

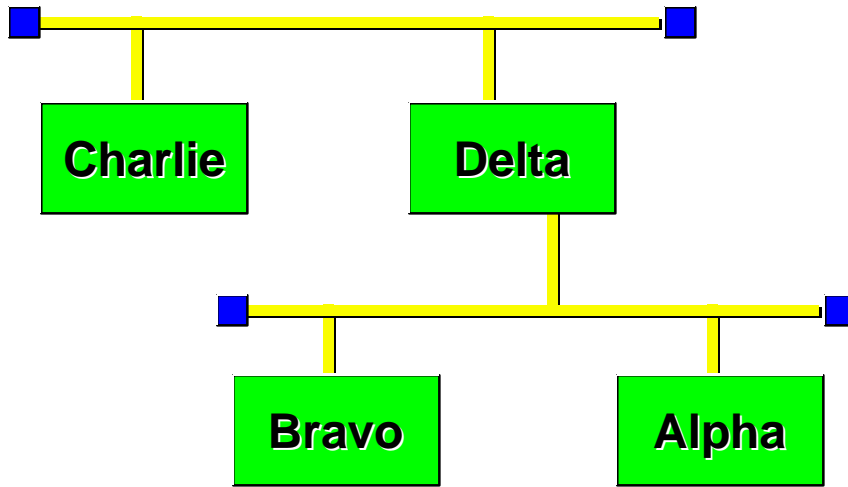
FORE  
SYSTEMS





# The IP Forwarding Process

V1.2: Geoff Bennett



This tutorial describes the steps in forwarding an IP datagram through an IP router.  
Here is a simple internetwork of four routers.  
I'll use this network to illustrate the concepts of the Routing Table.

## ***The Routing Table***

The fundamental data structure used by the router to control datagram forwarding is the Routing Table.




This is a basic Routing Table layout...



Dest. Net	Next Hop	Type	Cost	Status

Here are the column titles I'll be using to explain the basic Routing Table. In real implementations you'll see these, and perhaps several additional columns.



Dest. Net	Next Hop	Type	Cost	Status

The job of the Routing Table is to allow the router to make intelligent forwarding decisions. So logically speaking the first column of the table should contain the IP addresses of the *Network ID* that a particular datagram is trying to reach.

Note that by using the Network ID, rather than specific Host IDs, we can dramatically reduce the size of Routing Tables.



Dest. Net	<b>Next Hop</b>	Type	Cost	Status

If the router finds a match for the Destination Network, then it needs to know what the next hop should be to forward the datagram.



Dest. Net	Next Hop	Type	Cost	Status

The “Type” column indicates how the router has obtained this particular route entry. I’ll describe the different ways that this can happen later in the tutorial.



Dest. Net	Next Hop	Type	Cost	Status

The “Cost” column is used to store the cost of using this route. Different Routing Protocols use different ways to describe the cost of a route, and these are known as *route metrics*.



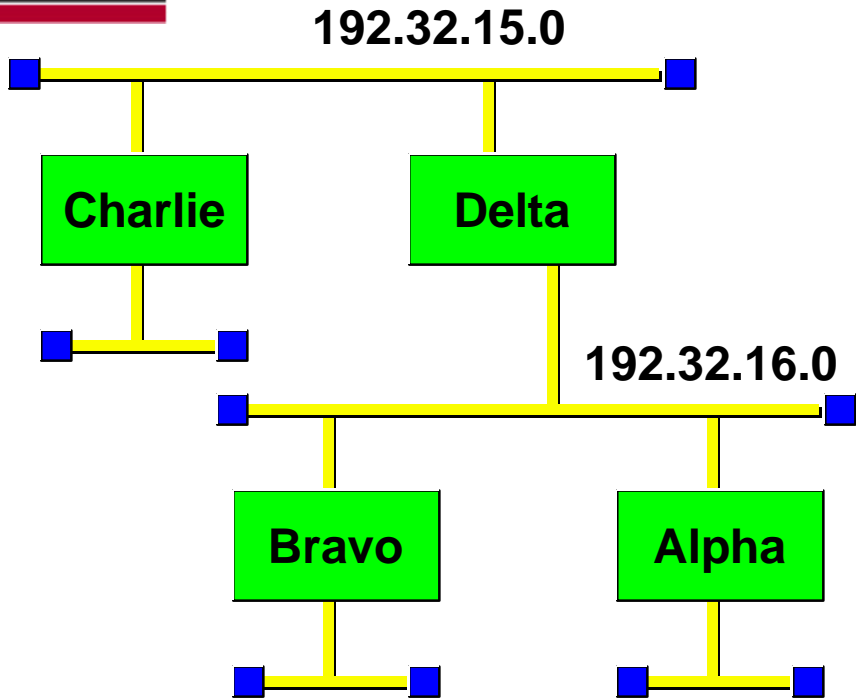
Dest. Net	Next Hop	Type	Cost	Status

The "Status" of a given route entry indicates if the router considers the entry to be working or not. In other words, is this route "up" or "down".

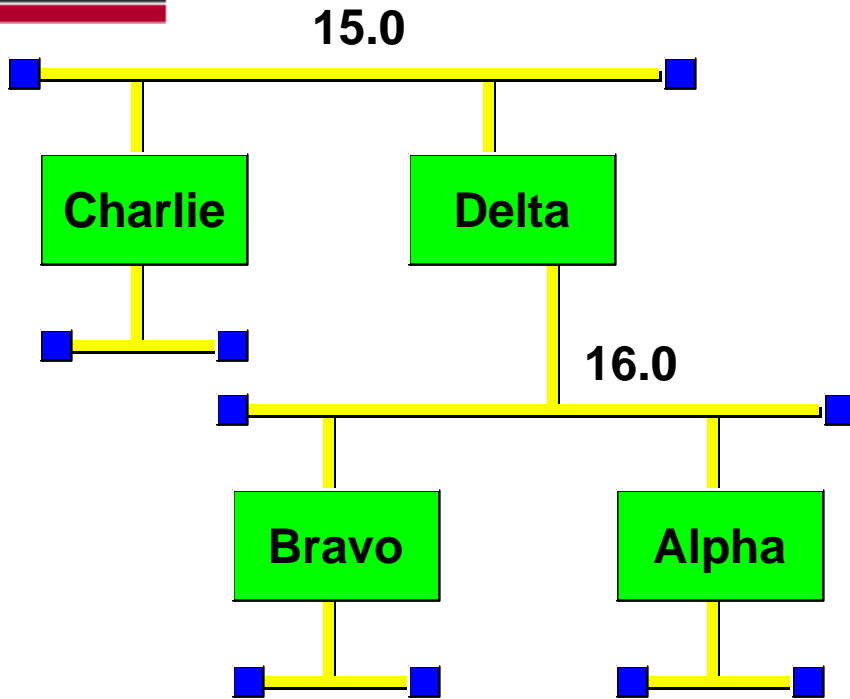


## ***Filling The Table***

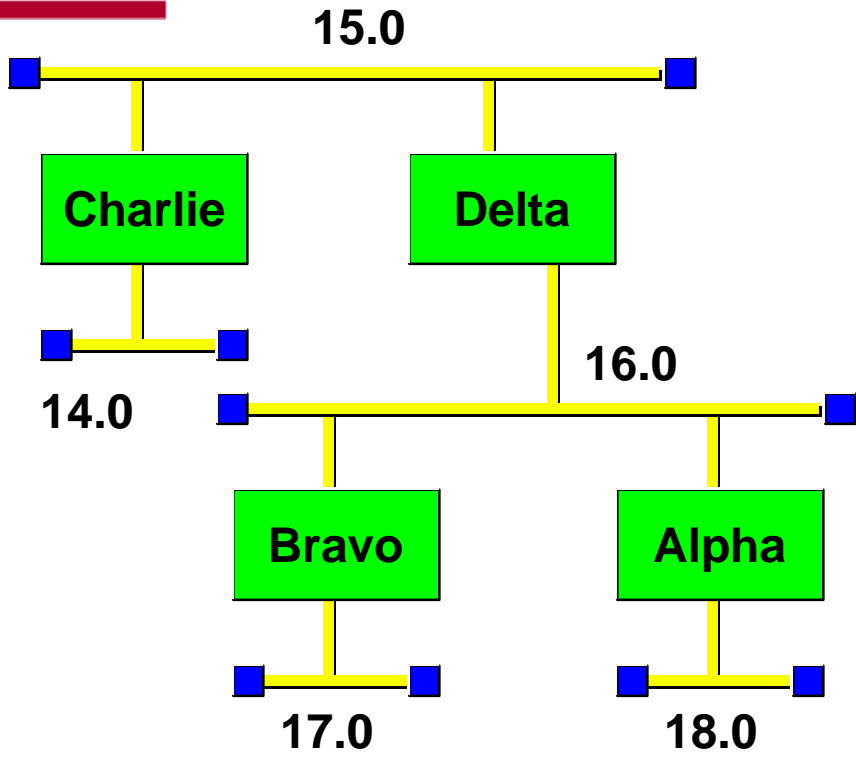
To build up these examples, I need to assign addresses to the sample network...



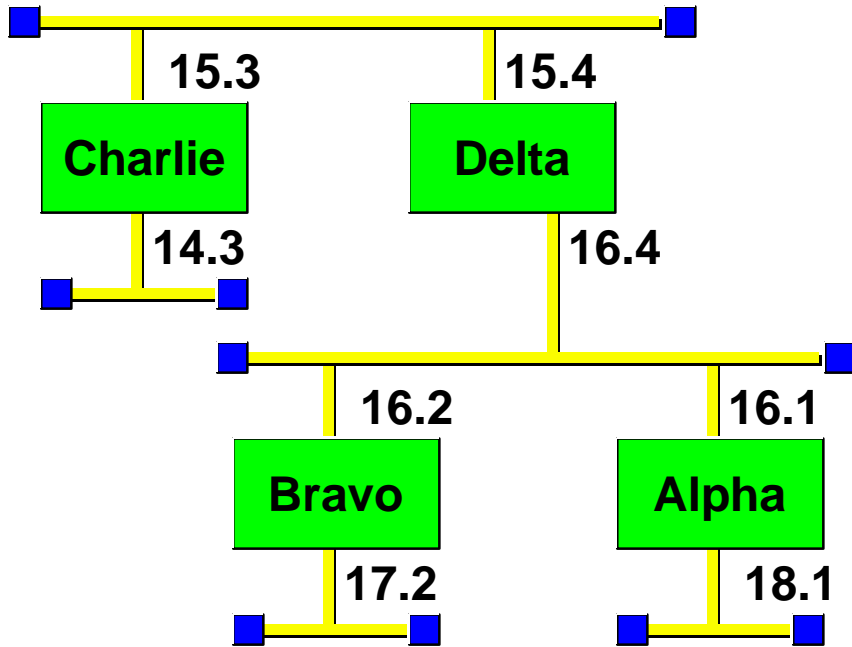
Here are the IP addresses for the two LAN segments in our example.  
But because these are routers, they'll normally have other LAN segments attached...



...to simplify the look of this diagram, let's assume that all of these network segments have the first two bytes numbered as "192.32".



Now I can add these other LAN segments.

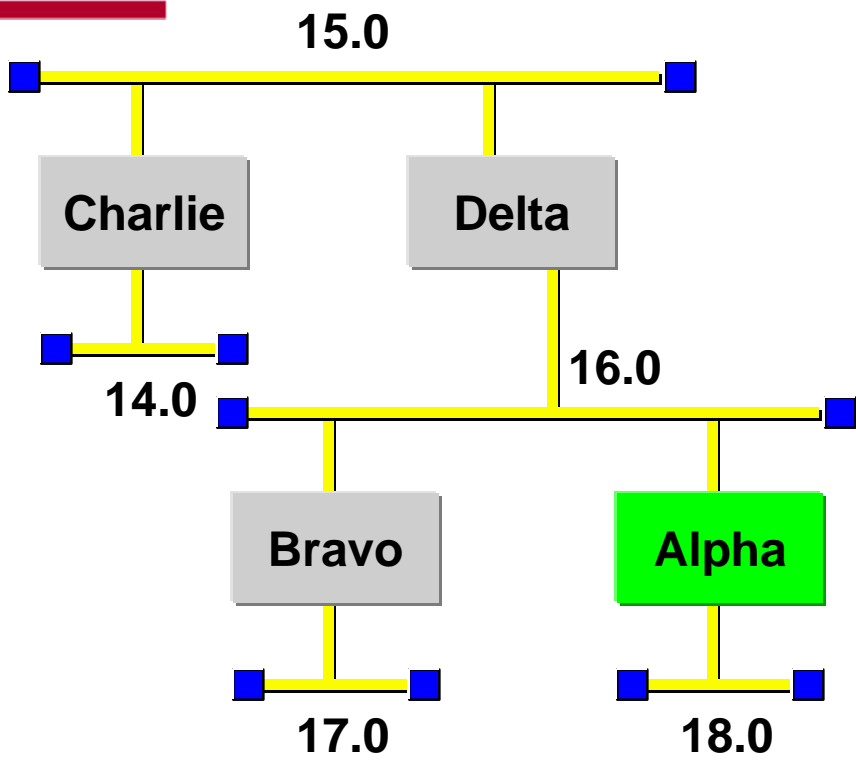


Here are the specific IP addresses of router ports.

Once again, for simplicity all of Alpha's ports will be ".1", Bravo ".2", Charlie ".3" and Delta ".4".

## ***Direct Routes***

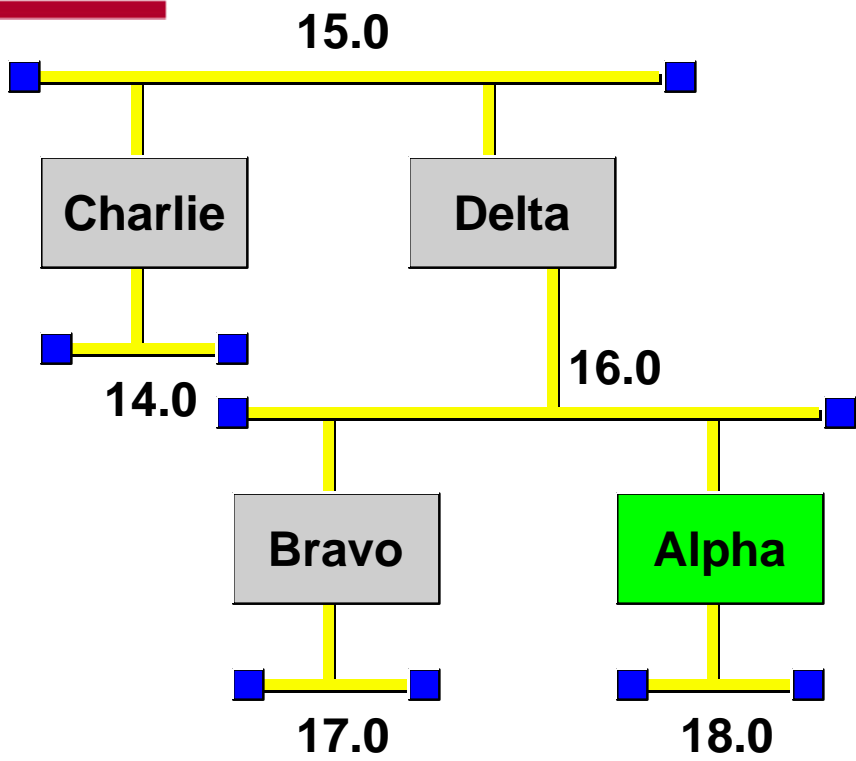
Now I can start to describe the way that routes are added into the Routing Table.  
First of all I'll describe the simplest type of route - Direct Routes.



### Alpha's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.16.0	-	D	1	U
192.32.18.0	-	D	1	U

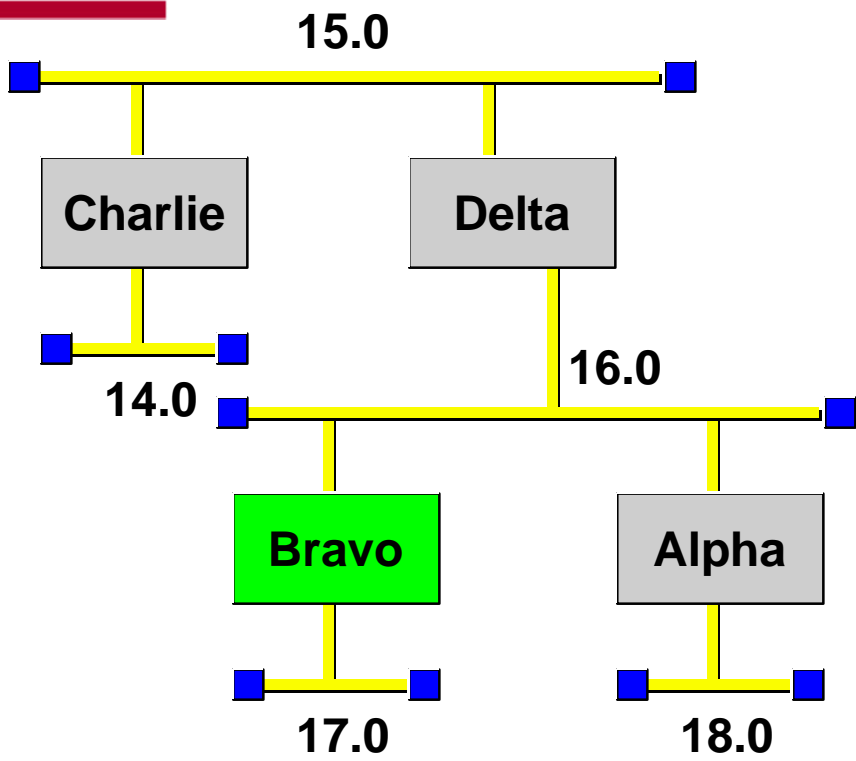
Imagine the view of the network that router Alpha enjoys.  
When we install this router, we need to type in the IP addresses of the LAN ports that are *directly attached* to Alpha.  
These addresses are the *Direct Route* entries for Alpha's Routing Table.



### Alpha's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.16.0	-	D	1	U
192.32.18.0	-	D	1	U

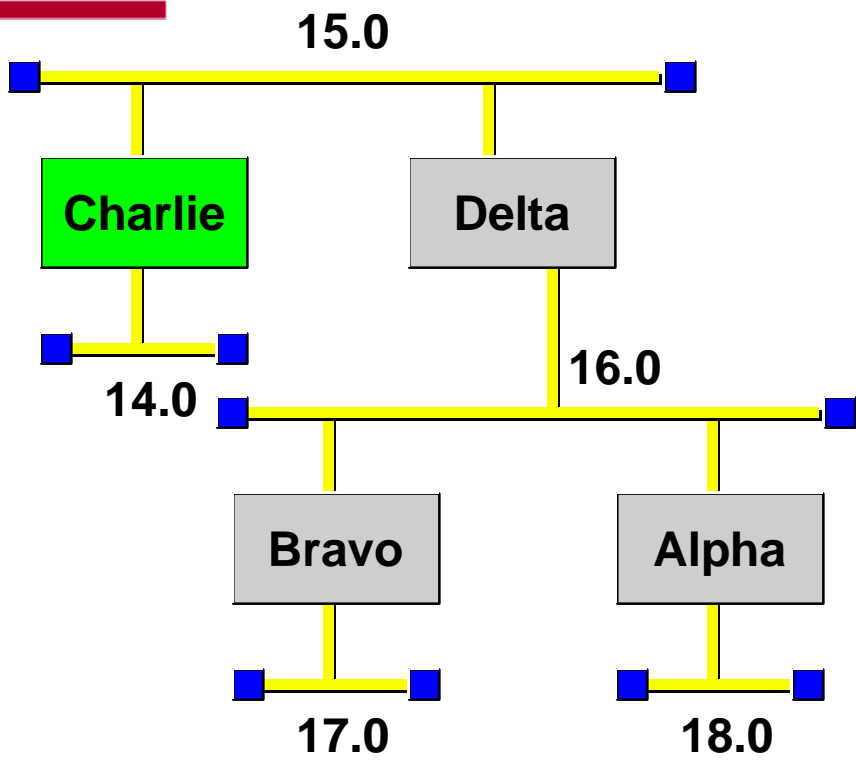
For Direct Routes, there is no "Next Hop" entry because the connections are indicated by an internal pointer (the nature of which varies from one manufacturer to another).  
I have inserted a cost of "1", which is the default value used by RIP.  
The "Status" is "Up".



### Beta's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.16.0	-	D	1	U
192.32.17.0	-	D	1	U

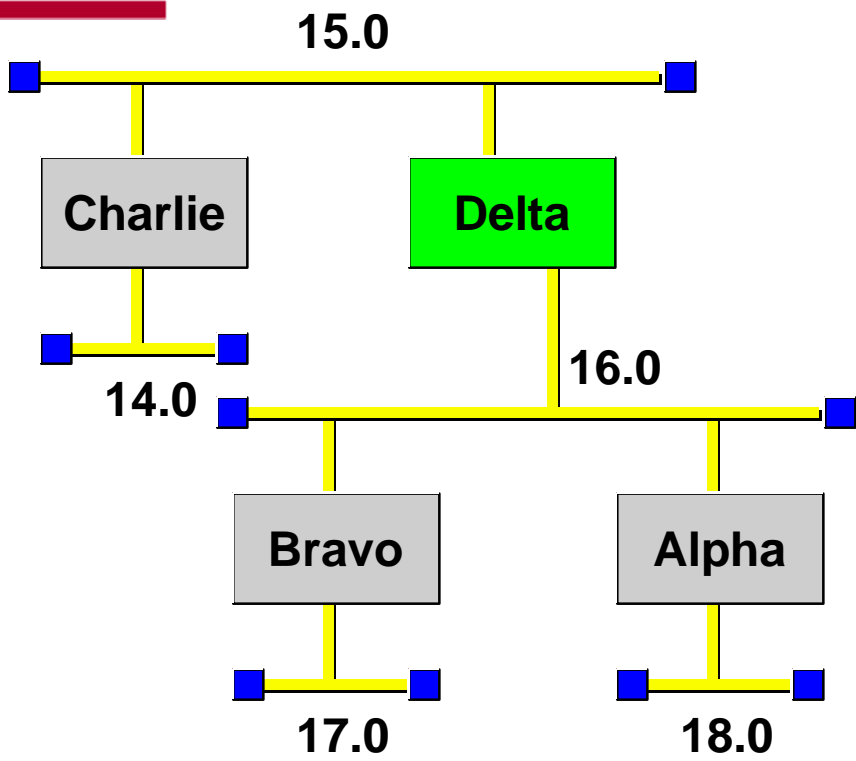
These are the equivalent Direct Routes for Bravo...



### Charlie's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.14.0	-	D	1	U
192.32.15.0	-	D	1	U

...for Charlie...



### Delta's Routing Table

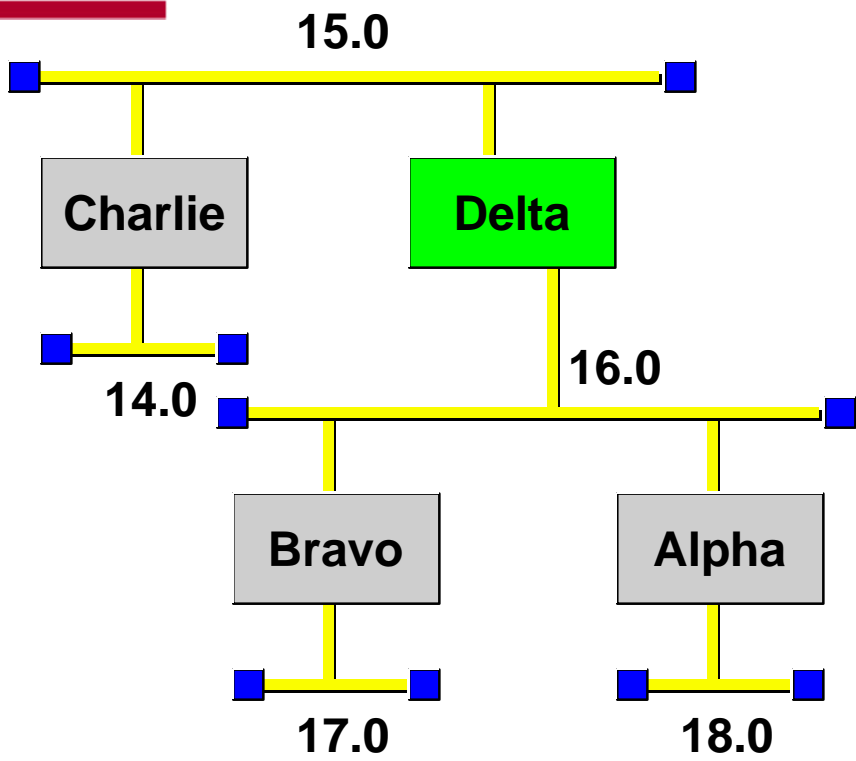
Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U

...and for Delta.



## ***Static Routes***

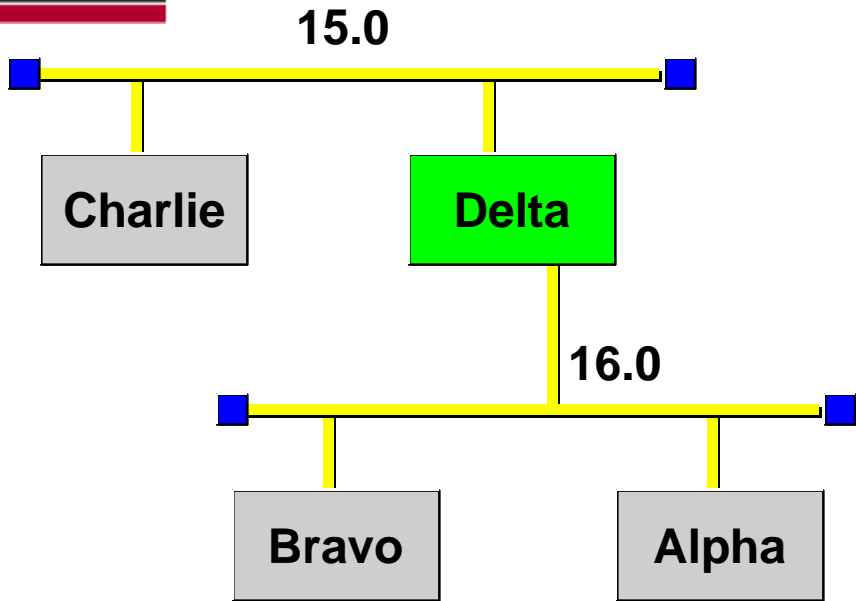
The next type of route entry I'd like to describe are Static, or manually-configured routes.



### Delta's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U

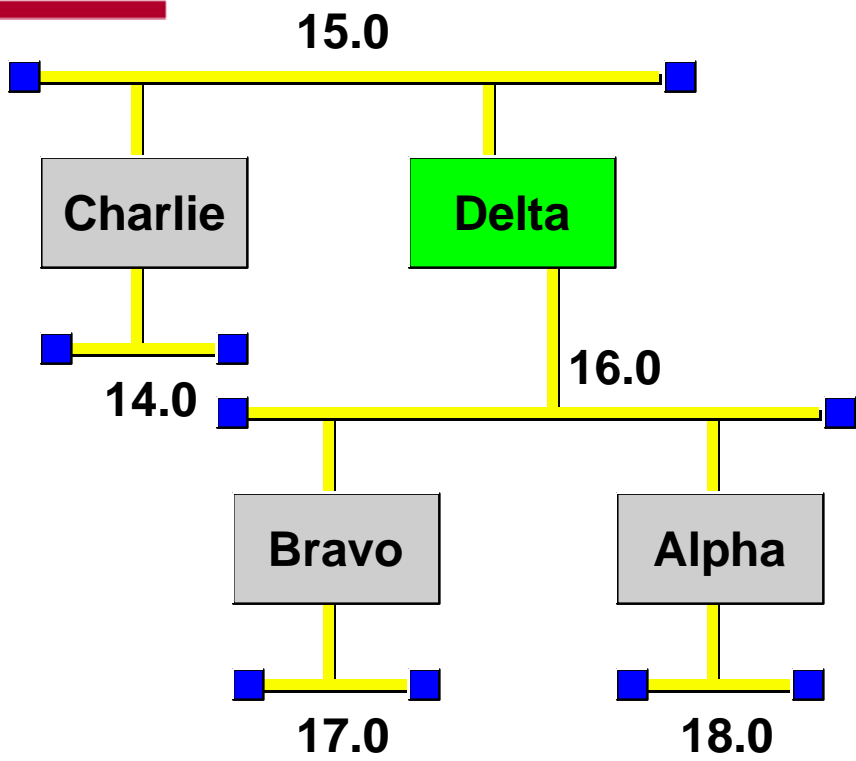
Let's stay with Delta's view of the network for a moment.  
Delta knows where networks 15.0 and 16.0 are...



### Delta's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U

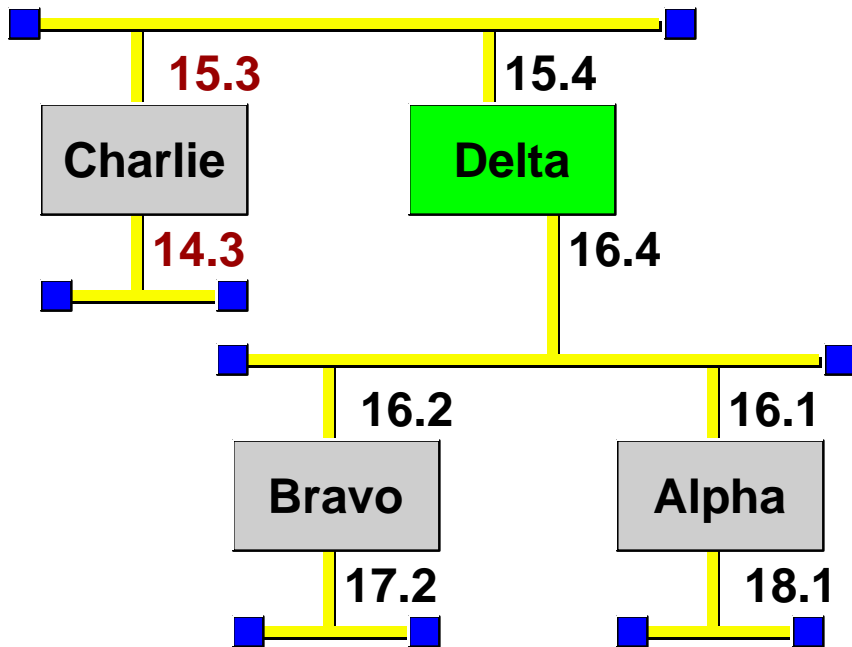
Let's stay with Delta's view of the network for a moment.  
Delta knows where networks 15.0 and 16.0 are...  
...but networks 14.0, 17.0 and 18.0 are effectively invisible, because they are not directly attached.



**Delta's Routing Table**

Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U

One way that we tell Delta about these networks is simply enter them manually into the Routing Table. This kind of entry is called a *Static Route*.



**Delta's Routing Table**

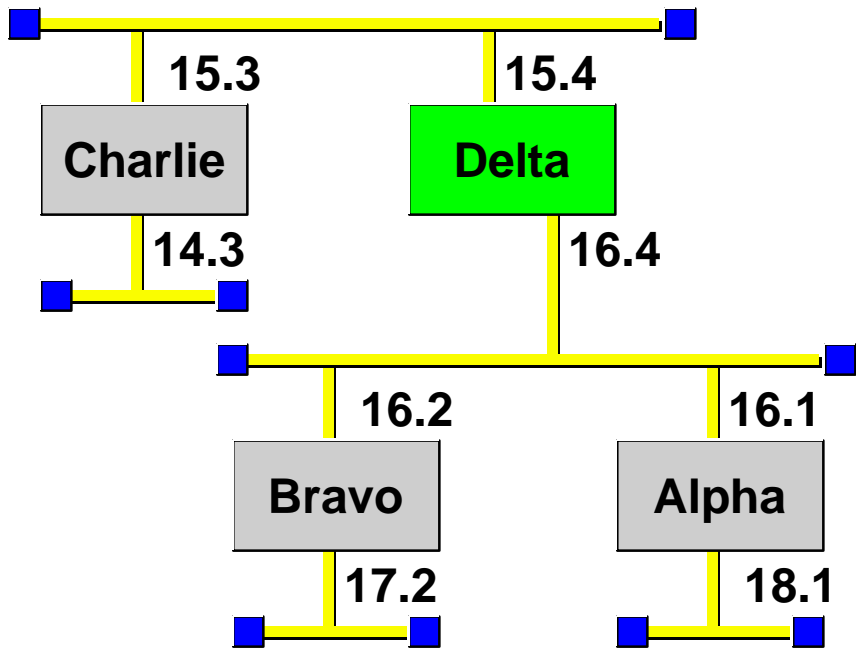
Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U
192.32.14.0	192.32.15.3	S	2	U

Here is the Static Route entry to allow Delta to reach network 14.0.

In the "Next Hop" column, we must insert the IP address of the next router in the direction of 14.1.

This IP address *must* be on a *directly attached* network - in this case it is port 15.3 on Charlie.

Notice the "Cost" entry is 2. This indicates that two routers (including Delta) must be crossed to get to the Destination Network.



### Delta's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U
192.32.14.0	192.32.15.3	S	2	U
192.32.17.0	192.32.16.2	S	2	U
192.32.18.0	192.32.16.1	S	2	U

Here is the complete Routing Table for Delta, showing Static Routes to networks 14.0, 17.0 and 18.0.

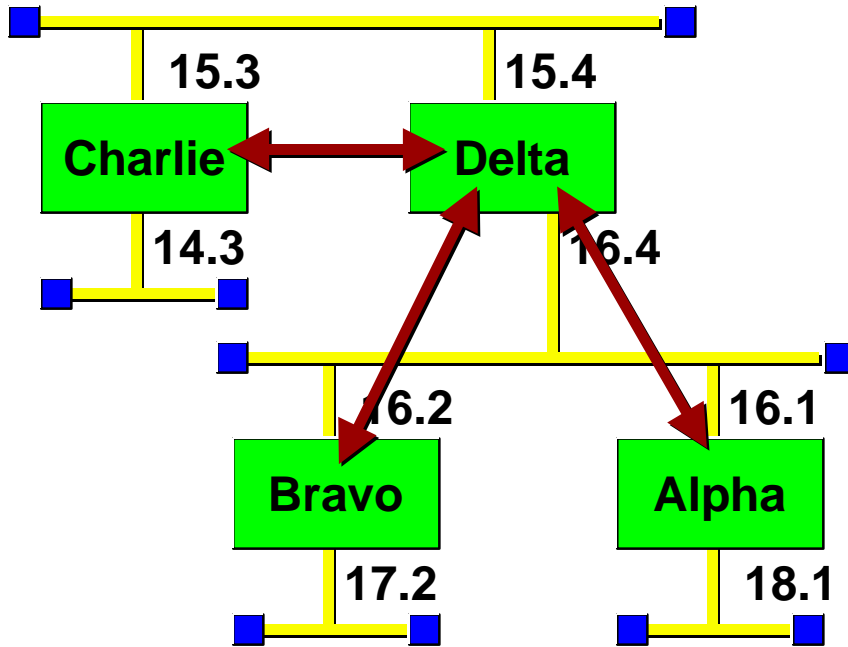
## *Dynamic Routes*

Early router networks were built using Direct and Static routes. However, this approach becomes difficult to maintain as the size of the networks increases.

A major advance in router operations came with the introduction of Routing Protocols.

Routing protocols allow the topology of the network to be discovered automatically. In addition, if the topology changes, then Routing Protocols will discover the new topology.

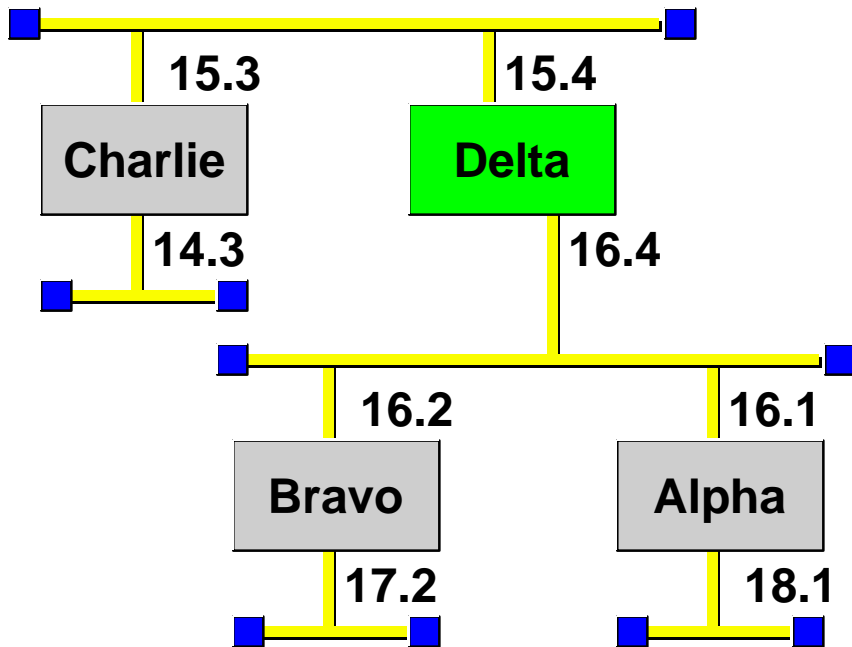
For this reason, the routes discovered in this way are called *Dynamic Routes*.



Routing protocols operate between routers, and not between hosts and routers.

In effect, routing protocols simply advertise the Direct Routes of each router.

As the information from routing protocols spreads around the network, all the routers will discover routes to all the networks.



### Delta's Routing Table

Dest Net	Next Hop	Type	Cost	Stat
192.32.15.0	-	D	1	U
192.32.16.0	-	D	1	U
192.32.14.0	192.32.15.3	RIP	2	U
192.32.17.0	192.32.16.2	RIP	2	U
192.32.18.0	192.32.16.1	RIP	2	U

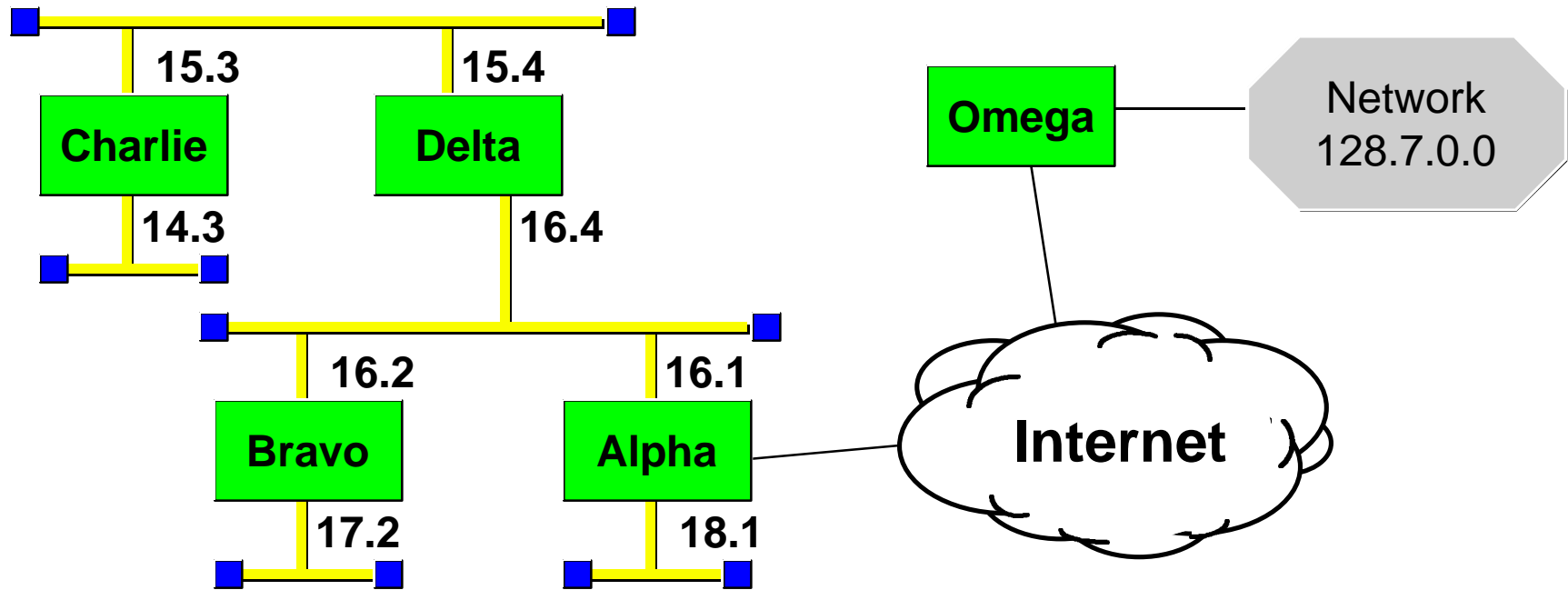
In this case, for example, we have not used Static Routes in Delta at all.

As the "Type" entries indicate, we have discovered the routes automatically - in this case using the *Routing Information Protocol* (RIP).

## *Default Routes*

The final type of route I'd like to discuss is the *Default Route*.

As the name suggests, a Default Route is the place that an IP datagram should send traffic if it doesn't know *specifically* where to send it (ie. from Direct, Static or Dynamic routes).

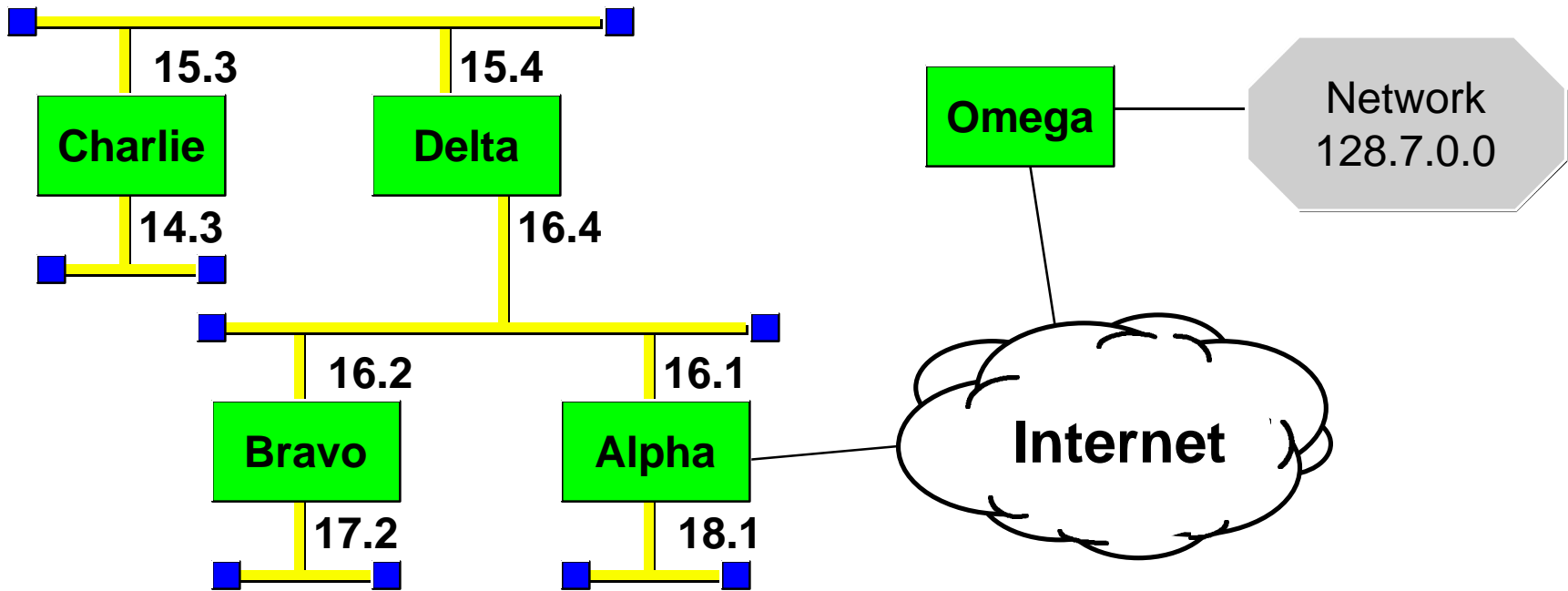


Alpha is the router providing our connection into the Internet.

The Internet consists of millions of hosts on tens of thousands of networks.

Do we expect all of our routers to have knowledge of all of the networks?

The answer is “no”, of course, but we still need a simple way for messages that are addressed outside of our own network to be delivered.



One of these mechanisms is the Default Router.

In this case, we would simply see Alpha as the Default Router.

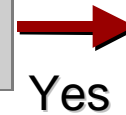
Table entries in Bravo, Charlie and Delta would point to Alpha for any traffic that they don't already know how to route.

Default Routes appear in Routing Tables as address "0.0.0.0".

## ***The Forwarding Procedure***

Given that we now have a range of mechanisms to enter routing information into the Routing Table, what is the sequence used to use these entries?

Does the Address  $A_D$  appear as a Direct Route?

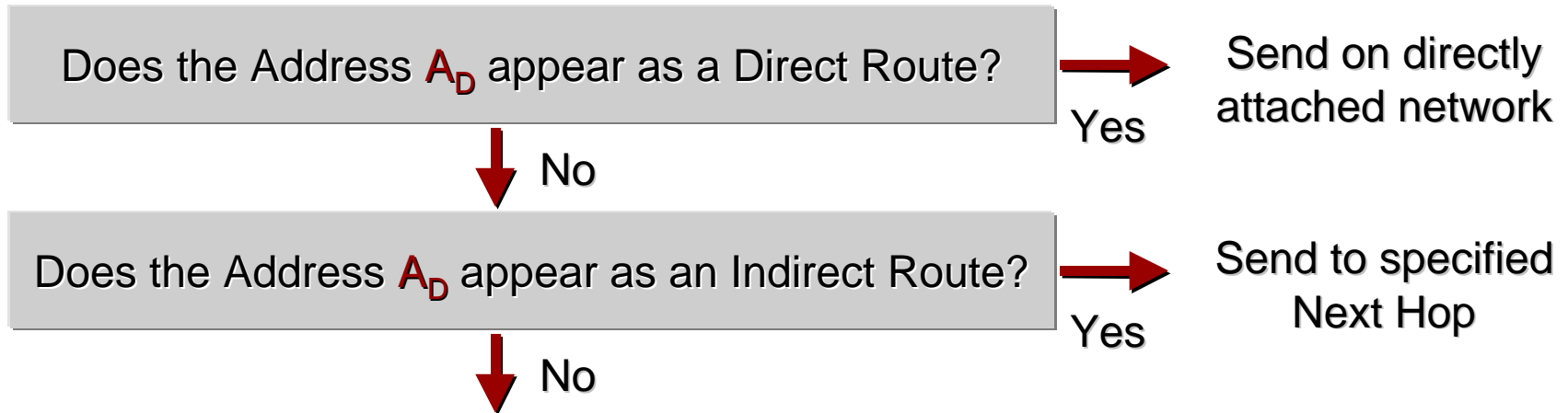


Send on directly  
attached network



When a datagram with destination address  $A_D$  is first received, the router will check to see if the destination IP address is on a directly attached network.

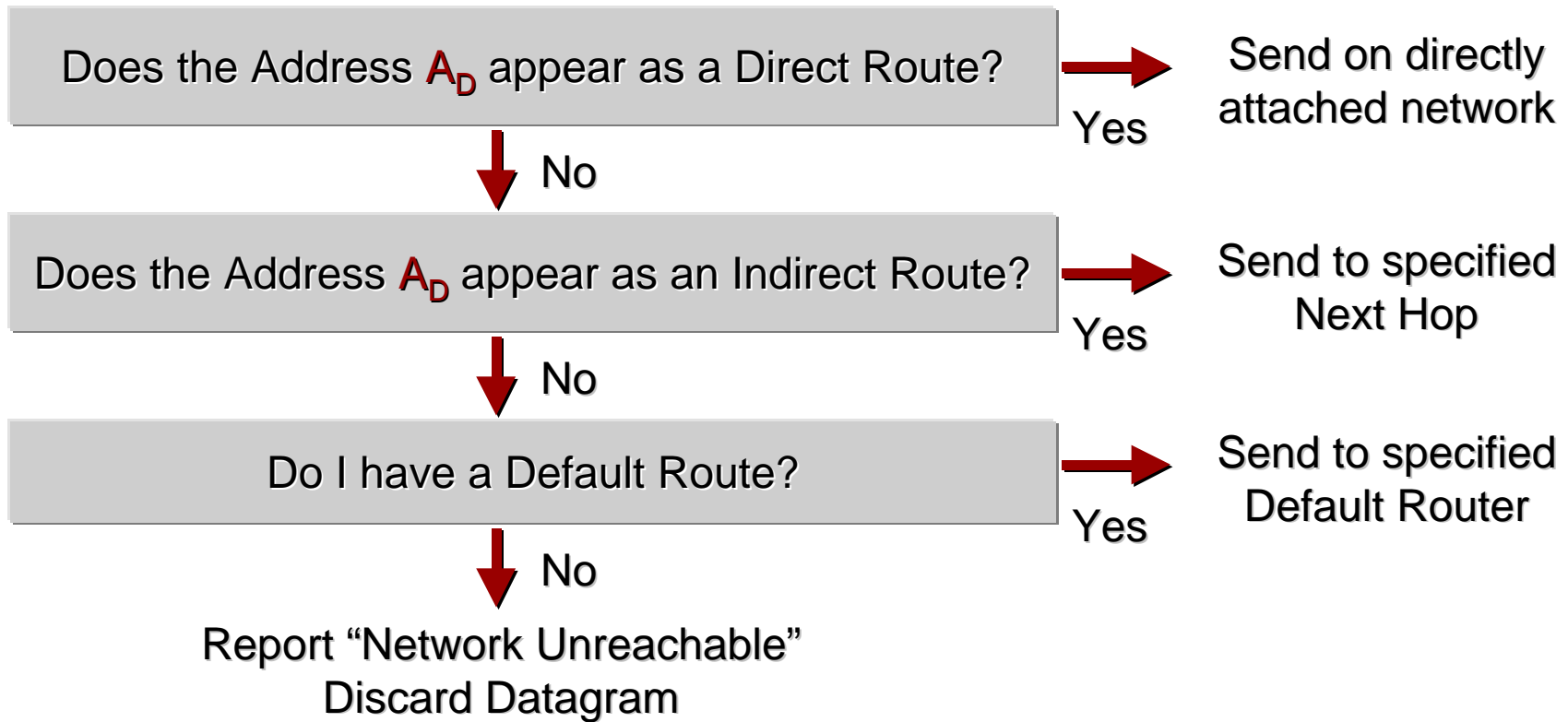
If it is, then the router will use ARP (or a statically configured address resolution) to send the datagram on the directly attached network.



If the route is not direct, the router checks for the *lowest cost* indirect route.

If an indirect route exists, the router forwards the datagram to the IP address specified in the Next Hop field of the Routing Table.

Remember that the Next Hop *must* be on a directly-attached network.



If no specific route is available, the router will check to see if a Default Route is configured.

If there is a Default, then the datagram will be sent to the specified router.

If there is no default, the router will generate an ICMP "Network Unreachable" error that will be transmitted back to the Source IP address on the datagram.

The datagram will then be discarded.



***The End***

This concludes the tutorial.

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