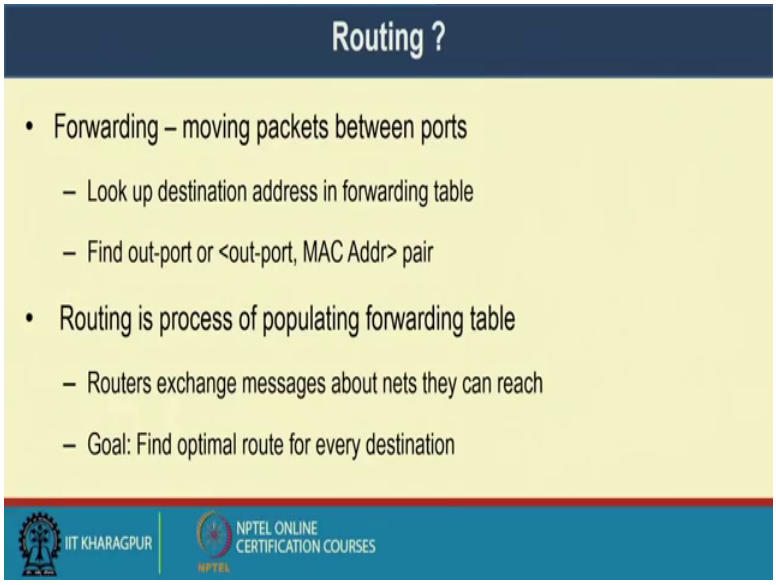
Computer Networks and Internet Protocol
Prof. Sowmya Kanti Ghosh
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 37
IP Routing - I (Intra - domain routing)

Hello. So, we will continue our discussion on IP Routing in our Computer Networks and Internet Protocol course. So, last day or in the last lecture I should say, we discussed about this IP address and allocation and how the routing come into play. So, today we will be little more going deep into the things. We will be having some basic introduction to this inter Intra Domain Routing and in the subsequent lecture we will be going to more detail about the routing protocols right.

(Refer Slide Time: 00:54)



So, when we talk about routing just to have a quick recap of the things or something already you know. So, one of the major feature or one of the major aspect in internetworking or our communication between 2 network 2 device connected on the network is to forwarding, right, moving packets between ports right. So, in this case we are looking at the network port. So, it can be from the host one end one host to other, intermediate host to router, router to router, router to host and anything. So, how things can move.

So, it may be on a single hop distance. It may be on a multi hop distance. So, it can be directly connected, or it can be connected over a large network. So, look up destination address in the forwarding table. So, as you remember in the last lecture we discussed about the routers basically maintains a routing table. So, that means if it gets a packet for a particular destination it says that it forwards a packet to a particular path or particular so, to say port or next destination or like that, right.

So, it has a routing table which has all ideally all the destination possible destinations and what should be its next hop or what should be the path to be forwarded, right. Or if it is in the in, let us in the we will see that one in subsequent lectures when we talk about layer 2 and type of things. Find out the find out port or output port and MAC address right, what is the port and MAC address pair right. Finally, what we will what we know that it finds a logical path; that is, at the IP level. Finally, in order to packet in order to forward the packet, we need to get that hardware address or the MAC address of the destinations.

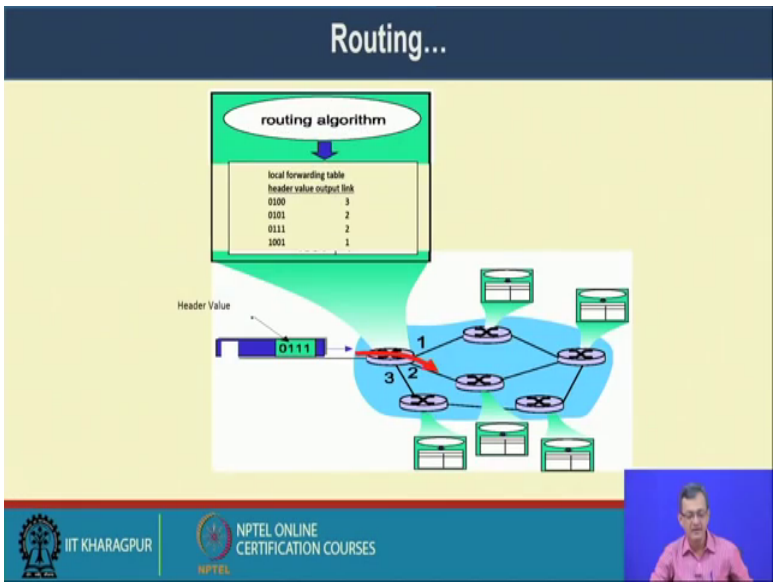
So, that is done by this some address resolution protocol, we will come to that. So, routing is a process of populating. If you look at that what is other way of looking, one is forwarding another is the routing protocol, right. So, one of that that it is a process of populating the forwarding table or the routing table, right? So, again I repeat. So, router is a (Refer Time: 03:21) 3 device which has a lookup table or routing table or forwarding table in the changeably we are using. And if a input packet comes to for some destination it concerns the routing table that where it need to be forwarded, it forwards it.

Now, overall inter network is a large network and that is dynamic and so and so forth. So, in other sense the router one of the objective is to maintain this routing table. How this routing table will be updated so that, any packet comes it gets that correct path to be forwarded, right.

So, the router exchanges; so, in order to update the routing table, the router should exchange messages about the network they can reach, right. So, a if a router 1 is connected to the router 2 and router 6, 7, 8, so, these routers exchange messages who they are network they are connected, and the other things gets updated. So, find what is my objective thing? Find the optimal route for every destination.

So, given a destination or given a destination finding the optimal route in the for every destination. Like, if we try to look at the analogy finding the if I am going visiting a place, so, one of the objective is that find the optimal route to visit that, to reach that particular destination. So, optimal route maybe the shortest distance, I may look for less congested route. I may have some other criteria. Like, I want to travel through a route which is safer and type of things right. Nevertheless, based on my criteria I want to find out that what is the optimal route from this source to the destinations or for that particular router to the destination, which way I should proceed.

(Refer Slide Time: 05:17)



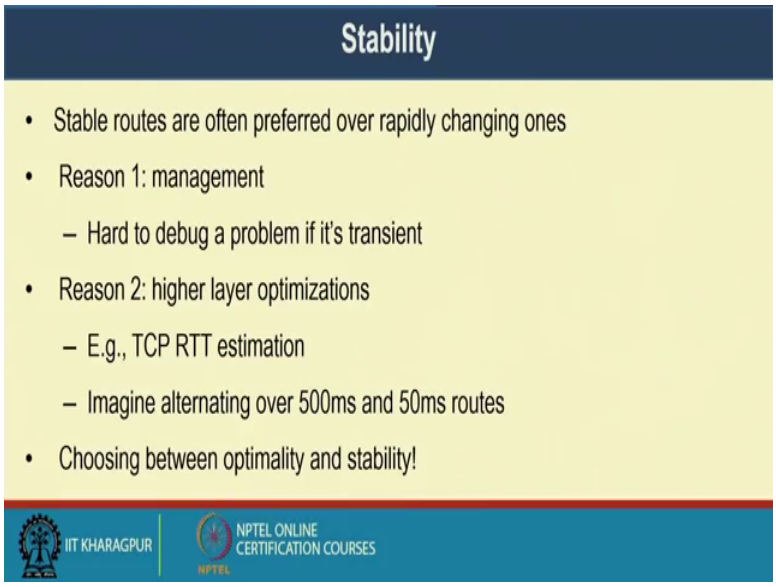
Now, if we look at, so, routing algorithms; so, it is getting some local forwarding tables are there. If these are the some for our discussions say, these are the different header values then these are the links which will be forwarded right. If it is 0100 to 3, 0101 to 2, 0111 to 2 and so and so forth and I have that. So, given a header value if this one, it concerns this table and forward it to 2.

So, one is this objective of the forwarding the packet is one of the work of this particular router. Another, this table needs to be updated for this router, right and every router had their corresponding table and is goes on forwarding the things. So, what we try to argue if somewhere other, if these tables are maintains properly or they are able to update themselves in a proper in a regular fashion then, the packets can be routed from

anywhere in the internet to any destination, right, any source to any destination through this different router.

One thing we should keep in mind in when we will talk about internetworking these are some sort of a, so called distributed system. And most of the cases they are loosely coupled or quote unquote autonomous system, right or several autonomous system though they are at domain control, will come in this subsequently in this top. So, in other sense I do not have a control that what that other router will do. It if it is the router is in my domain then I have some control. But, most of the cases if it is in the other domain I do not have any control. So, that is some sort of a message exchanging are going on and then and this routing table is getting updated. If these routing tables are updated, then we go on hopping the things.

(Refer Slide Time: 07:15)



So, one of the issue which come into play is the stability, right. So, stable routers are often preferred over rapidly changing ones. Or that in other sense, the routers where the routing table is stable right. So, that the exchanges are much faster etcetera. If the routing change because, based on the routing table or this lookup table, these packets are routed. So, if it is very dynamic it is unstable then the whole thing is unstable. So, that is one important aspect of the things, right. And there are several reasons. One may, is this manageability will be better right, hard to debug a problem if it is a transient right. So, if it is a if I if it is very dynamic and something at the when it is updating getting change

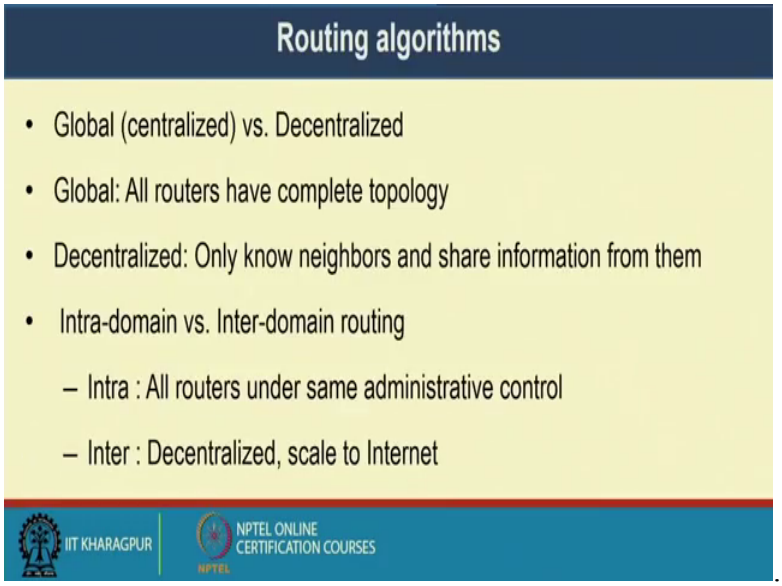
etcetera, there will be difficult to problem to manage this overall process. And if it is a large network then it is a or scale of internet, it is a very difficult thing.

Second reason is that higher layer optimizations like TCP RTT estimation like, as you have if you remember when this in this particular course we discussed about this TCP and round trip delay and type of things. And there will be challenges there. So, imagine alters. Suppose it is alternating every 500 millisecond or 50 millisecond or 5 millisecond routes and then how things will be there.

So, I need to, so, more I look for the stability then, I am less on the optimality, right. So, if it is optimal things means, at that time I want to find out a solution which is the optimal solution. And for that, I may need to be more dynamic or in other sense we are basically fighting between stability and optimality, right. I, if suppose ideally if nothing is changing then, it is a most stable. Say, for hours together nothing is changing. But, you may not get a optimal thing. But, if I allow it to change every now and then when there is a change then, it is more optimal. But, then the stability is hampered and that may cause different other issues.

So, there should be some way of looking means need to be optimize and things. And that is why when we talk about performance analysis of the network and several other matrices then, we talk we try to look at that what amount of the stability, optimality and etcetera we are looking for.

(Refer Slide Time: 09:48)



So, what we see? So, we have routing algorithms. So routing algorithms primarily what it does? It basically allow me to maintain this routing tables right, individually at every routers and now the routers becomes independently once it gets a packet and goes out and so and so forth. So, there can be global or some sort of a centralized taking a call, a taking the global consideration or it can be decentralized right. In global, all routers have the complete topology. So if I had the whole topology of the whole global scenario then I can make a optimize scenario right, but it may be possible over a small network, but it may not be possible on a large network. Whereas, in decentralized on the other hand, only know the neighbors and share information from them right.

So, I only know the neighbor. So, if the router RI, know it is only neighbor JKLM and it shares information about the thing. Similarly, another router RJ takes the things and going on, so it is a decentralized person. So, I am not looking at the whole world or the whole network and taking a call, but more taking a call taking at the at a only the local neighbors.

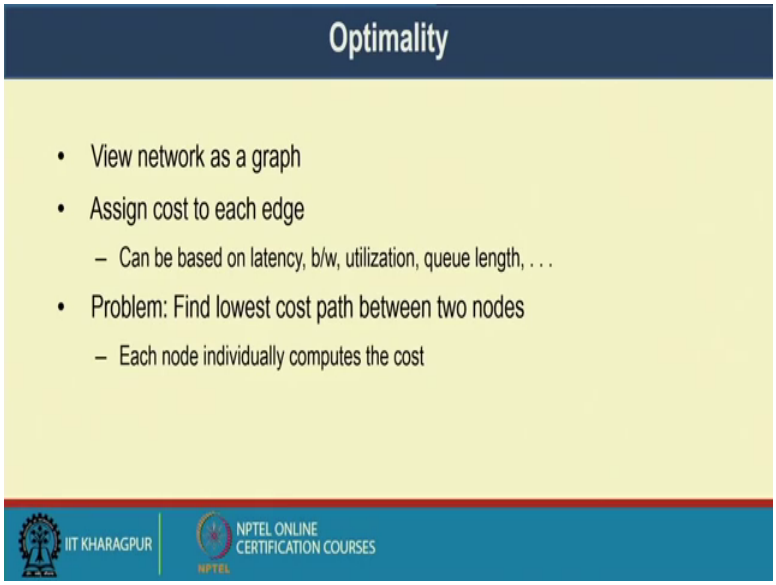
So, that is one, so we have a option of intra, that is 2 way of routing will be intra domain and inter domain routing. So, inter domain all routers under the same administrative control, when we say intra domain, it is under the same administrative control. It may be large network; like in IIT Kharagpur, we have say around 50 odd networks under, but under the control of IIT Kharagpur itself.

Whereas, inter domain which is decentralized, scale to internet, so huge amount of network and etcetera which are to the skelter scale of internet. So, these are inter-domain, so these are the broad category of the things. We will come back to those things shortly. So, we have 2 type of broadly routing, one is inter domain and one is intra domain. Intra domain is somewhat all routers under the single administrative control like, IIT Kharagpur network or any such networks or whereas inter domain is decentralized, so like scale of internet and type of things.

Now, as we understand these 2 aspects has 2 r outing and phenomena has different type of consideration so right. Once you have everything under control you have a way of looking at the problem or the routing algorithms and if you have that it is a decentralized and not under a single administration we have to do. So, today we will be

looking at some basics of inter domain, rather again, the in subsequent 1 or 2 lectures we will be looking at the intra domain and then we will talk about inter domain routing right.

(Refer Slide Time: 12:51)



So, before that we take up few couple of issues to show that we understand that what is the challenges right, one is the issue of optimality right.

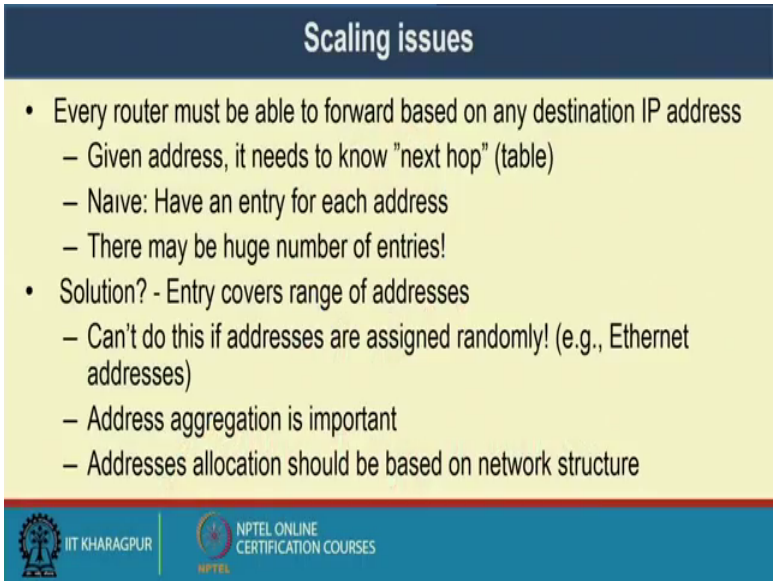
So, I can look the whole network or the in the portion of the network under consideration as a graph. So, nodes are router and links are your edges and then the edges has can have variable weight based on different considerations, it can be the conjugation level and or length of the distance and a different type of consideration we can have right. So, assign cost to each edge based on latency, bandwidth, utilization, queue length etcetera, right, so this can be the cost to edges.

Now, our problem is finding the lowest cost path between the two nodes. So, based on a my our, my metric or our metric under consideration I want to find out the least cost path between node a and node b or node source node and the destination node. So, each node individually computes the cost.

Now, if each routers had the capability to compute the cost and in a distributed fashion and then I find out the overall cost of looking at the things right, this is now what I looking at is a optimal solution but, it may not be possible to always get a optimal solution, so we can go for some optimal solution. In some cases, we will see that a

concept of default route is there. If I do not found a right route, then I may have a default path to forward the packets.

(Refer Slide Time: 14:41)



Other issues which are definitely come into play is the scaling issue, like how it scale, how the algorithm scale. So, each router must be able to forward based on any destination IP address. So our bottom line is that whatever is the destination IP address the router should be able to forward. So, given the address it needs to know the next hop consulting the routing table or the forwarding table. So, it has to know that where it should go next.

So, one of the naive approach maybe have a entry for each addresses right, one that I can have entry for each addresses but however, that will be a usually there can be huge number of entries there right the to the scale of 10 to the power 8, 10 to the power 9 type of entries, if you consider the all systems etcetera across the across the domain right. So, it will be huge number of address, then that is that may not be practically feasible.

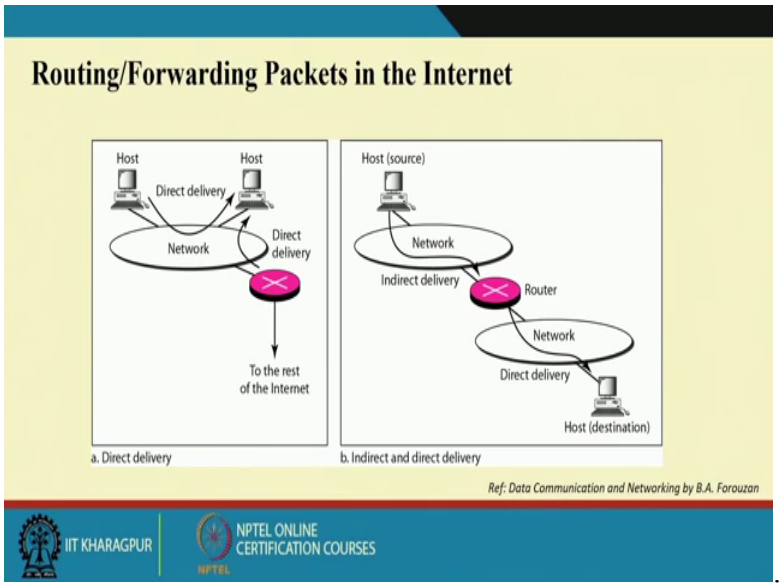
So, one solution may be entry covers a range of addresses right. So, I have a things which covers a range of addresses, like out IIT Kharagpur router takes care of the rest of the 20,000 odd systems within the campus right, systems in the sense systems, devices etcetera network enabled devices within each domain right but, for the external world it looks at only 1 router or maybe 1 or 2 routers which are looking at the things right.

So, that may be so I do some sort of a address aggregation on the things. So, one is that we cannot do this sort of things if the address are assigned randomly right like, ethernet address or hardware address which comes from the manufacture we look at when in our subsequent lectures. So, we cannot do something which is randomly assigned right. Address aggregation is a important aspect which we are looking at address allocations should be based on network structure. So, I can aggregate addresses provided that is the in the network structure.

Now, if you look at some a type of analogy when we look at our normal postal addresses etcetera, we are able to club them together because, there is a sense of inherent aggregation, if it is a randomly things then making things very difficult like, if the house number 1, 2, 3, 4, 5, 6 etcetera are closely in a particular locality then sending the particular forwarding that letters or sending letters with the postman is easy. But, after 1 if it is 101, then 49, then 216, then it is very difficult to pack them together or things. So, that it is that, otherwise what we require is that some sort of a that addressing mechanism itself favor this aggregation. So, that may be one of the requirement of the means, one of the way of looking at it. So, aggregation is important.

Now, let us come back to our basic problem. So, what we have seen these are some of the things which we try to address that scalability, optimality, stability and of the several routing protocols and if we look at the other way this, again come back.

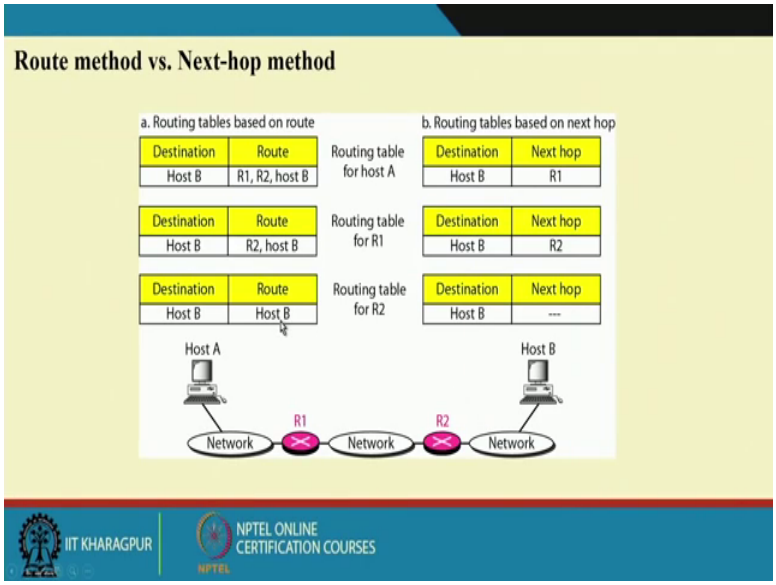
(Refer Slide Time: 17:57)



So, what we have that we can have a way of direct delivery say, 2 systems are connected by a cable and then I directly deliver one packet to another right, or I can have indirect and delivery system right or I can have multiple things.

So, I have in this case a router which forwards the things etcetera and there can be multiple where the routing come into play.

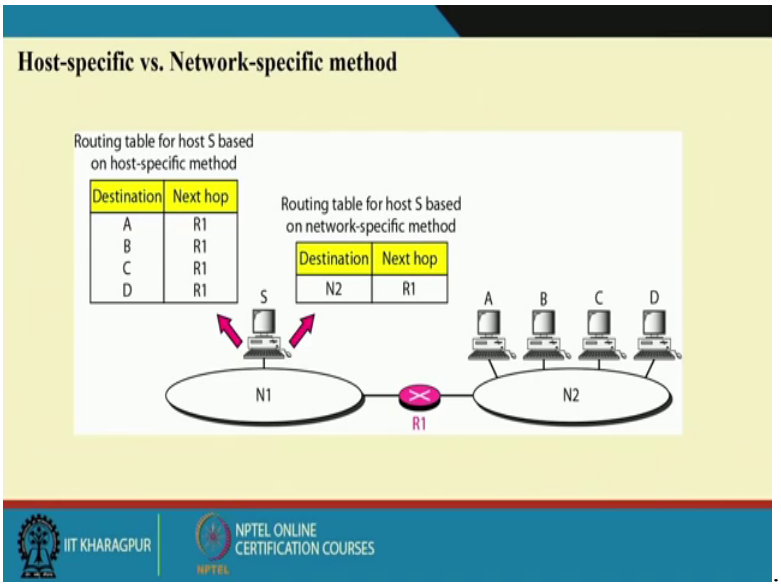
(Refer Slide Time: 18:21)



So, one route method that if I want to I can have a lookup table like, that if I want to go to a particular host, this is the series of things I need to do router 1, router 2, then host B right. So, it is explicitly specified that where things are there so, this route method is explicitly specified that, this is the route by which you. Other way I can only say that it is on the next hop, I only specify the next hop, the next hop takes care of that where it should go right, that in the routing table of A, in order to go to host B in this for host A, the it says that in order to go to B, you need to go to router 1. Router 1 says in order to go to host B, that is the router 2 is the destination or the next hop, I should say next hop, routing R2 says that it is connected with this particular network, so we can directly there is no next hop, you can go directly go to the things.

Now, you see this is the next hop-based things so, individual routers R1 and R2 they maintain that routing table, that given a destination where it should be pushed right so, that is next hop-based thing.

(Refer Slide Time: 19:40)

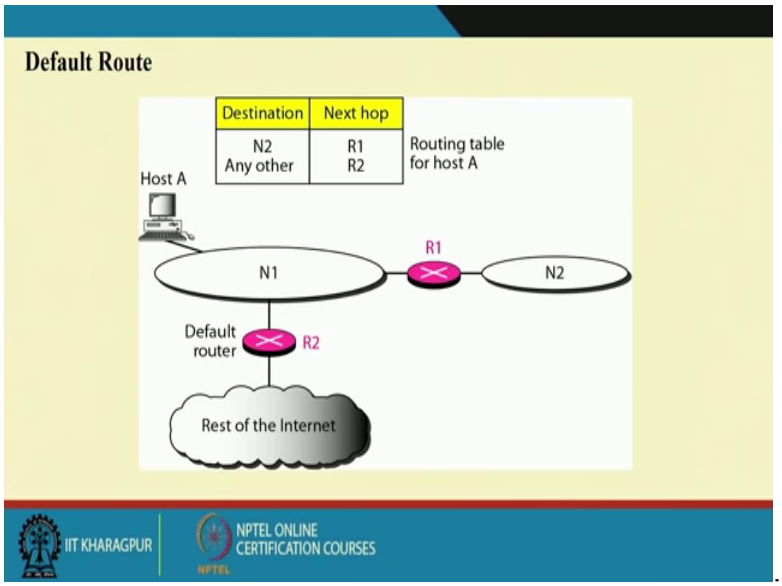


Then, we can have host-specific versus network-specific, last class if you remember, we are looking at that it is router is primarily between networks to network, not meant for host to host right it is not like that, cannot be done but, it is mainly for network to network.

So, if it is in the particular router a host is on the host specific method, if it is destination is A then, R1 is the next hop B is R1 C R1 and D, R1, so for all things are there and for routing table for host A is based on the network specific thing that, in order to reach because, A B C are all connected to this network N2 so, it has a one thing if it is a network, that in order to reach N2, that R1 is the next router right.

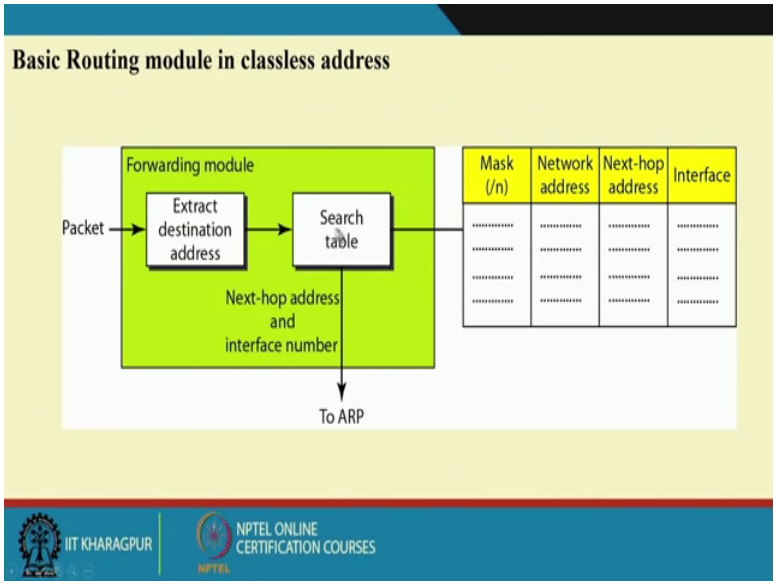
So, this network definition so, instead of taking individual host I take, we consider here the network where the host are like and then I forward the packet on the based of the network right.

(Refer Slide Time: 20:57)



So, there is a concept of default route. If I cannot find something where to be forwarded, then where should I forward? So, there is a default route like, in order to go to network N2, push it to R1. In order for any other network, push it to R2 right, so, this is a default route. So, there is a concept of default route if it is if it cannot find that where the routing table things are there, it will put it to the default route.

(Refer Slide Time: 21:25)

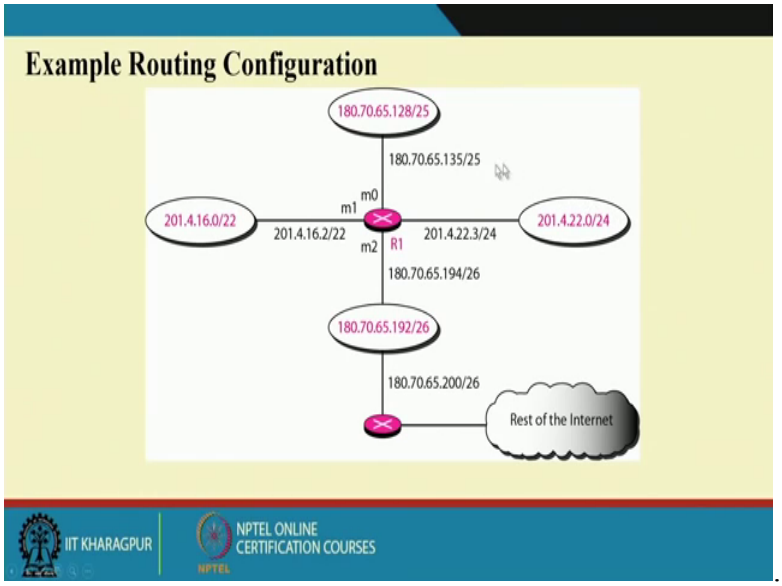


Now, if we look at the basic modules or very fundamental structure of the a particular router so, once it is received a packet you need to extract the destination address from the

IP address. So, these are routers are as I, as we discussed earlier that these are layer 3 switch which has enabled up to network layer. So, it opens up to the network layer and extract the destination address and the next-hop destination address and it next-hop address and the interface.

So, it extract the destination address, search the particular routing table or the forwarding table and find out the next hop address and the interface number, like it has to go to that particular address and to the interface number right and what happens when I want to push the packet to the things, I need to know the MAC address or the hardware address of the of the next hop. For that I require a ARP protocol, so that we will discuss later on. So, ARP protocol, so that I know that what is the next address and push it the things. So, in other sense I have some sort of a net mask, network address, next hop address and the interface of the router where it need to be pushed.

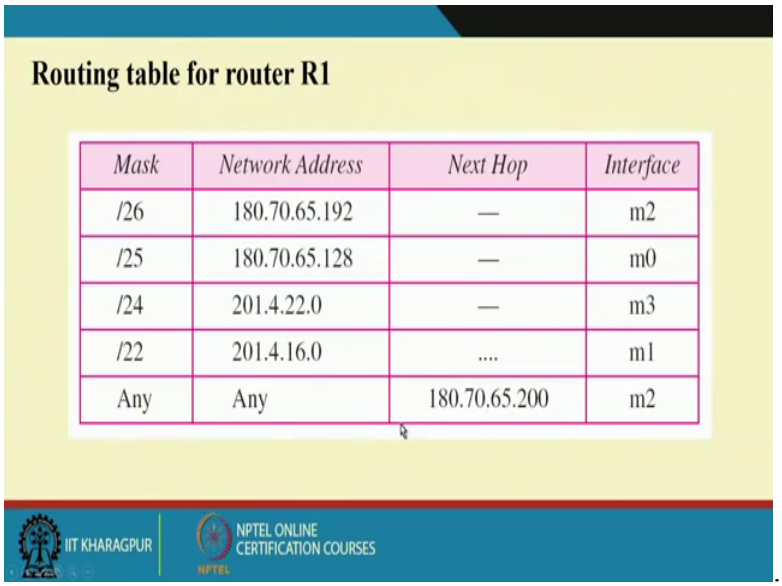
(Refer Slide Time: 22:46)



Like here what we are having, there are several network like starting point, 180 70 65 slash 25 here 20 14 dot 16 dot 0 and it is connected with different interfaces of this particular router right. So, it connected to the different phases of this router and there can be a default route, may one of this interface right.

So, these are this is a connection for 201 dot 4 dot 16 dot 2 slash 22, 180 70 slash 25 and so and so forth and there can be other router, sorry other router connected to this type of interface.

(Refer Slide Time: 23:35)

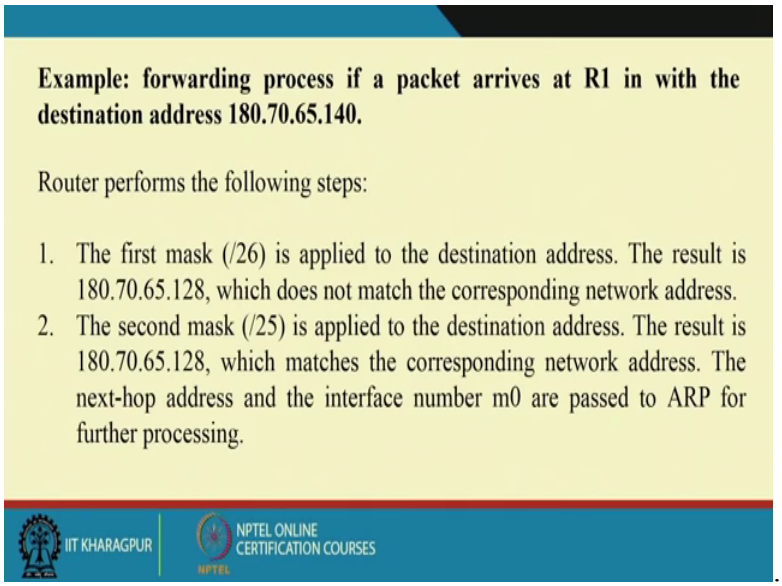


Now, if I see for router R1, if we look at if it is a slash 26 type of net mask with this network address then, the next hop is m2 right ok.

So, if you look at so, slash if the net mask is slash 25 and the network address is 180 70 65 128 then, the next hop is m 0 right similarly, so and so forth. So, slash 24 201 dot 4 dot 22 dot 0, it is m3 right so, this is this is the address that it goes to this network right 201 4 22 0, the next is slash 25 in the network, it should have been m3 out here there is a type here, not type that m3 came up into the this particular interface.

So, in other sense the routing table of this what it says when it is this net mask so, when it is gets a packet it checks with this net mask, if the address matches, it push it to that particular things right. So, I get a get a input packet from somewhere then, I extract that a particular destination IP, do a masking, if the address matches with these network addresses, just put it push it to their interface. If it does not matches then, it push it to this default interface right.

(Refer Slide Time: 25:19)



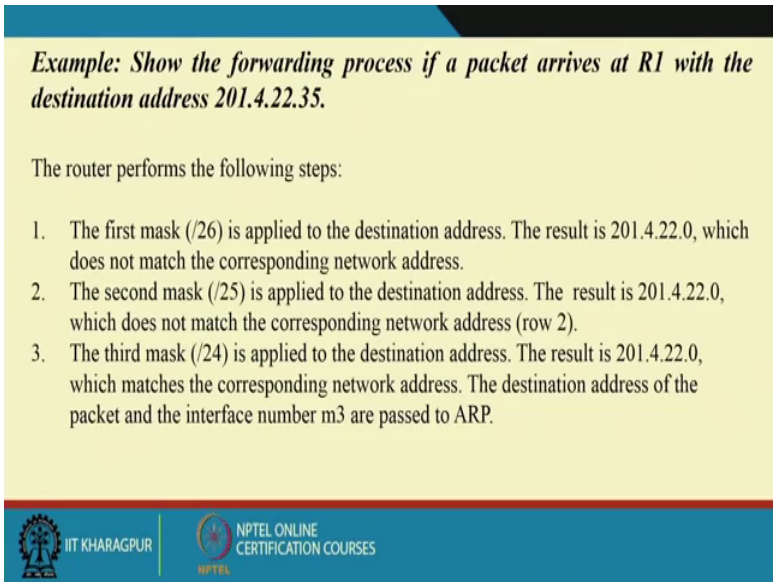
Like, some example forwarding process if the packet arrives at R1 in which the destination address is 180 70 65 140, right.

So, if it is there so, it does at slash 26 because, as you remember so, you on the longest prefix passed right. So, 26, 25, 24, 22 so, first it does a it has 26 applied, the result is 180 70 65 128, you can apply those this type of mask like; that means, 26 1 followed by their zeros and apply to this that the value will get that these values and this does not match with the corresponding address right, then it goes to the next slash 25 and it gives a value of 180 70 65 128 and it matches with the this one, the second entry of the thing.

So, it push it to the m 0 right. It matches with the corresponding and the packet is interface m0 passed to the ARP for further processing. Now, what m 0 interface, in order to go to this m 0, what it has do, you need to find out the hardware address of that particular interface so, it does a ARP resolution, address resolution protocol right. So, at the ARP typically changes a map say, IP address to a hardware address so, if it goes for a ARP request, it returns that what is the hardware address of that particular device, so that packet the frame at the layer 2 level can be forwarded.

So, your so, ARP things will be discussing later so, we need not immediately bother about the ARP. But see, if a packet comes first it follows these things in the in this order right, as we know that the we want the longest prefix match, so, 26, 25; first 26, then 25, 24, 22, if does not match go to this default right.

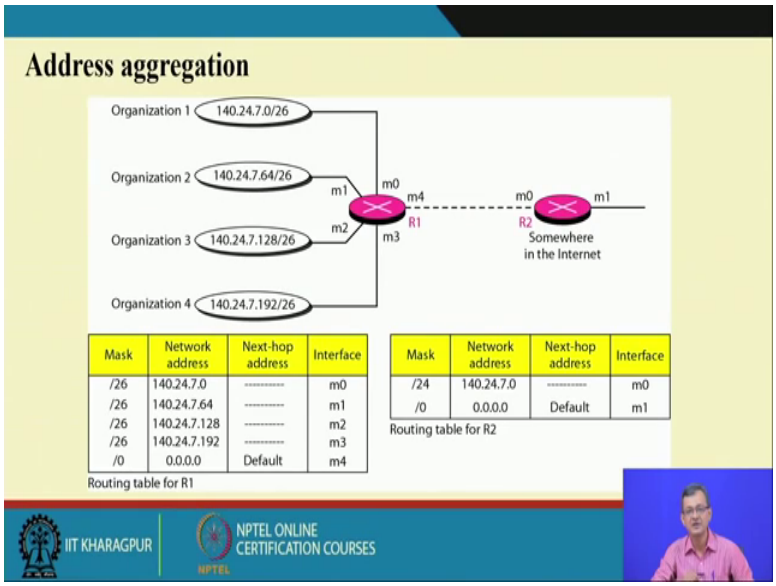
(Refer Slide Time: 27:16)



So, say another example. So the forwarding process if the packet arrives at R1 with 201 dot 4 dot 22 35, again do with a 26, is come up with a result 10 2 1 dot 4 dot 22, it does not match with the corresponding, there is no corresponding this, It then goes for the next slash 25 and does not match with the row next entry, does a third one in the 22 which matches with the corresponding right and then it goes to the this one destination, that it goes to the particular m3 and the at this particular resolution again will be done right.

So, what we see here that given a packet and given this type of net masking and looking at this I can basically forward the packet to the particular, to that particular destination interface and there is a address resolution; that means, I need to know the hardware address to forward the packet of the frame at the layer 2. So for that as, resolution in sequence but, the primary routing reason is taken care by this thing right.

(Refer Slide Time: 28:29)

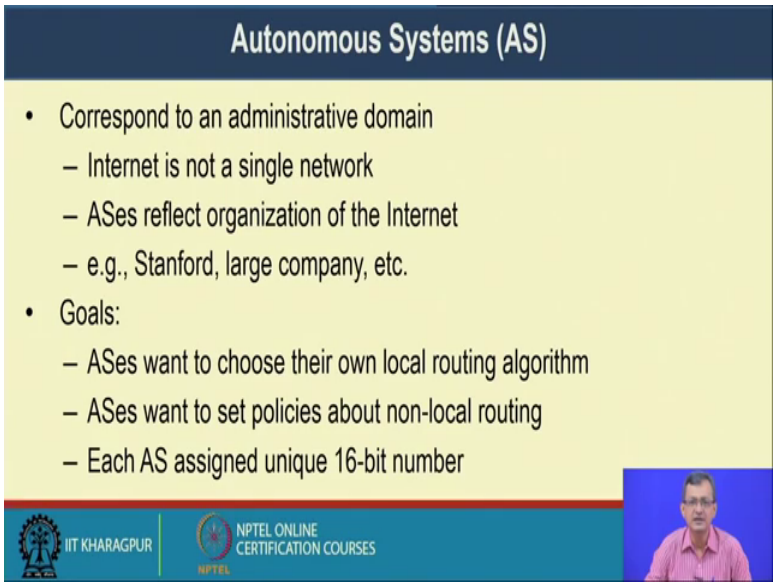


So, what we see there is there may be a need of address aggregation right, like in this case a organization 1, 2, 3, 4 may be taking service of a ISP and have different type of network addresses right. So, I instead of having all those entries I can have a particular network address and then I can have a next hop type of things.

So, I can so, in this particular thing I can have a entry like slash 26 if this network address is this, next hop is m0, m1, m2, m3 and m4. Whereas, in the routing table 2, I identify that all those things as a single network as this as 24 and it push it to the m0. In other sense, for this rest of the word or these routers R2, this is aggregated as the as a single network as with a mask of slash 24, 140 24 7 dot 0 slash 24 and any packet coming with that it will be forwarded to this packet right.

So, this is the way of looking at the things. So, these address aggregations helps us in clubbing these two, all this together for the rest of the so, you see for the entry of the R2 becomes much simplified right. So, if instead of these 4 organization, in 400 organizations such like this things that will be it will be heavy, a huge load on this type of router and the processing time will be much higher because, it need to go to this scanning these things.

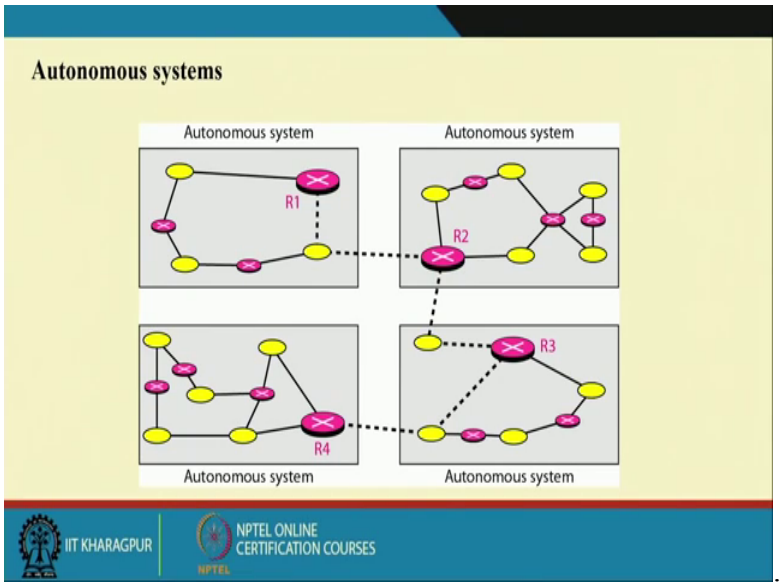
(Refer Slide Time: 30:23)



So, we come as a there is a concept called autonomous systems, like correspond to the administrative domain, internet is not a single network, it is there are several autonomous systems reflect organization network so, there are different autonomous systems which have some authoritative control or the administrative control of the network, like in this case, in your city likes Stanford a large company or IIT Kharagpur and type of things can act as an autonomous system. So, goal is autonomous systems want to choose their own local routing.

So, within the autonomous system the say IIT Kharagpur whatever the internal intra IIT KGP routing will be there it can choose. ASes wants to set up policies about non-local routing so, whatever for the non-local routing, for the external it can set up a policy. Each AS autonomous system is assigned a unique 16-bit number, like this is a scenario of autonomous systems.

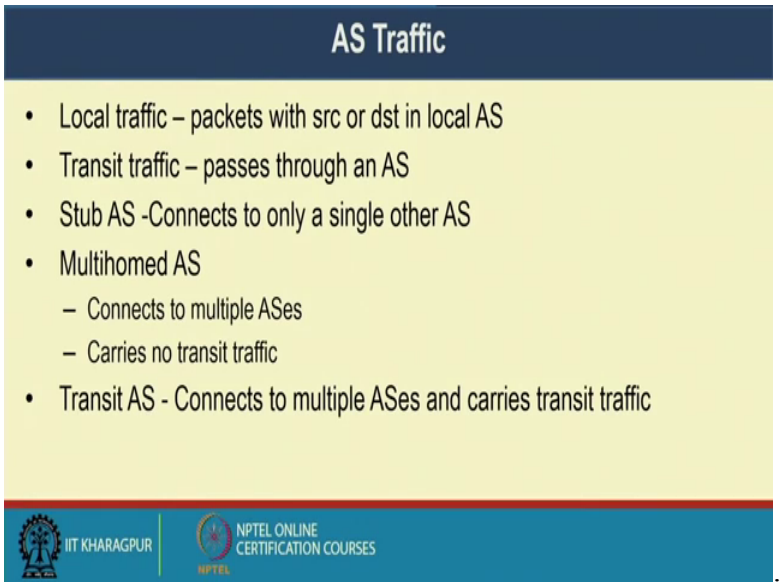
(Refer Slide Time: 31:16)



So, we will be going little bit on the that how these routing structures are there, there are backbone routers and other type of things but, nevertheless these are the different autonomous system, very loosely if you would like to see and these are different networks, they have a bunch of routers and type of things and they can, they have they can communicate between each other.

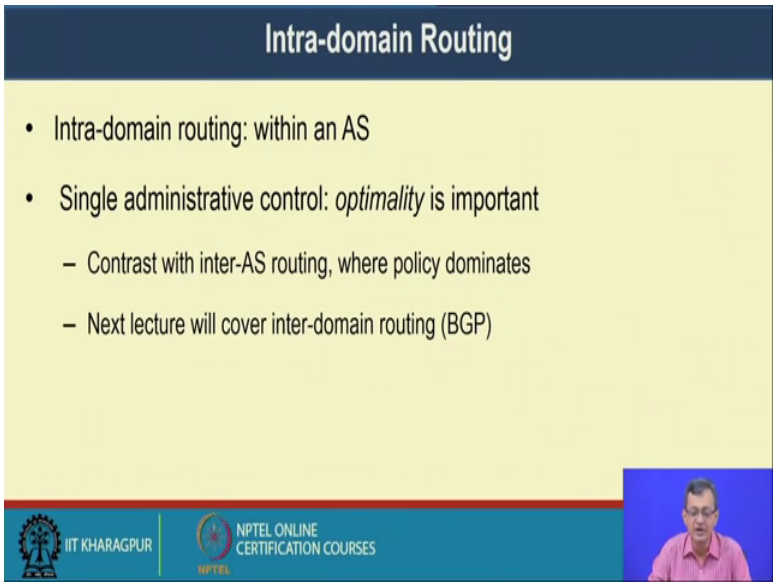
So, more you we say this built in the ASes or what we look at is a some mostly as a policy-based routing, whether within the autonomous system there is the local or intra, the autonomous system individual autonomous system has the authority or total control over the network and decide on the routing.

(Refer Slide Time: 32:02)



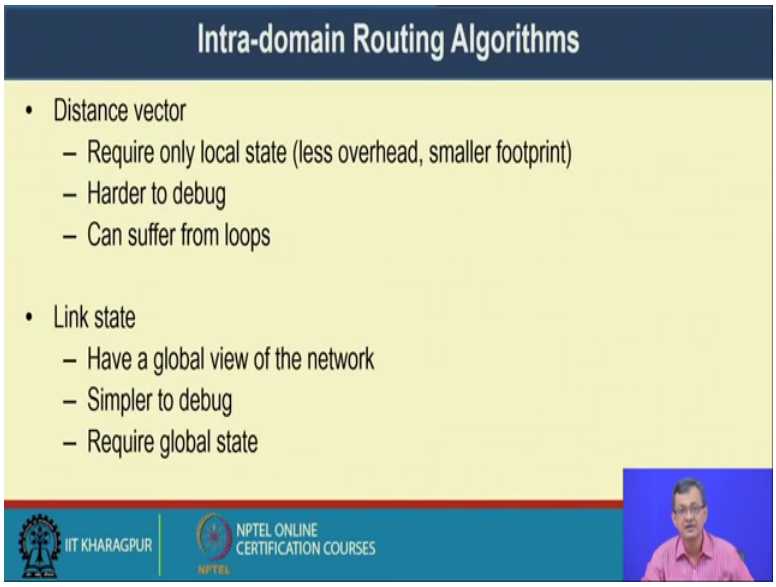
And there are different type of AS traffic, local traffic-packets with source and destination in the local AS, transit traffic passes through the AS, stub AS-connected to one single autonomous systems so, that is the type of stub, a router stub AS. Multihomed AS-connected to multiple autonomous systems, carries no transit traffic right. So, it is connected to the multiple autonomous system and push it to the respective. Transit autonomous system connects to multiple AS and carries transit traffic right. So, that is the multihomed where it is not carrying the transit traffic but, connected to the things and there is a transit AS.

(Refer Slide Time: 32:42)



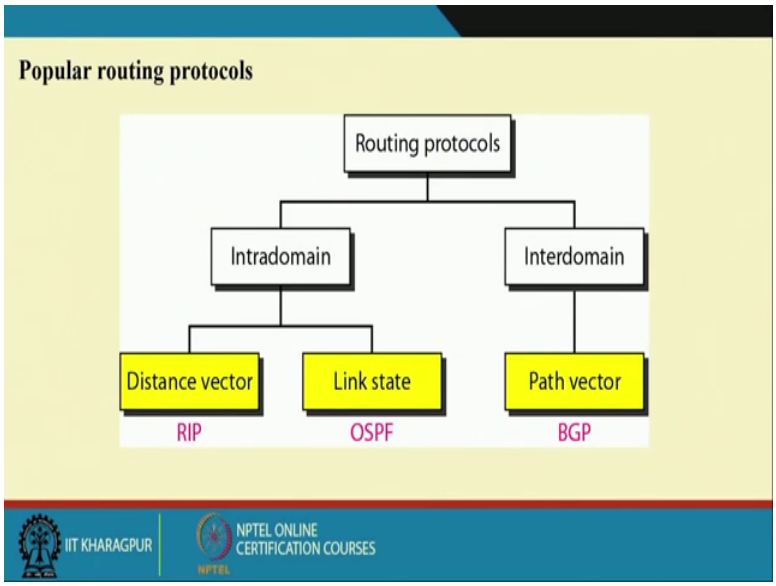
So, finally, we come to that intra domain routing with a, within an AS so, single administrative control: optimality is important, within the thing that optimality is important factor, contrast with inter-AS where policy dominates whereas, we will see that in our next subsequent not in the next lecture, subsequent lecture that inter routing protocol BGP where we will look at that policy-based routing or the inter-AS and predominant intra domain routing algorithms.

(Refer Slide Time: 33:10)



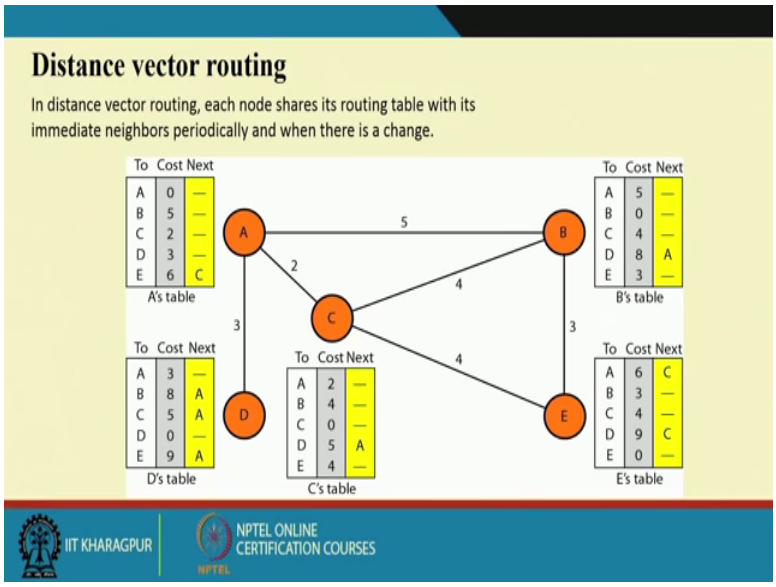
One is distance vector, requires only local state, less overheads, smaller footprint, it is sometimes difficult to debug, can suffer from loops, we will look at it. There is another thing called link state, have a global view of the network. What we are talking about the intra routing, simpler to debug, requires global state, that overall state of the network.

(Refer Slide Time: 33:38)



So, if we look at the routing protocols, so, we have intra domain and inter domain. Intradomain is distance vector and link state, inter domain is path vector, link state is RIP and OSPF and path vector is BGP. We will discuss those things in little later.

(Refer Slide Time: 33:55)

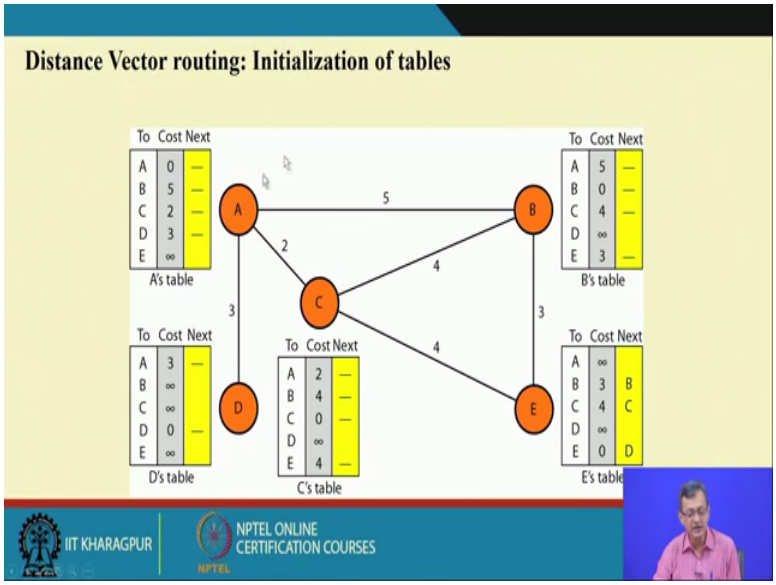


And just to have a view of this distance vector routing, so, every in a distance vector, each node shares its routing table with its immediate neighbor in a periodical in a periodical manner at every time interval say every 30 millisecond or so or based on the things and when there is a change.

So, whenever or and when there is a change, if there is a change it will change or it will go on sharing the things on a in a beaconing the things right and based on the things, other things decides, like if I say A, A has a direct connection to B where 5 is there, A has a connection to C where 2 is there, 3 is there so and so forth right, whereas A do not have any connection to E, where it has go to C via C and like this. So, it goes on updating the thing similarly, so for D, it is a only connected to A, it has different paths to look at the things so, if we want to go to B, it has to go via A and the cost for, to go to D to B the cost is 3 plus 5, 8 right.

So, there can be different type of paths. We will look at that what are the different types nevertheless if you see, every router is having its routing table, that if one on to go to these are these networks where it should fall. There could have been another entry here that is default, if it is something which is not known where it should forward to right.

(Refer Slide Time: 35:31)



So, if we initialize at the initialization at the initial step for A, where nothing is known say A starts up so, for A to A 0, A to 5 because, these are connected but, A to E, A doesn't know where E is so, it is infinity.

So, when gets A, but, it C knows where E is with 4. So, next time it gets the beacon or the miss update from the C, C is router update then, it updates it with the things. How these update process will go on, we will discuss in our subsequent lecture. So, this way it goes on doing that. So, we will be discussing more detail on taking into these inter

domain routing looking at different RIP, OSPF or distance vector and link state routing in our subsequent talk. So, let us stop here and with that basic understanding of what is routing, what are inter domain and inter domain, intra, inter domain routing and in the subsequent lecture we will we will discuss in detail those things.

Thank you.