you could have set up a direct virtual circuit. Now, another disadvantage of course remains and that is for all the IP over the ATM schemes is that, there is a considerable segmentation and reassembly overheads.

What does it mean? You have these IP packets. Now when these IP packets needs to be forwarded over an underlying ATM networks, IP packets could be of variable length packet, these packets needs to be segmented into the 53 bytes ATM packets at the ingress of the networks you know when the packets is to be forwarded onto the ATM switch and at the egress you know when the packet is again coming from the ATM world to the IP world the packets have to be reassembled. So this is a significant overhead that is coming up in terms of segmentation and reassembly. So basically you know it is like this here.

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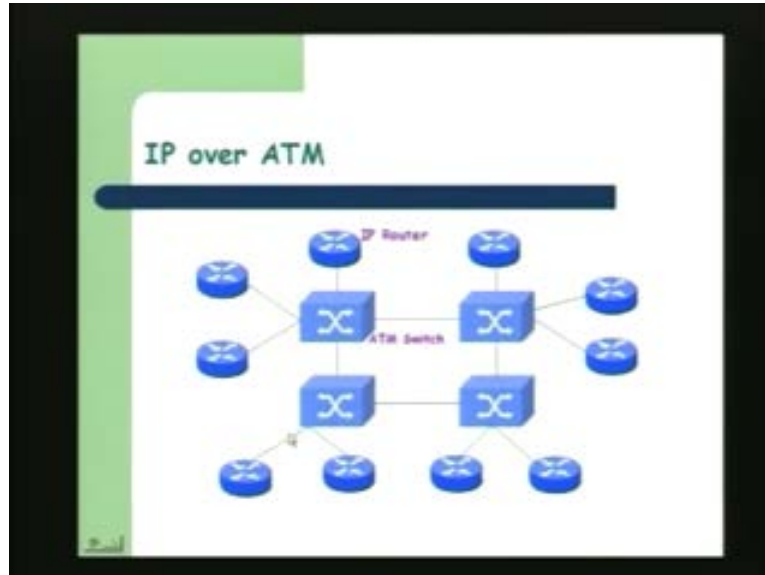
So at this point, when the IP packets have to go to the ATM switch you need to segment these IP packets into those ATM cells and in this ATM switch world actually, you are having the ATM cells only and when these ATM cells needs to be now go out to the internet, you have to sort of reassemble them into the IP packets. So, significant overhead is there in terms of segmentation and reassembly. Now, some of these disadvantages of the classical IP over ATM, we are addressed by a modification of these protocol and which was called as the NHRP or next hop resolution protocols.
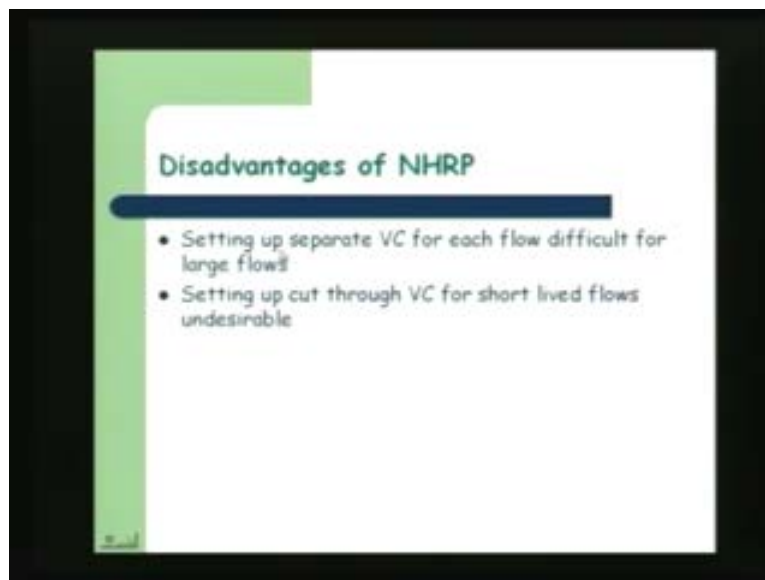
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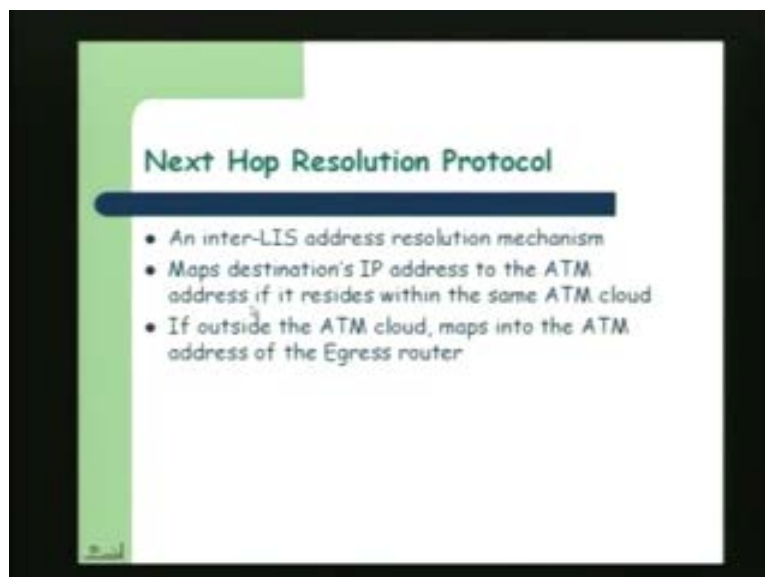
So, in the next hop resolution protocol what is done is that, there is an inter-LIS address resolution mechanisms. So in this NHRP, you can map the destination IP address to the ATM address the destinations IP address can map to the ATM address if it resides within the same ATM clouds and if it resides outside the ATM cloud, then it maps into the ATM address of the egress routers. So essentially you know in this diagram what we are saying is that there is a inter LIS address resolution mechanisms.

So once you to discover that ATM ARP server discovers that A and C are situated on the same ATM switch, then actually you can setup a direct virtual circuit between A and V also in NHRP and when you discovered that it is the outside the ATM cloud and it is not on the hosts are not situated on the same ATM clouds, then you will map into the ATM address of the egress routers. So this is the modification to the classical IP over ATM paradigm which is called as next hop resolution protocol. There are of course disadvantages of NHRP,
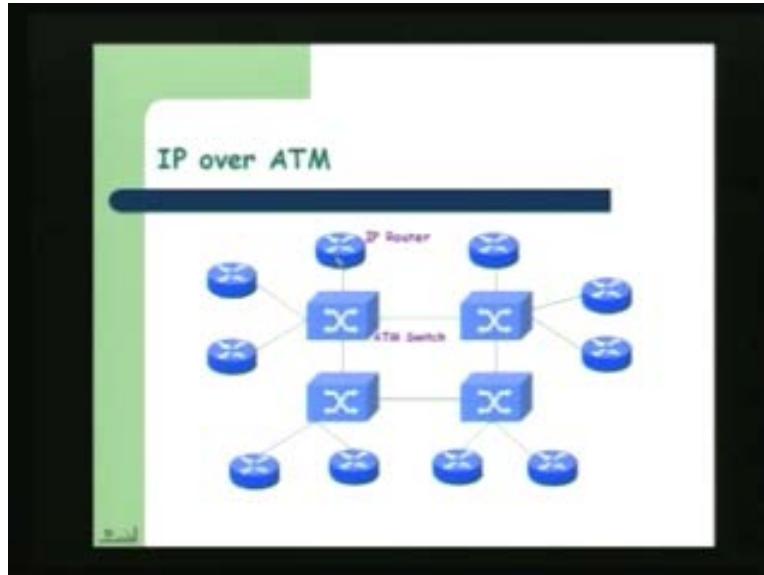
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Disadvantages of NHRP

- Setting up separate VC for each flow difficult for large flows
- Setting up cut through VC for short lived flows undesirable

and the disadvantages of NHRP is that setting up the separate virtual circuits for each flow is difficult for large number of flows you know you need to so so you need to of course determine whether the host are situated on the same clouds or on the different ATM clouds and also you know if the flows are short lived, then setting up this cut through virtual circuits you know that instead of instead of following the through the router is actually undesirable, if these are short lived flows. These two are the disadvantages. Of course, the disadvantage that segmentation and reassembly overheads will be there that actually continuous in the NHRP protocols also.

Now one thing is there that whether it is a classical IP over ATM or whether it is a next HOP resolution protocol or whether it is multi-protocol over ATM, you know whatever it may be there are certain limitations of the overlay paradigm and those limitations of the overlay paradigm is that, this overlay paradigm is actually uses complete or partial mesh of virtual circuits. So, what does it mean? You know it is something like this that if we had

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Consider here, now let us say that there are, on this ATM switch clouds so if you have an ATM switch.

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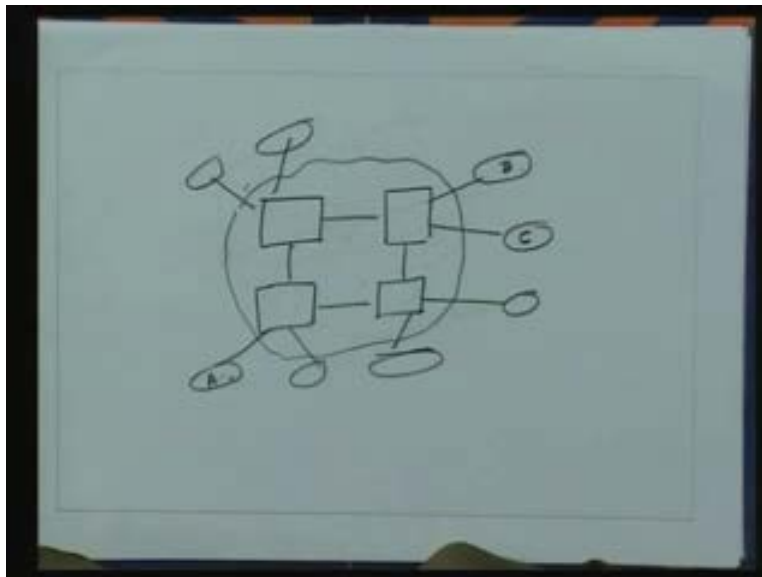
Now there routers attached to it. Now, if i want to send packets from set of A to B, i need to set up a virtual circuit in this ATM switch. Similarly i would like to send packets from A to C. I need to setup a virtual circuit. So if there are n routers, n routers connected to this ATM clouds, then i need to make a mesh of 'n square' of order n square virtual circuit. So that each router can transmit packets to any other you know any other routers.

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So the disadvantage, one of the important disadvantage of this overlay paradigm is that, you have to go for a complete or partial mesh of virtual circuits. In fact, the complexity is that if there are n nodes surrounding this ATM cloud, then the complexity of the mesh is order n square. Another disadvantage of that is that normally you know in a IP world each router is configured to consider its adjacency you know with each of its ==each of its== next hop neighbors. Now what happens? You have this ATM world. For example: you have this sort of ATM switch.

Now A, when it wants to communicate with B, it has set up a virtual circuit you know through this network now this cloud appears like a black box to A and B. It does not matter really how the packets are finally going to be forwarded into this clouds. As far as the IP router A and the IP router B is concerned, for A the B is like a next hop node. It does not really matter whether you know there were virtual circuit setup from this node to this node and this node and how packets went. This for A B is like a next hop router, for A C is also like a next hop router and so on. So basically for A all these n routers are actually the next hop routers.

Now, what happens because you know the A and B are unaware that the packet forwarding is taking place in the underlying network through an ATM switch, they are aware unaware of this. Now what happens is that whenever topology change or a link fails something for example: you know some link fails storm here. Now, because whenever a topology change takes place the IP routing protocol update this information to their next hop neighbors. Now, in this case A you know the router A will update in case of any topology changes will update the routing information it will send a routing updates to all the n nodes because it assumes that all the n nodes are actually ==are actually== its next hop neighbors.

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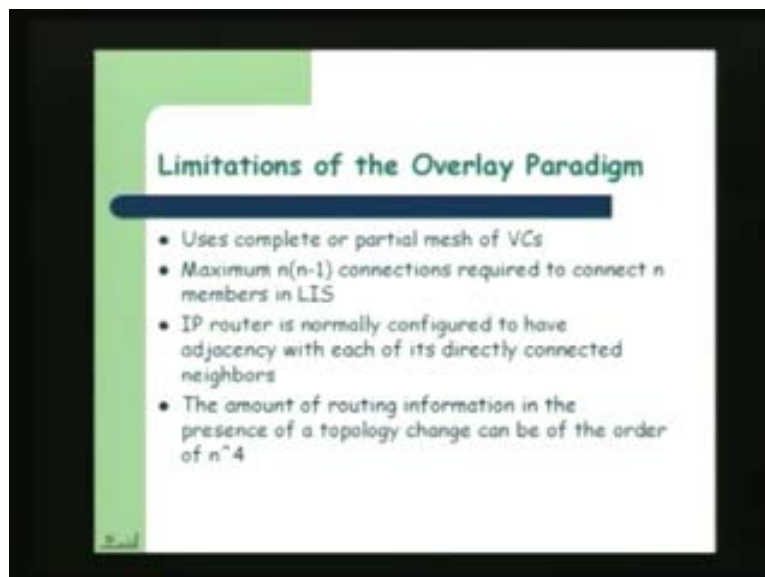
So as a result the amount of routing information that you are transmitting in the presence of topology change in fact it can be shown that can be of the order of n raise to power 4. You are having a complete or partial mesh of order n square and the amount of routing information or

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routing updates that you will send in the presence of topology changes can be of the order of n raise to power 4. So there is a lot of you know update packets that will flow through which could have been simply avoided if the IP routers were aware of this ATM clouds and you know that computational complexity is of course directly proportional to the number of links.

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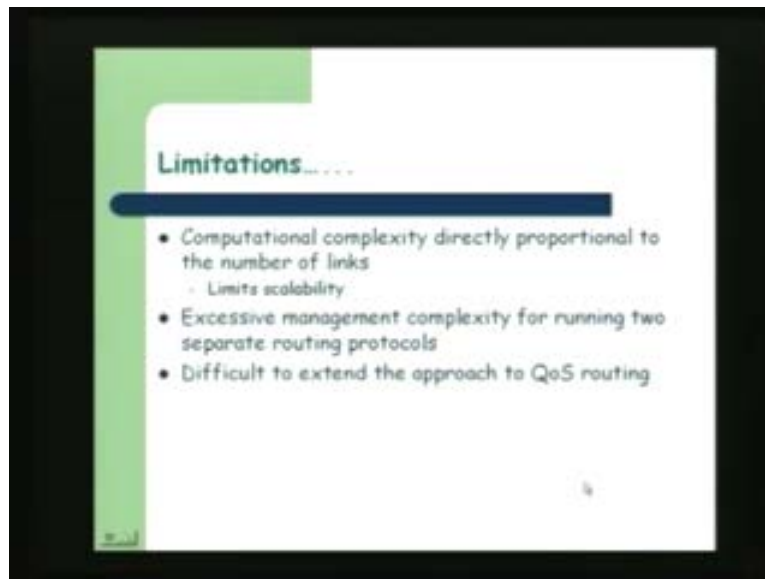
So definitely, it limits scalability and again there is an excessive management complexity for running two separate routing protocols. You know on the one hand, you are running the IP routing protocols and then this virtual circuits are established using a separate ATM routing protocols. So you have to manage both the IP routing as well as ATM routing and of course the disadvantage of segmentation and reassembly overheads continues and one more thing is that even though the ATM network supposedly provides quality of service guarantees, it is difficult to extend the quality of service guarantees to the IP world.

So even if the underlying network is capable of providing quality of service guarantees, it does not really matter because those QoS which is available at the link layer cannot be extended to the IP layer, because IP is not supporting any quality of service guarantee. So, therefore you know the QoS advantages of the ATM are also not there by using this overlay paradigm. So, basically the question then is that what are basically we are looking for what we want really is that, we want the scalability, flexibility and robustness which are very similar to the IP world. So that is what really we want. It should be scalable or flexible just like the IP world.

So we want to retain all the advantages of the internet on the one hand on the other hand what really we want is that in the core of the network we do not want a hop by hop routing or something like that, we basically want that IP packets must be forwarded based on virtual circuits. So, what we should do is that in the ingress in the ingress of the core networks, we should aggregate those IP packets into a virtual circuit put you know bundle them into some virtual circuits and then do the forwarding based on this virtual circuits, numbers or something

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like that. So what does it mean really is that, we would like to have not an ATM switch. It should not it should not segment those IP packets into a ATM cells and then reassembles those ATM cells into IP packets it should not go into these segmentation and reassembly overheads it would have been quiet good if these ATM switches instead of working on the ATM cells or directly working on the IP packets themselves.

So what really we are looking for is that, we would like to see that if ATM like switches if ATM like switches if they start participating in the IP routing itself and in the core set up, the routes based on something similar to virtual circuits only, then we will have what is called as label switching paradigm that leads that leads to a label switching paradigm. So that gives a birth of label switching paradigm.

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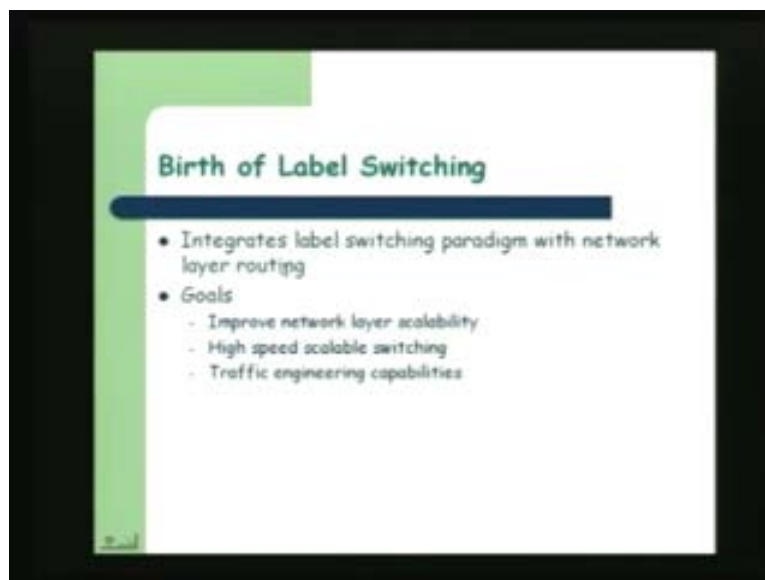
The important ingredient of a label switching paradigm is that it integrates the label switching with the network layer routings. So if i let say that ATM switches sort of participate in the IP round routing, then we would sort of would have developed some kind of label switching. So what we want really is that our goal is that we would like to improve the network layer scalability. So, the network layer scalability should be similar to the IP world that is what we are looking for we want high speed scalable switching. So in the core, we do not want the disadvantages associated with longest prefix match basically and we would also like to have the traffic engineering capabilities in the IP world. So, if you integrate the label based switching with the network layer routing, then we basically have what we called as the label switch routers.

So, historically however you know if i see the birth of label switch router actually arose from the difficulties that were associated with longest prefix match. What was envisaged that instead of looking up the destination IP address you know and do the longest prefix match, if we could attach some kind of a label with an another shim header and if we could attach label just like in the ATM world where we are doing the switching based on virtual circuit identifier or virtual

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path identifier and not based on ATM addresses. So, if we can do that what we do is that you setup a label switch path and then do the forwarding based on this label and the length of this label should be small, so that a direct index took up is manageable and possible.

So instead of having 32 bit IP address, we can have a 16 bit label or 20 bit label so that you know the number of entries in the table would be the order of 2 raise to power 20 or 2 raise to power 16 and not as 2 raise to power 32, then a direct induct took up is possible and as a result the problems that are associated with the longest prefix match that will that will go away. So, just like you know similar to the ATM world. So, originally you know the idea was that would attach some kind of a label and then do the high speed switching based on this label, but slowly you know it was found that when many when many forwarding algorithms for proposed in the literature for high speed forwarding, it was soon discovered that actually speaking the IP address took up problem can be addressed by the modern algorithms and real advantage of the label switching paradigm lies in addressing the traffic engineering challenges that exists in the IP world. So let us see you know, what are the key features of this label switching paradigm?

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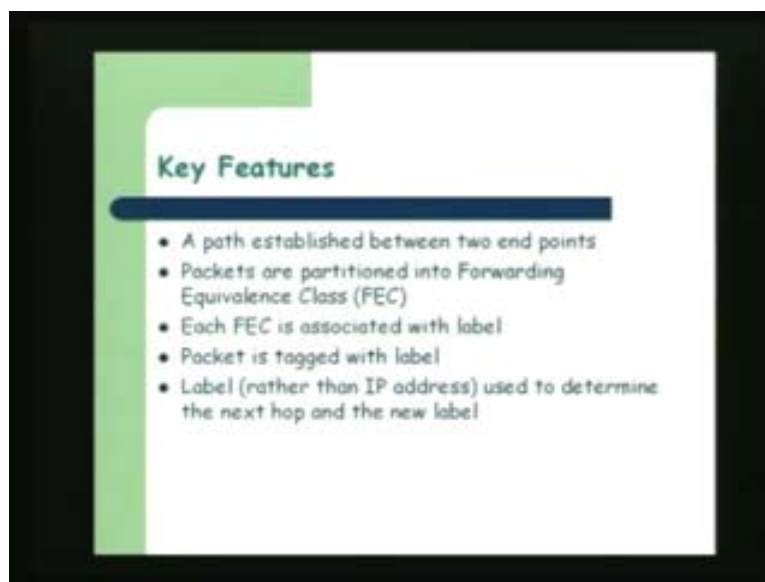
Now, the key features of this label switching paradigm are that just like in the ATM world, a path is basically established between two end points. This is like this is like a virtual circuit path. Now at the egress, at the egress of the network the packets are partitioned into forwarding equivalence classes. Now so this is the concept that has been introduced i will just elaborate on this. So what you basically do is that you want to determine how you want to set up a path between two end points.

So, suppose you want to set up a path between two end points with certain bandwidth guarantees, then what you do is that at the ingress you partition the packets into forwarding equivalence class. Now each of this forwarding equivalence class may have a certain quality of service attributes associated with it. So at the very cores level, a forwarding equivalence class may be

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associated with a destination IP address prefix an IP address prefix that means you are doing the routing just based on IP address prefix that is at the cores level. At the at the finest level your forwarding equivalence class may be associated with an application layer flow. So, therefore you may classify the packets into different flows also and set up a path for each forwarding equivalence class or setup a path for each application flow. Now what you will do is at the each of these forwarding equivalence class you will associated with a label, At the ingress, the packet will be tagged with a label.

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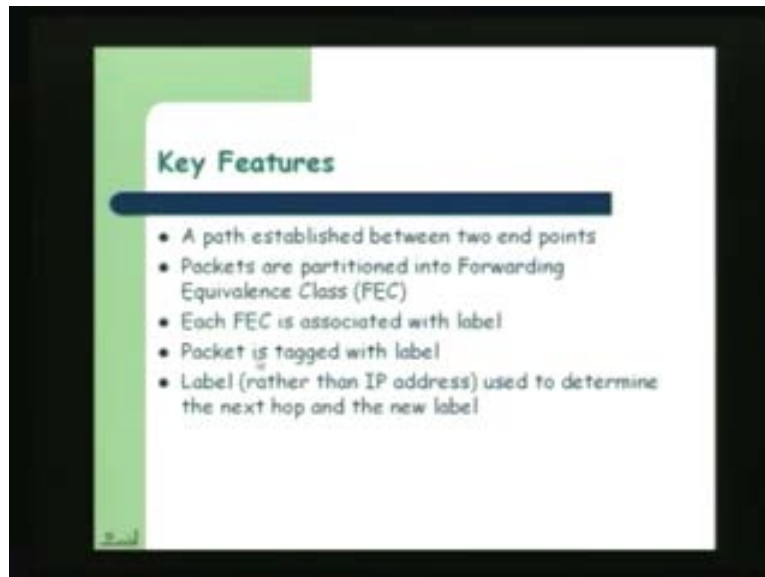
So at the egress packet is tagged with a label and then the label the label will be rather than IP address in the core. The label then will be then used to determine the next hop and the new label. Why a new label because remember that we are following the label swapping paradigm. So, the old label is swapped may or may not be swapped, but it may be swapped with a new label and then you will determine what is the next hop over which the packets needs to be forwarded. So there are so what does it mean at the ingress at the ingress of the network you are doing multi field packet classifications.

Now the classification rules can be determined based on your definitions of the forwarding equivalence class or the fec rules. So at the ingress you are doing multi field classification of various IP packets that are coming into you into one of these forwarding equivalences or one of these flows. So, why you know the ingress routers are little more complex, in terms of operations then will require a multi field packet classifier, they have to attach a label and then sort of forward the packets. If the packets are not tagged and if the packets are tagged of course you know they will have to switch the packets based upon the tag. In the core in the core of the networks you know the labels which routers are very simple they just look at the tag and then do an index took up and determine on which hop the packets needs to be forwarded.

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So the core you know is very simple. So we have a label switch router what is called as an LSR which is a basically a core router and we have a label edge router LER which is situated at the e ingress of the network. So LER is at the ingress of the network LSR is in the core on the network what is called as label switch router. So a label switch networks then looks something like this.

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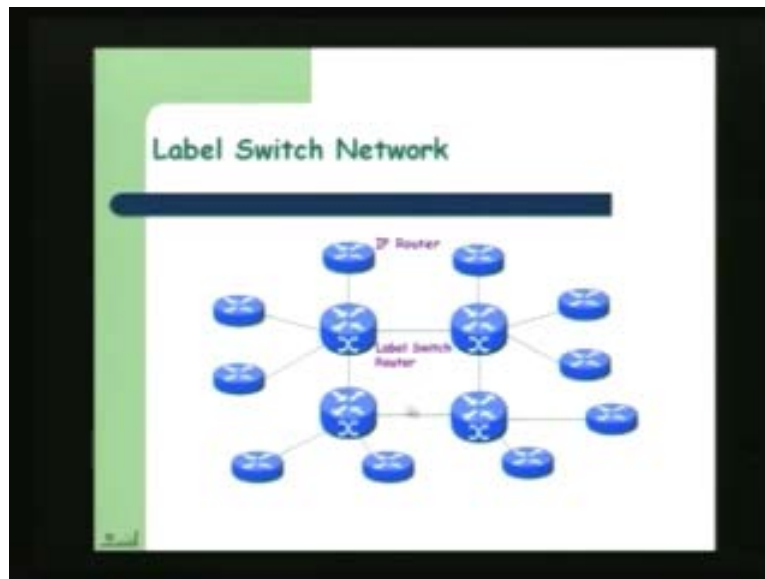
So remember that here in the core of the networks, we were earlier having an ATM switch. Now instead of ATM switch having what is called as label switch routers and these are all IP routers. So you can see that these label switch routers, here your IP packets need not be segmented into the ATM switch or ATM cells are so they are working on the this label switch routers are working on the IP packets themselves. So that is one advantage that we have is that now you do not have to no longer work with the ATM cells, but you are directly working on the IP packets themselves and then like in the ATM switch in this network of the label switch routers you are determining a path based on certain rules or classifications criteria. You are determining a forwarding you are classifying packets into forwarding equivalence class and then determine label switch path in the label switch networks.

So what is really happening is that now the IP routing is tightly integrated with your determination of a label switch path in the core of the networks and routers are also working on the variable length IP packets and not on the ATM cells. So, we have integrated with many of the concepts of the ATM world with the IP world and have given raise to the concepts which is called as IP label switch router which is also called as multi-protocol label switch routers. So we will look into what are the various protocols and other features of MPLS later.

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