Computer Networks and Internet Protocol
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Lecture - 36
IP Routing - Introduction (Routing Table)

Hello, so today we will continue our discussion on Computer Networks and Internet Protocols. Today we will be stating or stating our couple of lectures on IP Routing. So, already you have seen that how a application layer in our VLSI or TCP IP model works. You have already looked into several transport layer protocols and also the basics of IP layer protocols

So, IP as such is IP layer or it is also known as the network layer is primarily responsible for forwarding packet from one network to another right. So, it is a if we look at the internet which is a network of networks. So, the IP layer is primarily responsible for connecting the two or more different network x was the thing.

Now, one major aspects of this particular forwarding things that, how the packet will be forwarded across the global internet, right. So, internet as such we have seen a having truly speaking that a millions of systems, thousands of routers and so and so forth right. So, how a packet from one to another it will be getting forward, like if you from your system if you are typing www dot iitkgpes dot in, then the IITKGP page gets displayed on your screen. So, how your request comes up to this IITKGP web server and then IITKGP web server replies back to your systems right. So, if you are requesting from a far network so how it will go on hopping to through this router.

So, = if we imagine a overall internet or not imagine if we look at the overall inter internet. So, if there are several networks and there are a router switch connects these networks right. So, routers are responsible for forwarding packets from one network to another network and type of things. So, if there are multiple hops are required the router should be responsible for doing that right.

So, today or from coming couple of lectures, will be discussing or different forwarding mechanisms. How the packets are getting forwarded from one network to another network to another networks till then the destination host is reached right. So, if we look at we will be primarily looking at following things IP addresses and address allocation already you have gone through that we will quickly brush up on the things.

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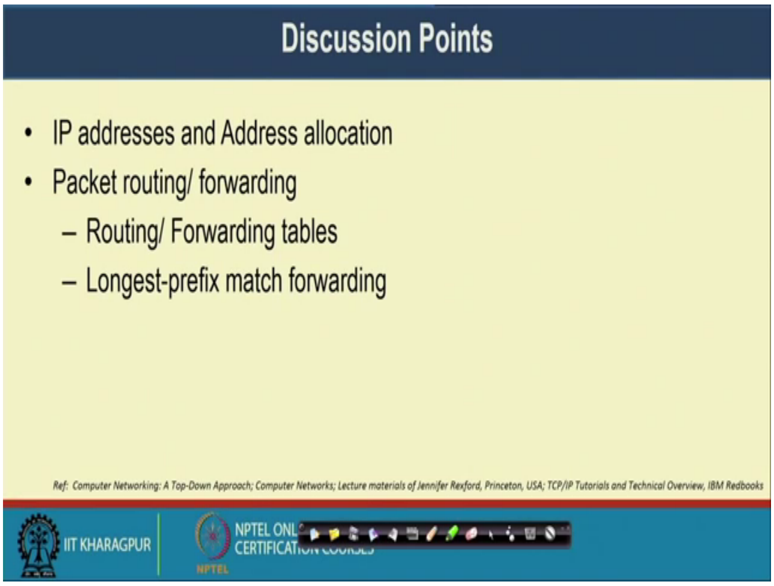

And we will start looking at packet forwarding or routing or there are will say forwarding table or routing table will be a little bit interchangeably using. The tables which are looked at the in the router and there is another concept whenever we come into play that is the longest prefix match sometime LPM forwarding right. So, longest prefix match and will be primarily referring this in the in whole of these lectures or series of lectures will be primarily referring some of the books and reference note and difference reference materials and of as mentioned there and as we have mentioned in our earlier slides also right.

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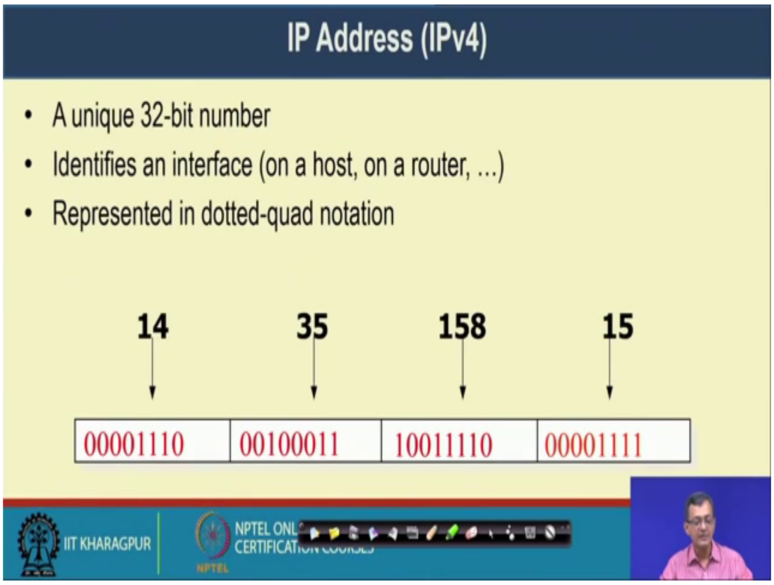

So, IP address is a already all of us or you know that it is typically when we as of now we are talking about IPv4 all our dealing of this routing will be primarily based IPv4. So, it is a 32 bit address with every 8 bit dot, 8 bit dot, 8 bit dot, 8 bit right. And it uniquely identifies a particular machine, logically provide a logical address to a particular systems which is connected in the internet.

In other sense we can say that a two systems on the same on this network cannot have to same IP address then it will not be able to identify those uniquely right, but there are way out still we are having those type of things that will come slowly. But nevertheless we think that this is the logical address which goes to the things. Later on in this particular course we look at another type of addressing what we say physical or MAC address, which comes with your network interface card right.

So, that is the address by which by the system is identified so, but this is logically able to identify the systems. So, these IP address is typically provided by the system admin or in some cases are provided through some other mechanism like DACP and type of things right.

So, uniquely it identifies in interface on a host on a router there is a interface right. So, where the thing where the network is connected represented by dotted quad notation right, this is known fact. And in everything in the thing everything in the system or the is represented by binary. So, if it is 14, 35, 158, 15 it is represented by like this right.

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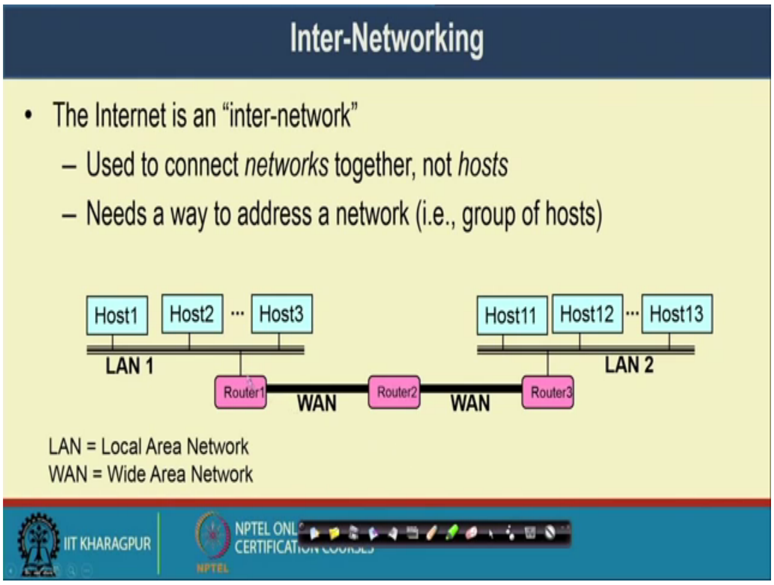

Now, if we look at internetworking so used to connect networks together not primarily network. So, there are several networks which are connected together. So, we need say way to address a network or group of host right. Like I say that I require IIT Kharagpur as a network, in inside the IIT Kharagpur I may have different sub network like say, center of educational technology, may have a network computer science and engineering can be a network, administration of IIT Kharagpur can be network and like that right. And so there are several networks and in other way we need a way to address this network also right; that means, if I am going from one network to another I should be able to know that address of the network.

As we have discussed at the previous lectures initial lectures like so, this network layer is the is responsible for routing; that means, for forwarding packet from one network to another right or we say that in other words these routers are having that layer 3 capability or it can see packet up to layer 3 or network layer in TCP IP model right. So, we have physical layer MAC layer and then ordered link layer and then the layer 3 and router can look at the layer 3 capability.

So, it can look into the network to network communication right. So, here also we can say this is a typical one LAN having some host, this is another LAN having another host and there can be bunch of routers and we can say this is a something in the intern networking or sometimes we say there is a wide area network. But nevertheless what we require that different routers which allows me to connect there. There can be 3, 1 n number of routers which allows to the connect to the network right and there can be different other networks which are counted to the network.

So, the every router has a some interfaces right sometimes we represent by the serial port of this router 1, 2, 3, 4, 1 slash like this type of representation we will see some of those. But nevertheless that router has interfaces, every interfaces connects connect allows it to connect to another router or another network in the things right.

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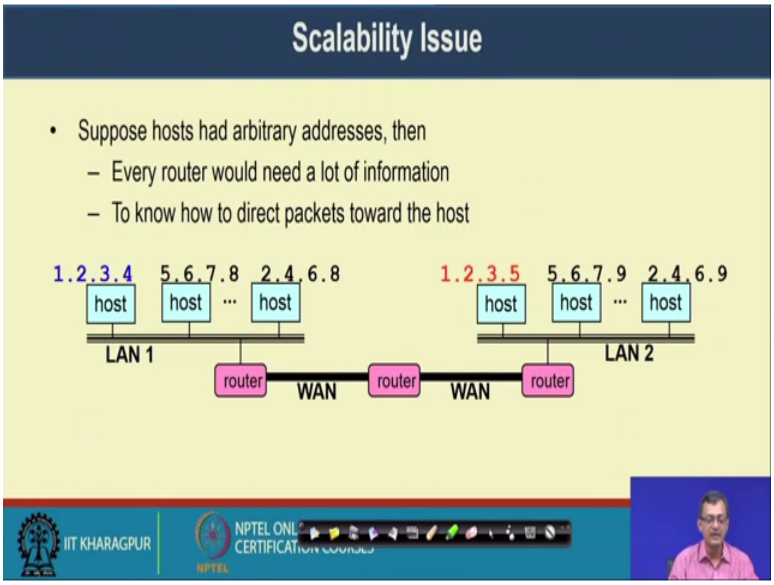

So, the one major is challenges in any system is the scalability right, like one way of looking at this router is that the router knows router somewhere or other knows that if I get a packet from say host a to host b to be forwarded a to b or c say a to b or c to d to be forwarded. So, the router knows that if from here it is generated then where it should be forwarded which router to be forwarded, then somewhere is to be forwarded and so and so forth. That means, there should be somewhere a what we say a some sort of a lookup table router looks at a table and see that this is the packet so forward these to the things right.

The problem becomes that any system added or other since deleted from any of the network needs to be again the now routing table needs to be updated across the all network all routers across the world. Otherwise it will not be able to forward packets right. So, there should be some mechanisms that we will see slowly that how to forward these packets from one to other.

Now, if we holistically try to look at a router is primarily a it gets something from one interface looks at the destination where it should go consult its some table or some information. And say now you go to that to this particular through this channel right, or in other sense if I try to make an analogy like I want to go from here to say Nasik and then try to go a major corner I ask that traffic fellow. Now, I want to go to these Nasik this, then which way you go, he has some information that in order to go that it has to follow this path. Then go and meet the at the next traffic person and who will redirect etcetera. So, it has some informations which allows it to route it.

So, what we what in other sense what we say these are the router maintains a table which is called Routing or sometimes Forwarding Table which allows to forward these things to the destination right. And this how this table will be constructed how this table will be maintained there is another challenge, but nevertheless having this table will be pretty large considering even considering the number of networks and routers and in the our internetworking

And as we understand this is very dynamic because we do not have any control or that there cannot be a overall centralized control that how man how many networks etcetera there. And not only that there can be more systems coming in going out more network being generated. So, it becomes a major challenge in the in routing the packets right. So, every router needs to needs lot of information’s and to know how to direct packets towards the host.

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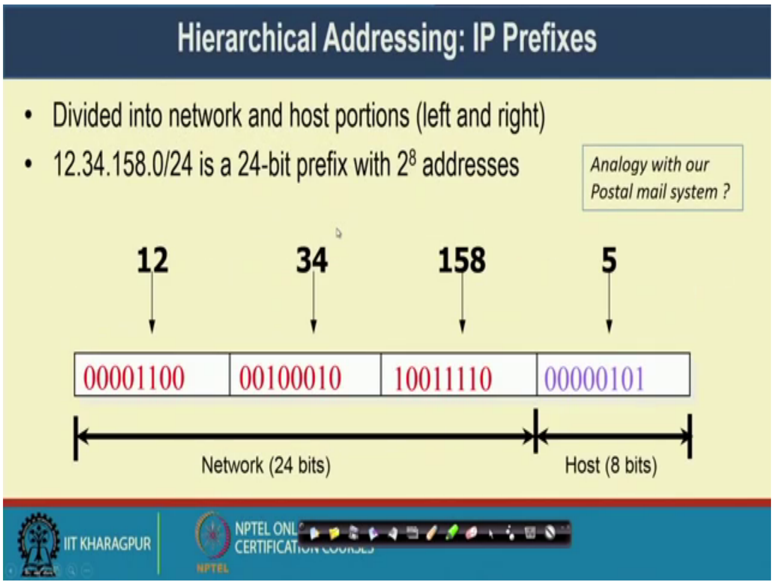

So, divide the network into host portion is the first thing what we have seen right. So, if I if I have so have some hierarchal sort of things or I divide that it is a host portion and a sorry network portion and by a host portion right. And that already you already you know that there is a the net mask which allows that if I musk it and then so net mask is a mask which followed by a it is also a 32 bit number or 32 bit address where it follows by a series of 1 and then a series of 0. So, there cannot be in between 0 1 type of things right. So, it is series of one followed by things it mask it and whatever it mask it out it is the network address right.

So, like here what we say 24 bit address slash 24 representation. So, the first three octet they represent that network or the 24 bit network and rest is the host of the thing right. And if you try to look at something analogy with our postal mail system also we have different category of the things right. We have say country, state, district, city, then maybe a area, location and then the house address and type of things right.

So, if I want to mask that whatever is for West Bengal say West Bengal, India I can mask it an segregate I can say Kharagpur, West Bengal, India segregate then IIT campus Kharagpur and type of things and so and so forth. So, it depends on that how, so it is there is some rough so I what we can say I can approach the problem in a hierarchical way right.

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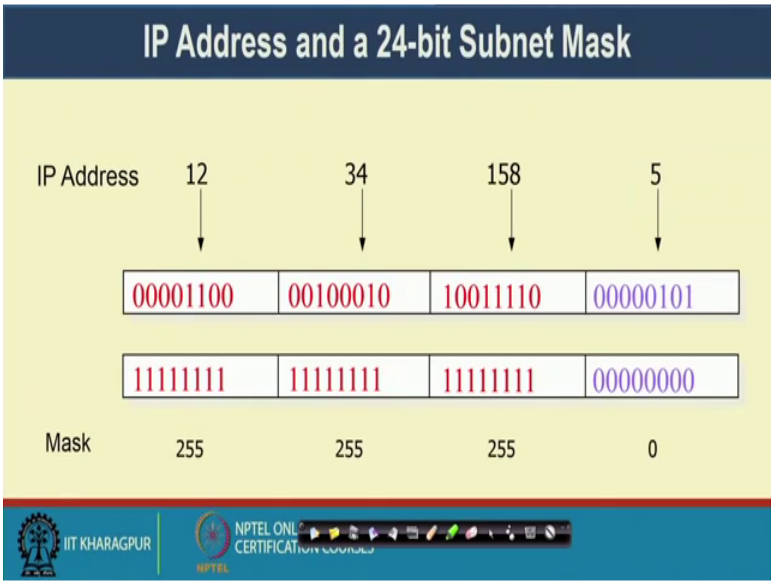

So, I can make a hierarchy that given address so this is the network address and type of things right. And this is typically a mask of 25 bit and if I mask it out and we get that IP address that already you have seen right.

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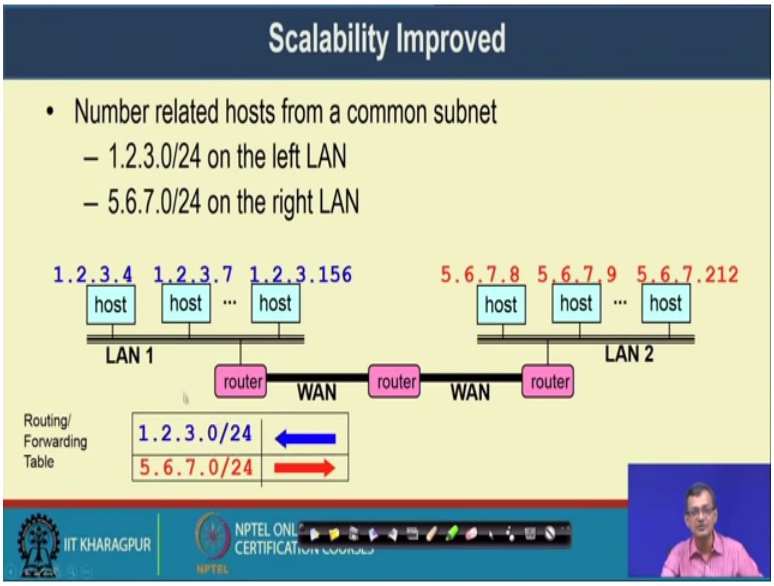

So, in other sense we have improved some sort of scalability like I can say that this is identify that particular with respect to a network address. And now with the LAN 2 if this was the way it was the table was maintained in this router. That this way incoming with 24 bit whoever is matching you will be coming here or going out.

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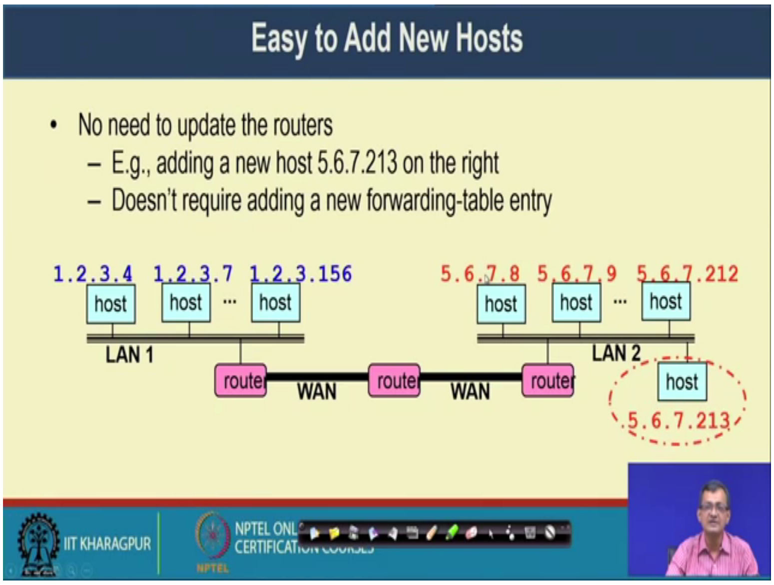

So, in the LAN 2 if I add a new host so you does not require adding a new forwarding entry into the table. So, it now does not address host by host, but address a network. So, this network what we see is 5, 6, 7, 0 slash 24. So, it is a net network address is with 24 bit mask and if I add something like this I do not require that all these routing things individual routers across the world need to be changed, still it is in the same network.

In other sense this way of representation allows me to identify a particular network through a identifier right. So, I mask it and this network has this network address and forward that. And then rest is the host address will be inside the thing right. Now, so this is this way we can look at some way of addressing the scalability issues.

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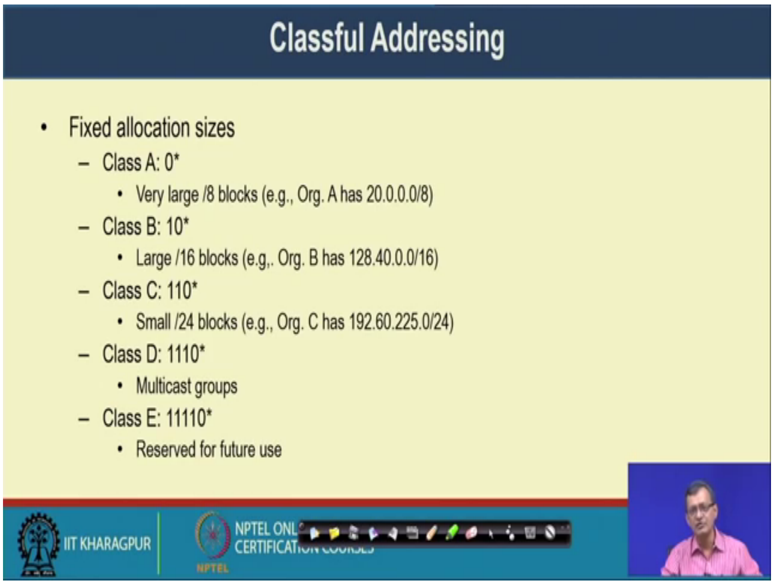

And then if you look at the IP address allocation again you have gone through that you know those things, but just to again to (Refer Time: 15:47). So, one is that we have some fixed address allocation or we say class full addressing right like class A address which starts with a 0 and star class B address 10 rest anything after that, class C address 110. There are two other one is for multicast group another is a reserved for future use right. These two other addressing schemes are there these are class full addressing mechanisms or in this case we have a very large block of slash 8. The network number of network is less whereas, the number of host are much larger whereas, in class B it is slash 16.

So, it is somewhere it is something large number of networks are with first 16 bit representation and rest are with the number of hosts. And 24 is where number of host in these organizations are much less that 8 bit is there and there are two multicast things. So, as we know that this type of addressing or which addressing you will choose based on that what sort of requirement you are having at the at your organization level correct.

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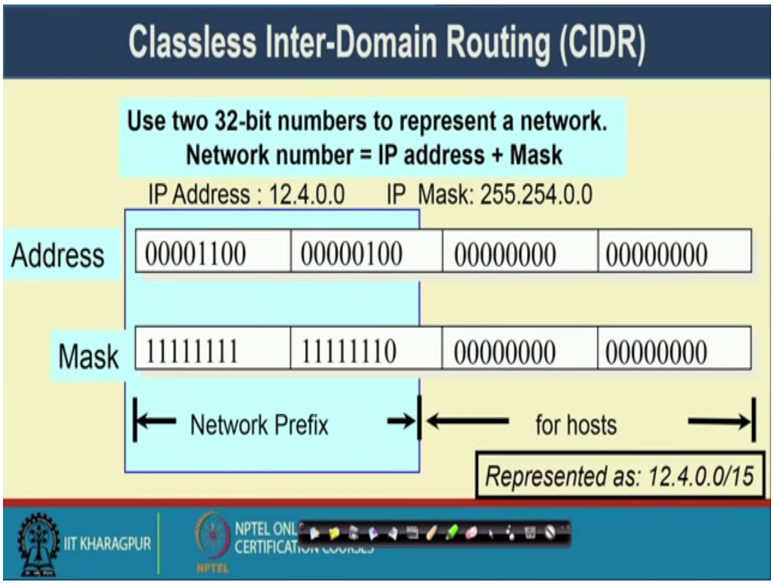

And then we have also seen that classless inter domain routing where instead of this class full we represent by an IP mask right of any variable length again followed by 1 and then 0. Like here we say that one 12 dot 4 dot 0 dot 0 with a mask of slash 15 and can be like this. So, that first 15 bit he represent the address and the rest represent the host like here what we see right. So, may not be the figure fitting properly, but first 15 bit and the rest is on the host site.

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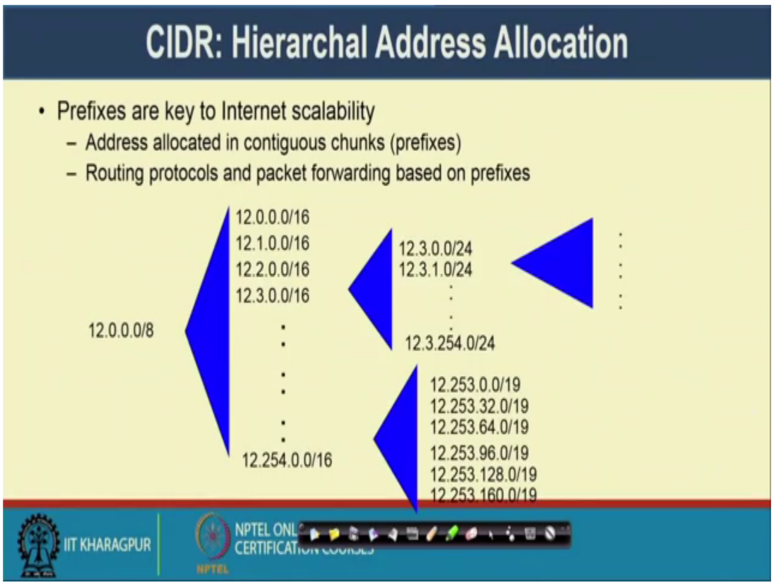

And in other sense if we can see that if I get a this sort of things then I can go on dividing them into different subnets right or sub networking. In other way we can have a better manageability of the things in a hierarchical fashion right. So, prefixes are key to the internet scalability challenge, address allocated in contiguous chunks prefixes, routing, protocols and packet forwarding based on these prefixes. So, the while we route we route between these addresses. So, I can have different hierarchy of this sort of mechanisms right and this is the and I can manage IP in a the whole IP things in a better way.

Not only that our I can manage the routing information or the routing table or the forwarding table in the router in a much efficient way right. Otherwise I need to have all the things into the things like think of again not may not be very strong analogy with the postal, but think of that I have to keep every post office need to keep individual address of rest of the world or even rest of India right. So, if I want to send a message to x y z at somewhere Nasik then I need to know that were to send. Instead I divided that I if I am sending something to IIT Kharagpur.

So, it is a state of West Bengal, then district a particular district, then particular city, then particular area of that city and then the thing. So, I divide into different stuff. So, similarly here also we have that type of we can divide them into this sort of things. These are already you have you have studied in your IP address allocation etcetera, but we can utilize this phenomena for our routing.

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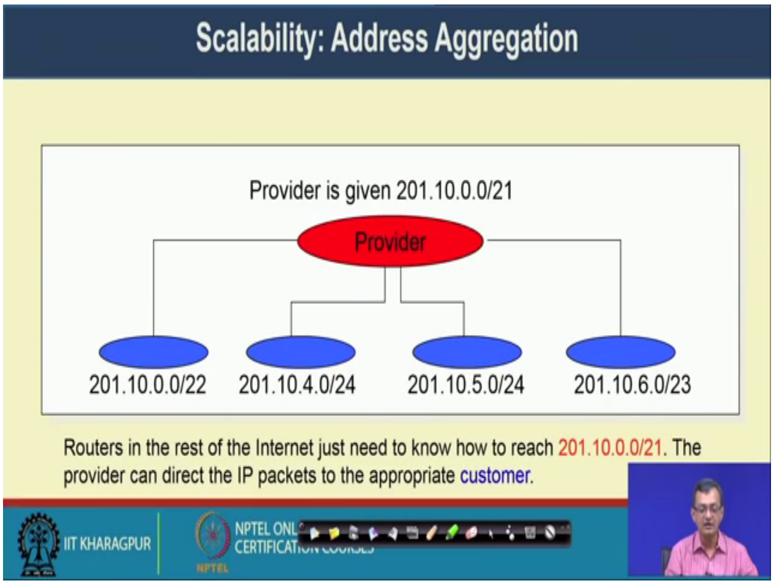

So, we can have aggregation of the things like if there are these different networks. Then I can have a aggregated network so I have 2 201 dot 00, 22, 24, 24, 23, type of things. Then I can have a aggregated network of 201 dot 10 dot 00 slash 21 right. So, routers in the rest of the internet needs to know to reach only 2 naught 1 dot 10 dot 00 slash 21 rest are handle at the lower level at the at the inside the inside that particular domain.

So, the provider can now direct the IP packets to the appropriate customer ok. So, if the provider has these are the customers right routers only need to know this higher level IP only right. This can have different so this if this is a some sort of a IP ISP provider. So, its customer's things are handled like this right.

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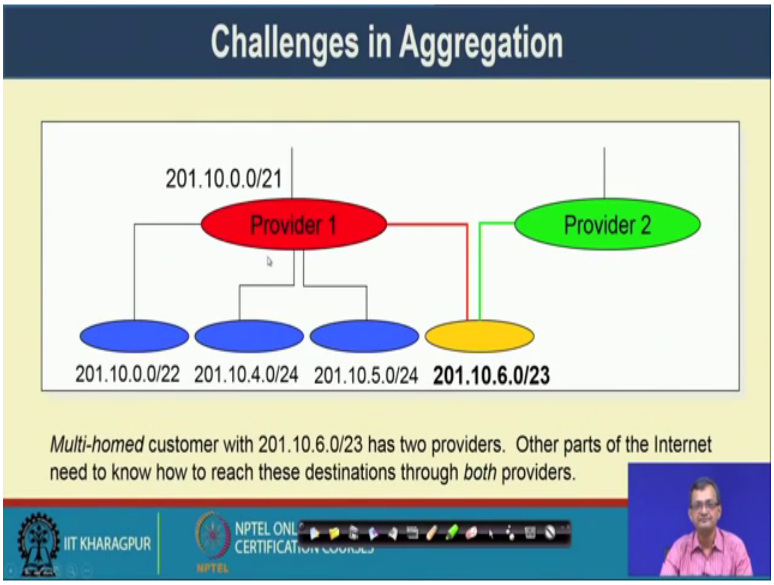

So, but there are challenges in aggregations if there is scenario of dual homing or multi homing right like say IIT Kharagpur takes a internet connection from provider 1, another connection from provider 2, another connection from provider 3. Then that particular network has different multi homing things. Then it then I cannot identify this overall aggregation by a simplified thing so I need to work on some other things. So, there are challenges, but nevertheless there is a there is a way to aggregate this sort of IP addresses. And then my load on this routing information or routing table can be reduced.

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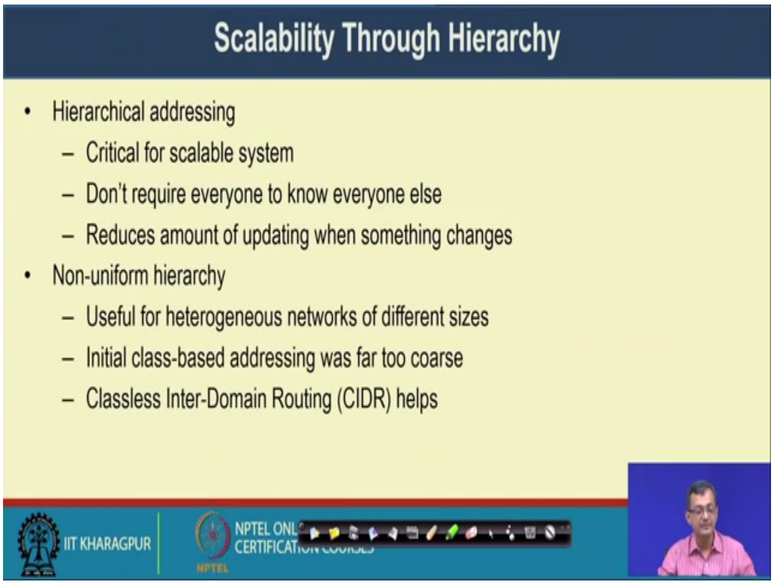

So, as we are discussing the scalability through hierarchy is one of the way we handle. So, the hierarchical addressing critical for scalable systems do not require everyone to know everyone else for that matter because it is only the hierarchical and the in router needs to know or the intermediate router rest of the things reduces amount of updating when something changes right. So, if something changes it reduces the amount of updating in the things right. Like as again try to put on the analogy if the number of quarters in IIT Kharagpur increases the address need not to be to be published to whole rest of the world right.

It is only the IIT KGP post office needs to know and update it and all the packets comes to its and it gets displayed or type of things. And if there is a and there are non uniform hierarchy useful for heterogeneous network of different sizes. So, either it can be uniform non uniform initially class based addressing was far too coarse because the addressing what we have a class full type of addressing. So, CIDR helps it in that, but it brings its own challenges in handling those that we will see.

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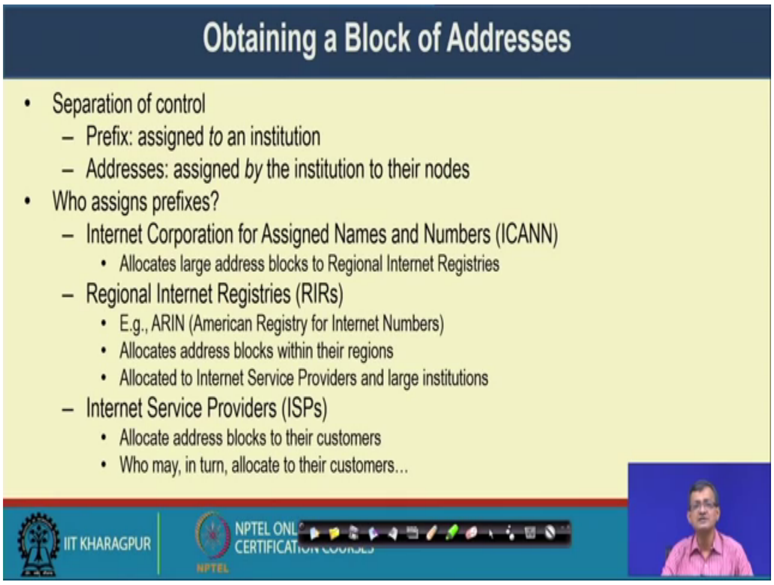

So, we can have a block of addresses the separation of control prefix assigned to a particular institution, address assigned addresses assigned by the institution to a host like IIT Kharagpur it may have this is the network addressed and this is your host portion. How you address the host portion; is basically determined by the institute network administration right or the institute network policy there how the things will be there. For the rest of the world the network IP IIT Kharagpur network is like this right. So, it helps and who assigned prefixes in a at the top level.

There is a consortium or association call or internet corporation for assigned names and number ICANN allocates large address blocks to regional internet registries. So, registry which maintains the IP blocks regional internet registry like ARIN. We have the American registry for internet numbers, allocates address blocks to their regions, allocated internet service providers. And there are ISP's allocated address blocks to their customers who may be in turn allocate their to the custom customers and so and so forth.

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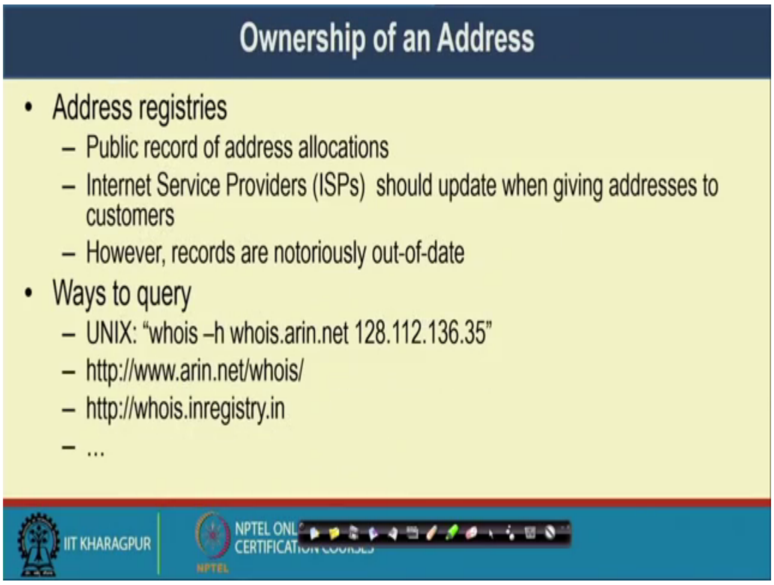

So, there are several address registries and there are several address registries which maintains like who is in registry dot UNIX in the Indian context. There are domain wide pages we will show you some of the things where if you give the address who is the owner etcetera it displays the things.

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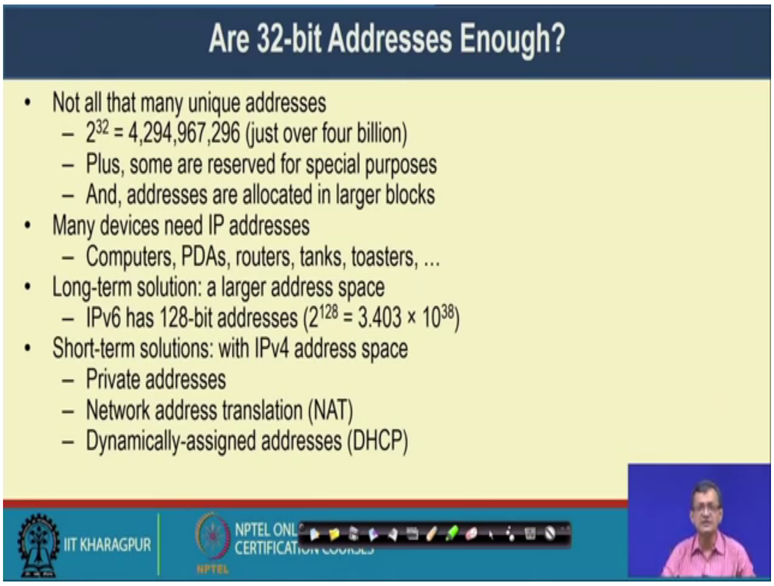

Now, definitely whether it is 32 bit addresses is enough or not that is a serious question with huge number of devices or network connected devices in place. This is a major challenge and we have IPv6 and so and so forth, already you know a overview of the things. So, there is a there are several long term solution of IPv6 and short term we can have private addressing scheme right this IP addresses private addresses we are not route non routable addresses like 10 dot star dot star dot star this type of addresses are non routable. So, within the thing so I can have some mechanisms called network address translator which translate to a public IP and goes and type of things. There are there are way to dynamically allocate addresses that you know that DHCP type of things. So, those are solutions which are available on the IPv4.

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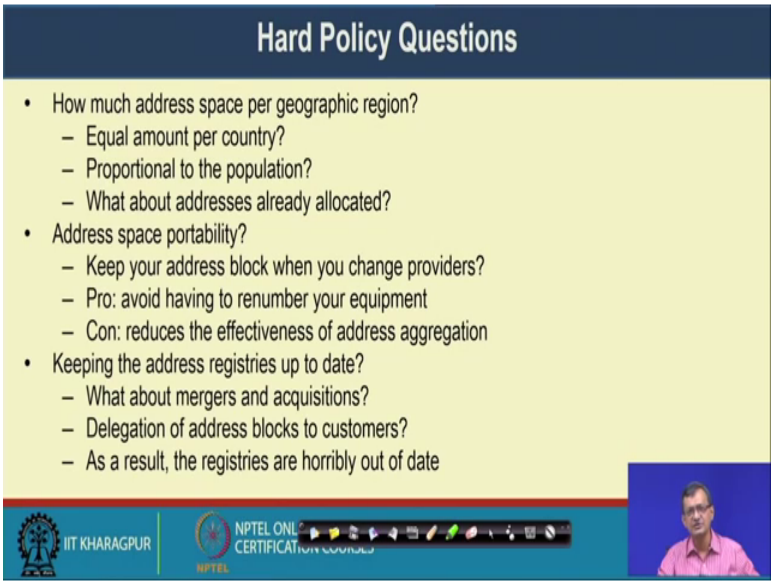

So, there are several other challenges in the IP related that how much address space for geographic region. Address space portability whether you carry over the address space keeping the address registries up to dates there are several challenges there are what we say so called quote unquote hard problems which are people are looking a work it.

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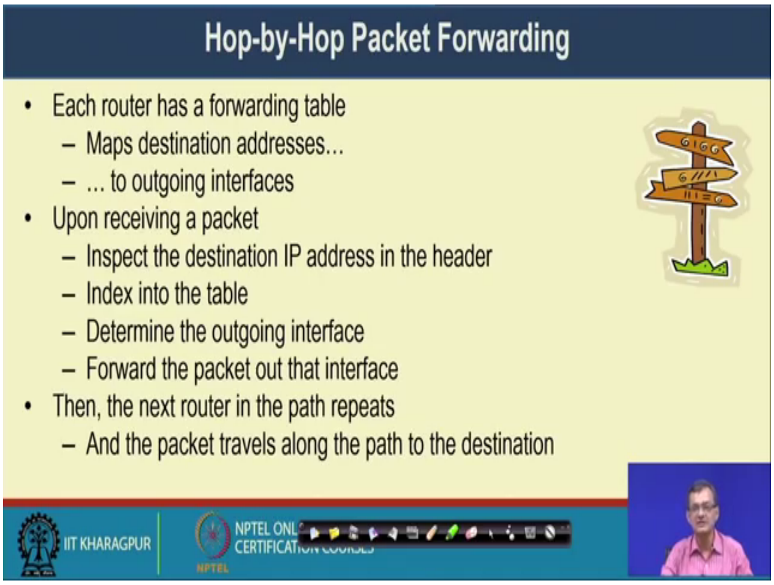

Now, if we with this context if we try to look at that packet forwarding. So, what we try to say that each router or layer 3 enabled devices which connect networks has some information's or forwarding or routing table which maps destination address. So, router what it is getting a address for the destination, like if I say www dot iiitkgp dot ac dot in from this particular machine or IIT www nptel dot in, nptel dot ac dot in from this machine it goes to the nearest router and it looks the router gets a destination as nptel dot ac dot in.

And it tries to find out that where this IP is there either the information should be victim or it should know that what should be my next hop right. Nevertheless it takes up it looks as a lookup table or what we say forwarding table or routing table and sees that what is the next hop. So, the router in other sense has to maintain this table, like anything it gets in one interface check the table and send that appropriate interface right. If it is not in that table so there is a concept of default route if it is not finding on the table by default it will deduct to that particular interface right.

So, upon receiving inspects the destination IP address in the header, index into the table, determine the outgoing interface forward the packet to the interface right. And they are in some situation it can change the some update the header that will come later right. The next router in the path repeats the thing so it goes on hopping, hopping, hopping, hopping like that right. So, it checks and go to the hop.

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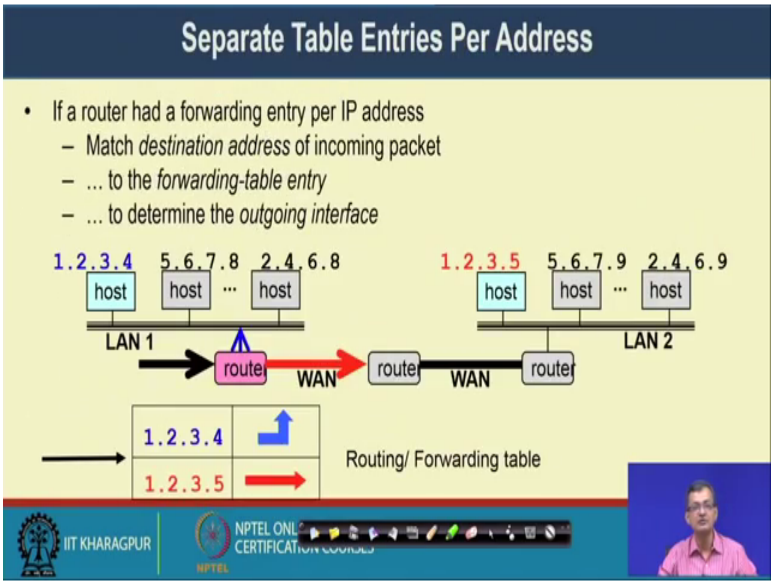

Like here it get say get say if the router forwards a as per IP match destination incoming packets forward the table entry determine the outgoing interface. So, it goes on forwarding the table one after another right.

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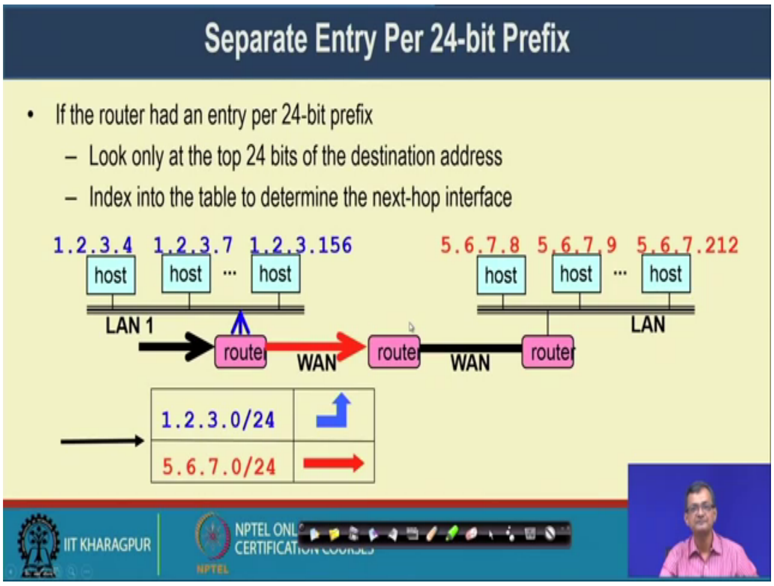

Here slash 24 is the IP yeah is the mask so; that means, it case that first 24 base is the network. So, if gets if it gets a packet like this 1 dot 3 dot 24 it forwards out here this or it gives that 5 dot 6 dot 7 dot 0 slash 24 that if the this is the network address is forward here right.

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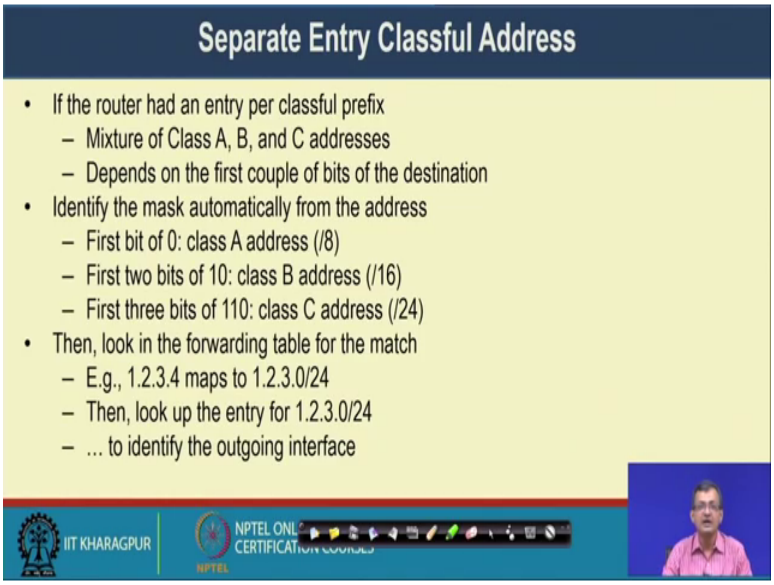

Now, I can have separate entry for class full type of address, each router had an entry per class full prefixes, a mixture of A, B, C addresses; depends on the first couple of bits on the destination as we have seen in the class full addresses. So, identify the mask automatically from the address like if it is bit is 0 the mask slash 8 10 mask is less 16 and 110 the mask is less 24 right. Look at the forwarding table of the match and then it goes to on the onto the things right.

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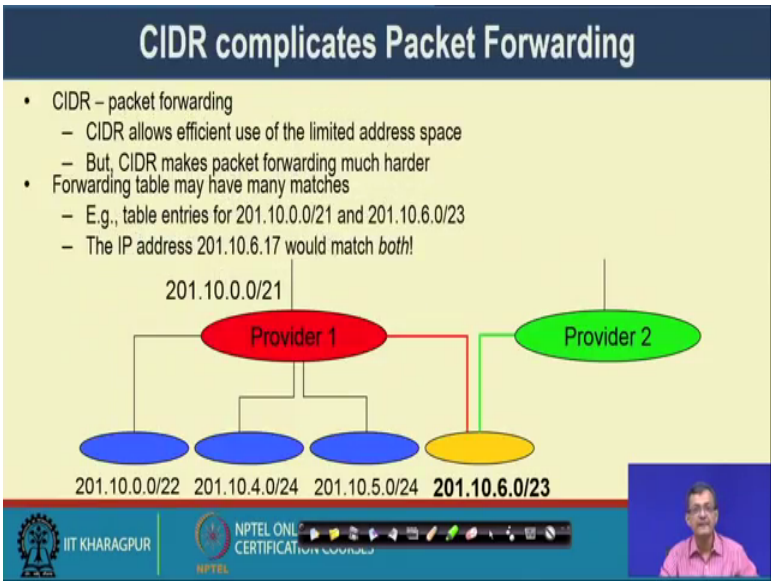

Now, CIDR complicates this right because now it has any type of mask right. So, CIDR allows efficient use of the limited address space that is absolutely fine the address space is not wasted or I should say efficiently used, but makes the packet forwarding much complicated right. Forwarding the forwarding table can have many matches like 201 dot 10 dot 00 slash 21, 2010 dot 6 dot 0 dot 23 can have more than one matches. So, where it will forward so that is a challenge. So, the policy it is followed is the your longest prefix match. So, where the longest prefix is matched then it is forwarded right.

So, like here in this case it needs to be forwarded 201 dot 6 dot 0 because that is the longest prefix which match whereas, others can have a much less prefix that is this is the longest prefix which matches right. So, that that way it takes care of the thing right.

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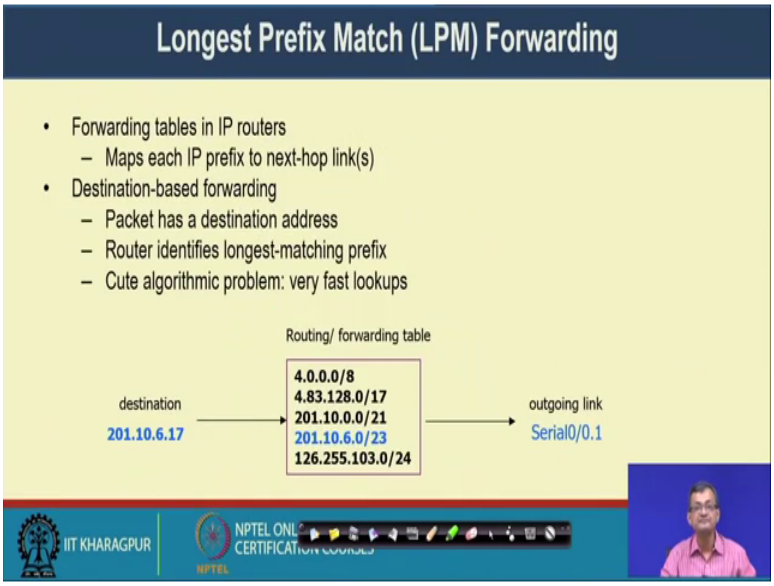

So, forwarding table in IP router so map each IP prefix to the next hop or links, destination based forwarding, packets has a destination address right. So, when I am I am sending a packet the packet has a destination address. So, when I am saying www dot iitknptel dot ac dot in so a www dot ac dot in has a after DNS resolution IP which is the destination IP for my packet. The router identifies the longest matching prefix and some algorithms should have to be look up on the things right.

So, routing and forwarding table so I have that destination addresses and it goes on to the lookup tables. Now, it is what it does it does say maximum prefix match. So, though this up to 1201 dot 10 and these are both are matching, but the maximum prefix match says that the other destination this needs to be forwarded out to the 10 dot 201 dot 10 dot 6 dot 0 right and which is connected to serial 0 or some particular interface of the router outgoing interface of the router.

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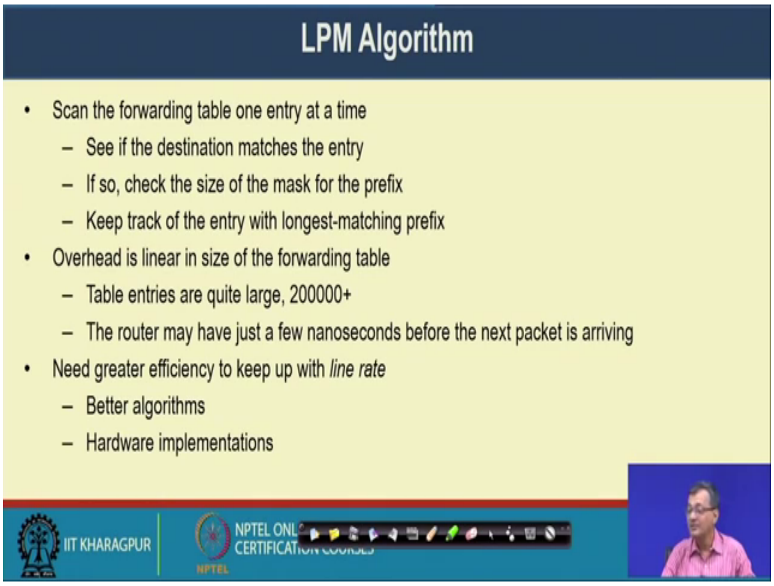

So, now that is the longest prefix match algorithm is maybe as or a simple or complicated there is a major challenge because that it is have major time. So, the router may have a huge number of entries like the scan and forwarding table one entry at a time may take a huge time into the thing. So, that that it requires some better algorithm to handle this like there can be huge entries like 200000, 200000, 300000 entries into the overall entries.

And looking at in a linear time will take a huge time whereas, the packets are being pumped into the router maybe every nanosecond right. So, it is huge number of things need to be processed. So, we need to have a better algorithm to find out this how this longest prefix match can be done so that is a major challenge. So, these days it is hardware it is handled to the hardware.

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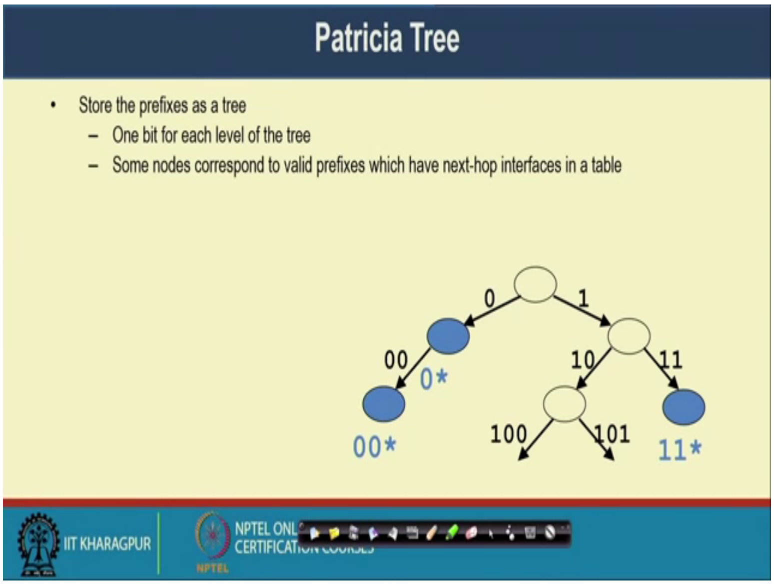

So, one very traditional way of or looking at it is this Patricia Tree; where it is in this case it is a binary, where you have 0 and 1 and type of thing. So, one bit for each level of tree some nodes correspond to be varied prefixes which I have next hop interfaced on the in a table. So, wherever the match goes it goes on, but in some cases it may not be very efficient because, the tree can be skewed and large number of entries can be there and type of things.

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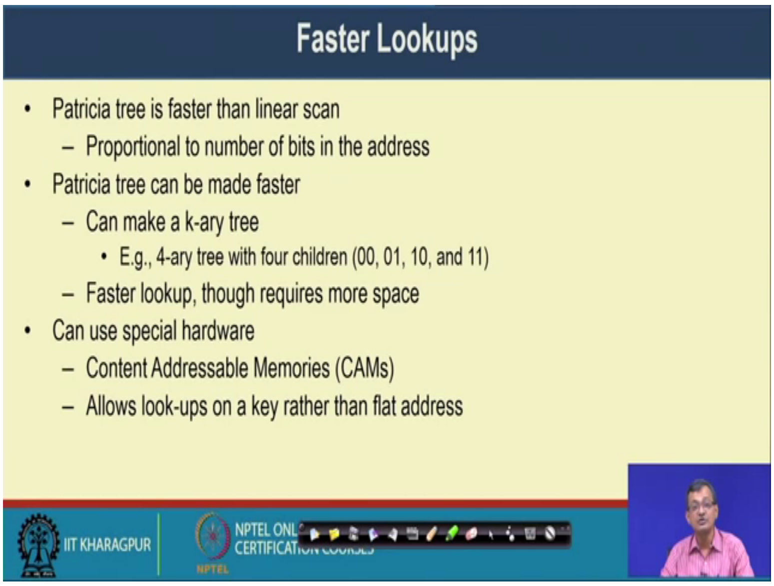

That will be can have a some faster look up by having instead of binary k-ary type of tree where things can be there much faster lookups. And, these days or we you there are use of special hardware like content addressable memories cams also looks up at the key rather than the flat type of addressing in looking at the things right. So, these are there are efficient technologies look to look at, but the basic philosophy it is need to such that longest prefix match right where it needs to be forwarded.

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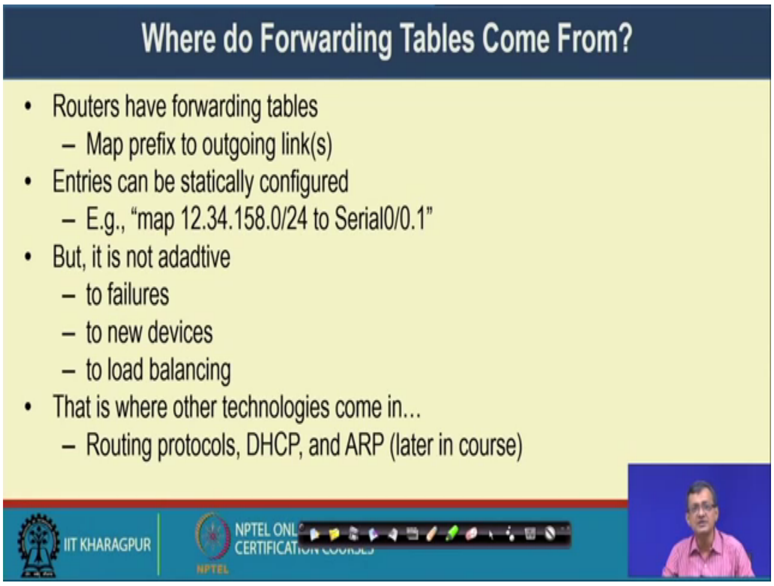

Now, where do the forwarding tables come from. So, routers have forwarding tables may map prefix to the outgoing links. Then how does this forwarding table are when it will come? Either it can have a some sort of a static entry and type of things right. So, it says that map so and so to this particular serial port, but this is may not be adaptable right, to failures new devices added new devices taken out. Then you need to intervene right and in some cases there are issues of load balancing right.

So, there are they are then the concept of routing protocols come into play. That how these packets how do you update this appropriately, how do you applied this efficiently this forwarding tables or the routing tables so that packets are forwarded. So, these are called Routing Protocols. We will look into this routing protocols in our subsequent lectures and the protocols which are being routed through these particular things what we say it is a routed protocol right. So, we are primarily interested in this routing protocols is how these tables are will be generated so that the packets can be forwarded correct.

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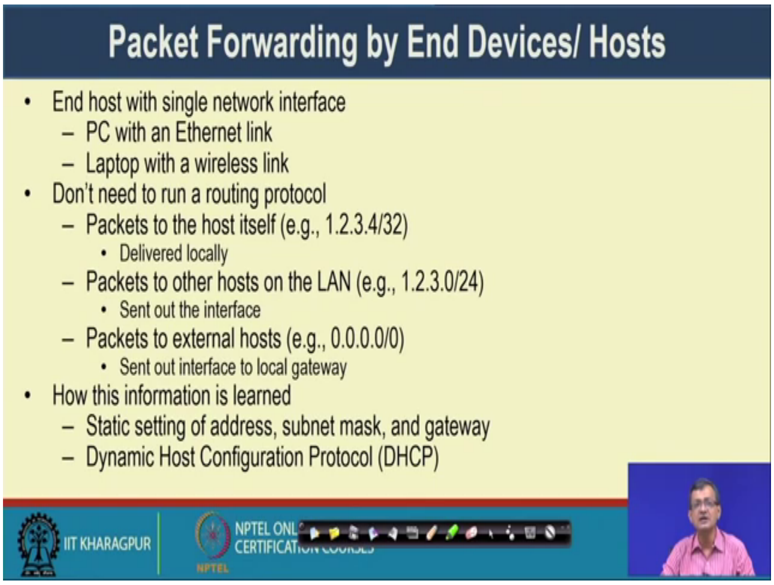

And packet forwarded by the forwarding packets, forwarded by there is a type of forwarded by the n devices or the host like. So, at what we are having at our end is the Ethernet link. This machine has some RJ 45 connection to the cable to the next things. So, PC with Ethernet links, laptops with wireless links, does not need to run a routing protocols. So, right it forward to that particular local or the next hop whatever the gateway is defined into the things right.

So, packet to the external host to a particular gateway, where this gateway is defined it is defined in my own TCP IP properties or the network setup. And how this information is learnt that where the get add and where to forward; that is either it is statically it has learned, my admin system administrator I told that you configure like this or there can be a DCP type or dynamic host configuration protocol that which allows me to dynamically configure this protocol (Refer Time: 36:39).

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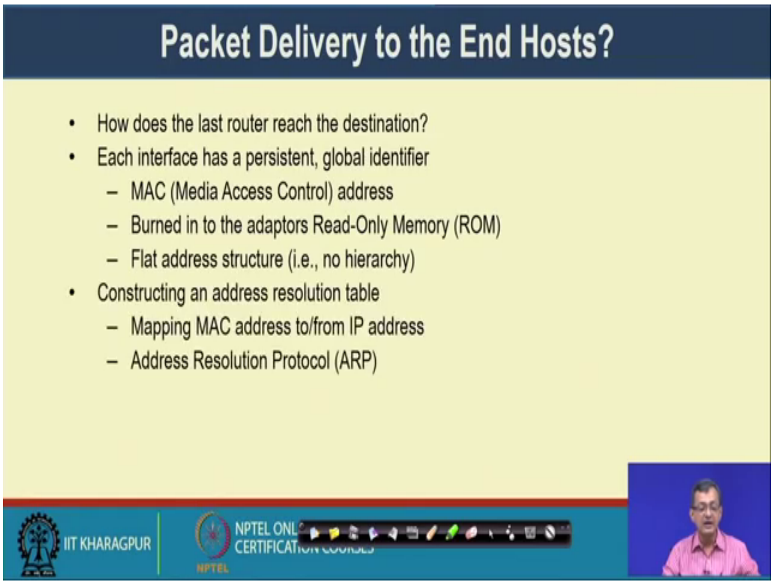

And finally, how this packet is delivered at the end host; so, at the end finally, we will see in subsequently that whenever say router forwarding to a router, router forwarding to a particular host, or whatever it does there should be a resolution to the MAC address right. So, finally, it should find out that what is the next hop MAC address and deliver the things, for that we require a protocol called ARP address resolution protocol

So, there are some address called MAC address as many of you know that is the hardware address. It comes with the network interface and in order to resolve these from IP to MAC we require a address resolution protocol. So, mapping MAC address to and from IP address or ARP and RARP reverse ARP type of things so we have this type of a addressing scheme.

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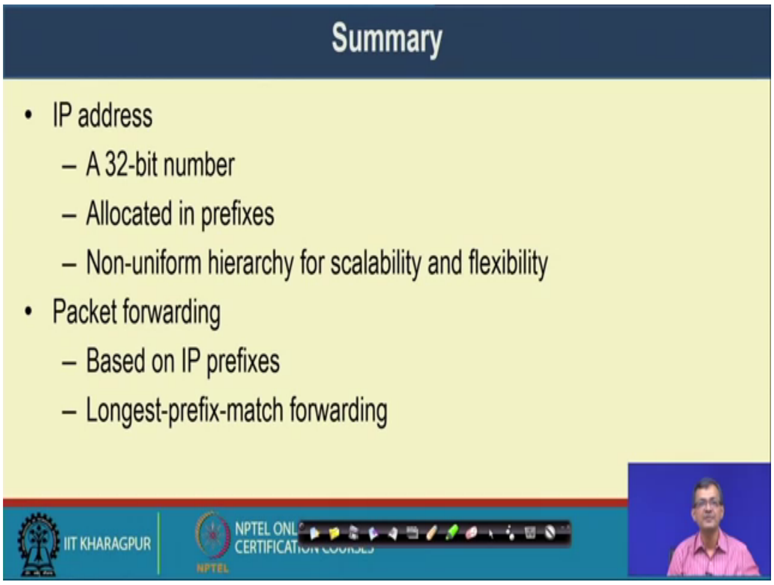

So, finally, what we look at that IP addresses and different allocation quickly already you have known and seen that packet forwarding based on the IP prefixes right. So, looking at that routing routers how it forwards and what we look at this long longest prefix match when there are more than one matching coming up that where the longest prefix match is there. So, with this we conclude our today's discussion. We will continue these routing IP routing mechanisms in our subsequent lectures.

Thank you.