Network Layer: Delivery, Forwarding, and Routing
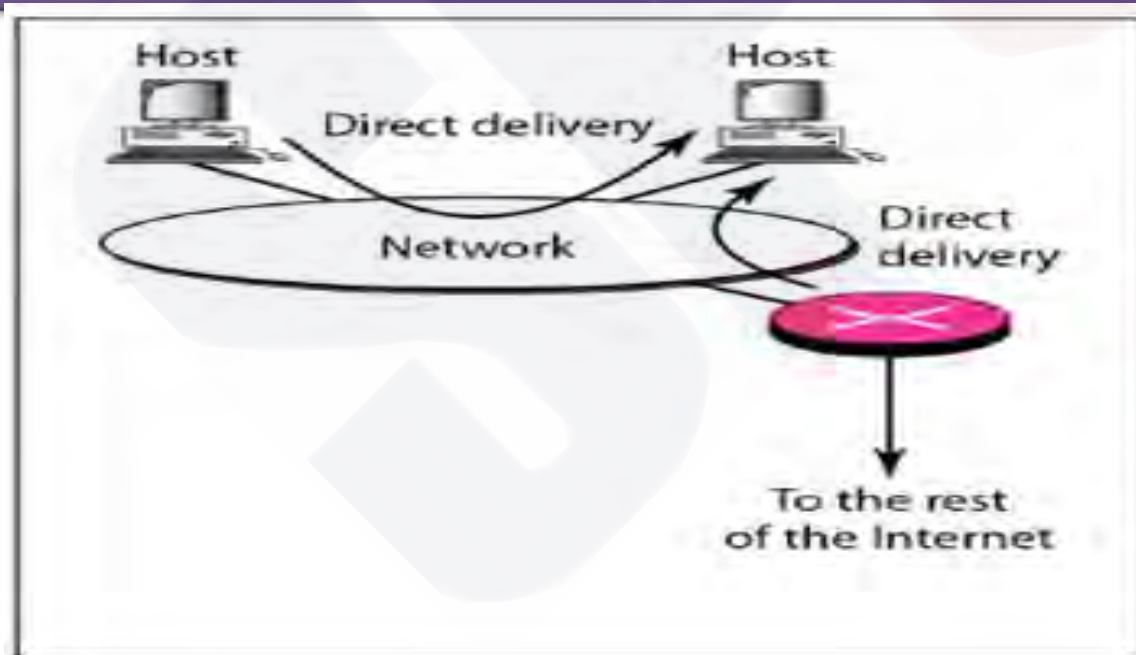
DELIVERY

- *The network layer supervises the handling of the packets by the underlying physical networks.*

- *We define this handling as the delivery of a packet.*

Direct Versus Indirect Delivery

The delivery of a packet to its final destination is accomplished by using two different methods of delivery, **direct and indirect**.

Direct Delivery

Direct delivery occurs when the source and the destination of the packet are located on the same physical network or when the delivery is between the last router and the destination host.

Indirect Delivery

If the destination host is not on the same network as the deliverer, the packet is delivered indirectly.
In an indirect delivery, the packet goes from router to router until it reaches the one connected to the same physical network as its final destination.
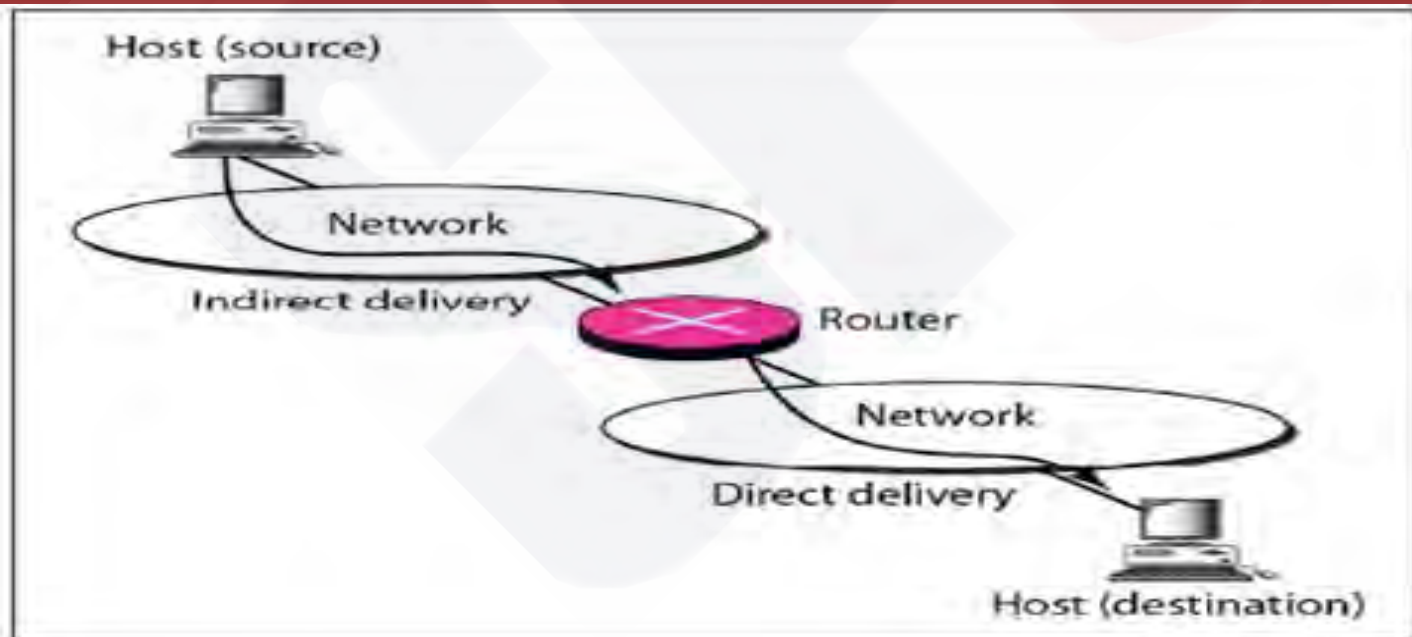
FORWARDING

Forwarding means to place the packet in its route to its destination.

Forwarding requires a host or a router to have a routing table.

When a host has a packet to send or when a router has received a packet to be forwarded, it looks at this table to find the route to the final destination.

Forwarding Techniques

❑Next-Hop method versus Route Method

❑Network-specific Method versus Host-specific Method

❑Default Method

Route method versus next-hop method

Host A

Host B

R1

R2

Network — R1 — Network — R2 — Network

a. Routing tables based on route

Destination	Route
Host B	R1, R2, host B

Routing table for host A

Destination	Next hop
Host B	R1

b. Routing tables based on next hop

Destination	Route
Host B	R2, host B

Routing table for R1

Destination	Next hop
Host B	R2

Destination	Route
Host B	Host B

Routing table for R2

Destination	Next hop
Host B	—

One technique to reduce the contents of routing table is called **next-hop method**

In this technique, the routing table holds only the address of the next hop instead of information about the complete route (route method).

The entries of a routing table must be consistent with one another.

Host-specific versus network-specific method

Routing table for host S based on host-specific method

Destination	Next hop
A	R1
B	R1
C	R1
D	R1

Routing table for host S based on network-specific method

| Destination	Next hop
N2	R1

Here, instead of having an entry destination host connected to the same physical network (host-specific method), we have only one entry that defines the address of the destination network itself.

In other words, we treat all hosts connected to the same network as one single entity.
 For example, if 1000 host are attached to the same network, only one entry exist in the routing table instead of 1000.
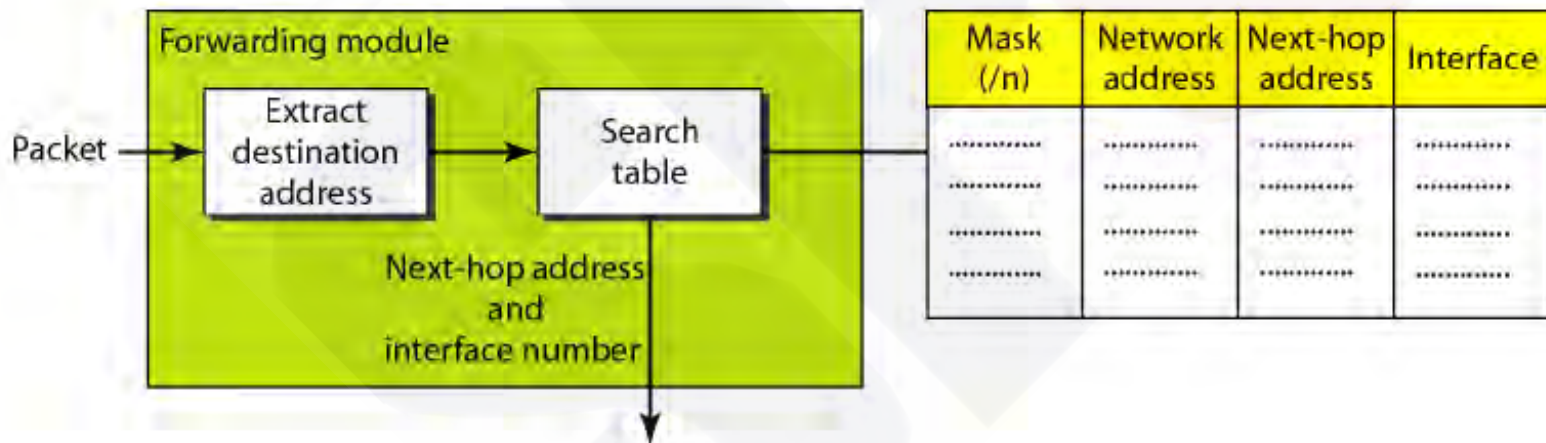
Default method

Destination	Next hop
N2	R1
Any other	R2

Routing table for host A

Host A

N1

R1

N2

Default router — R2

Rest of the Internet
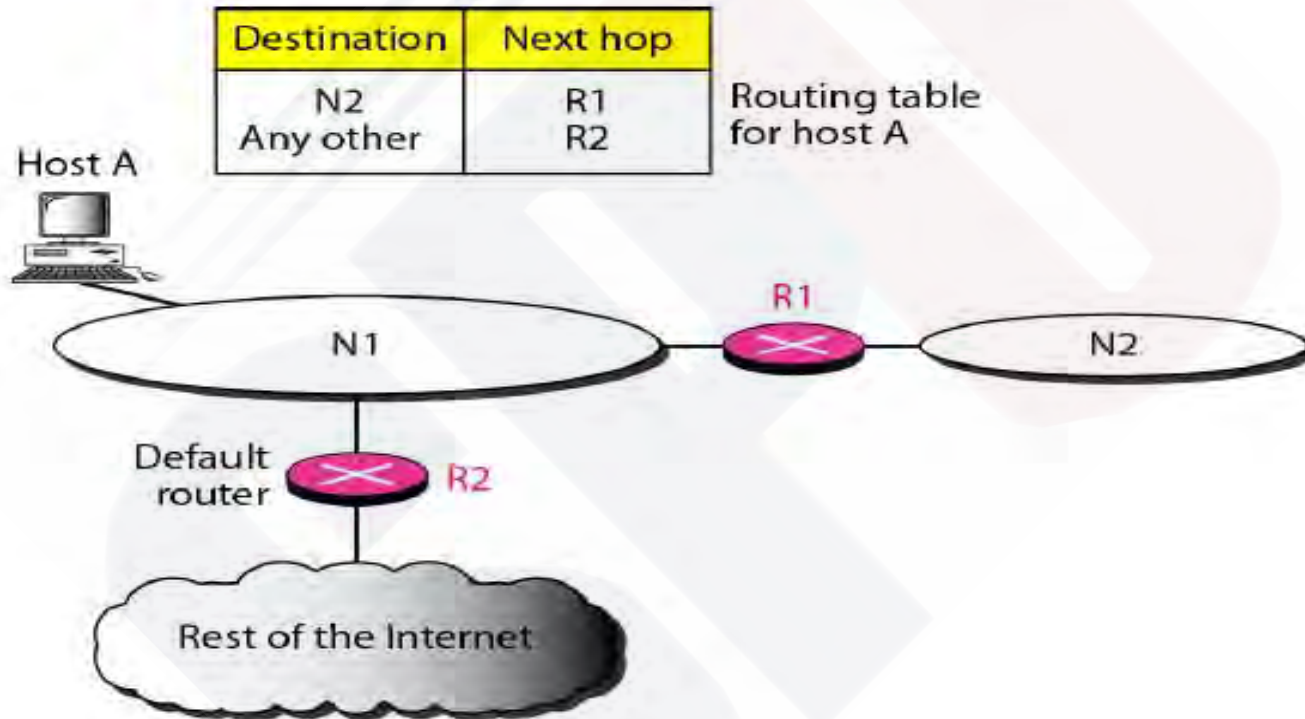
Forwarding Process

Let us assume that hosts and routers use classless addressing.
In classless addressing, the routing table needs to have one row of information for each block involved.
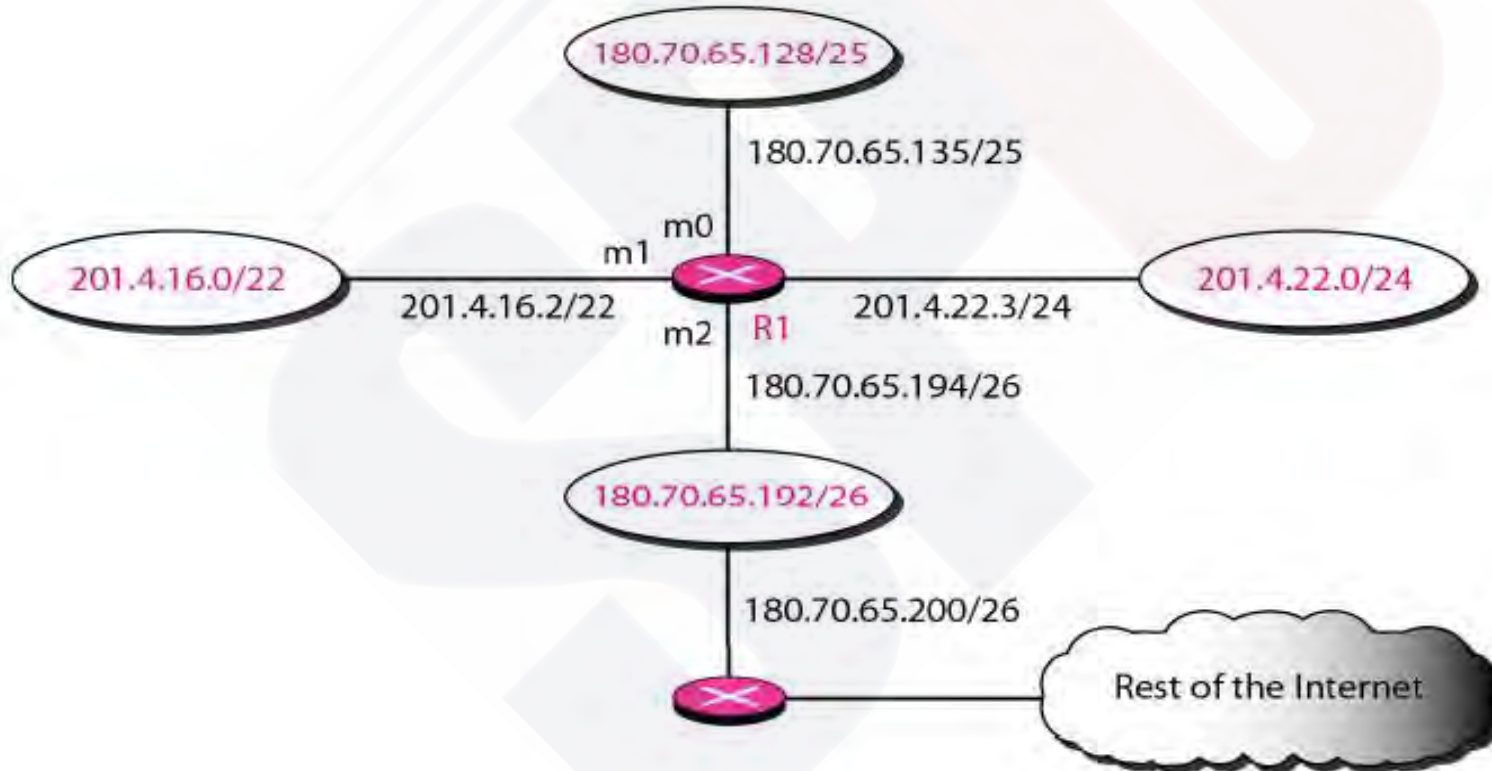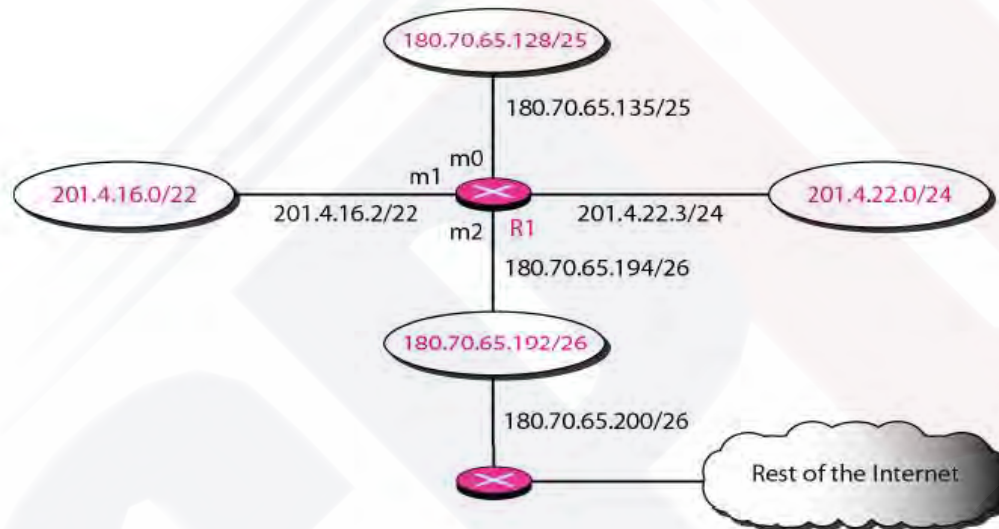

Note

In classless addressing, we need at least four columns in a routing table.

Example 1

Make a routing table for router R1, using the configuration in the Figure

Solution

Mask	Network Address	Next Hop	Interface
/26	180.70.65.192	—	m2
/25	180.70.65.128	—	m0
/24	201.4.22.0	—	m3
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

Example2

Show the forwarding process if a packet arrives at R1 in Figure with the destination address 180.70.65.140.
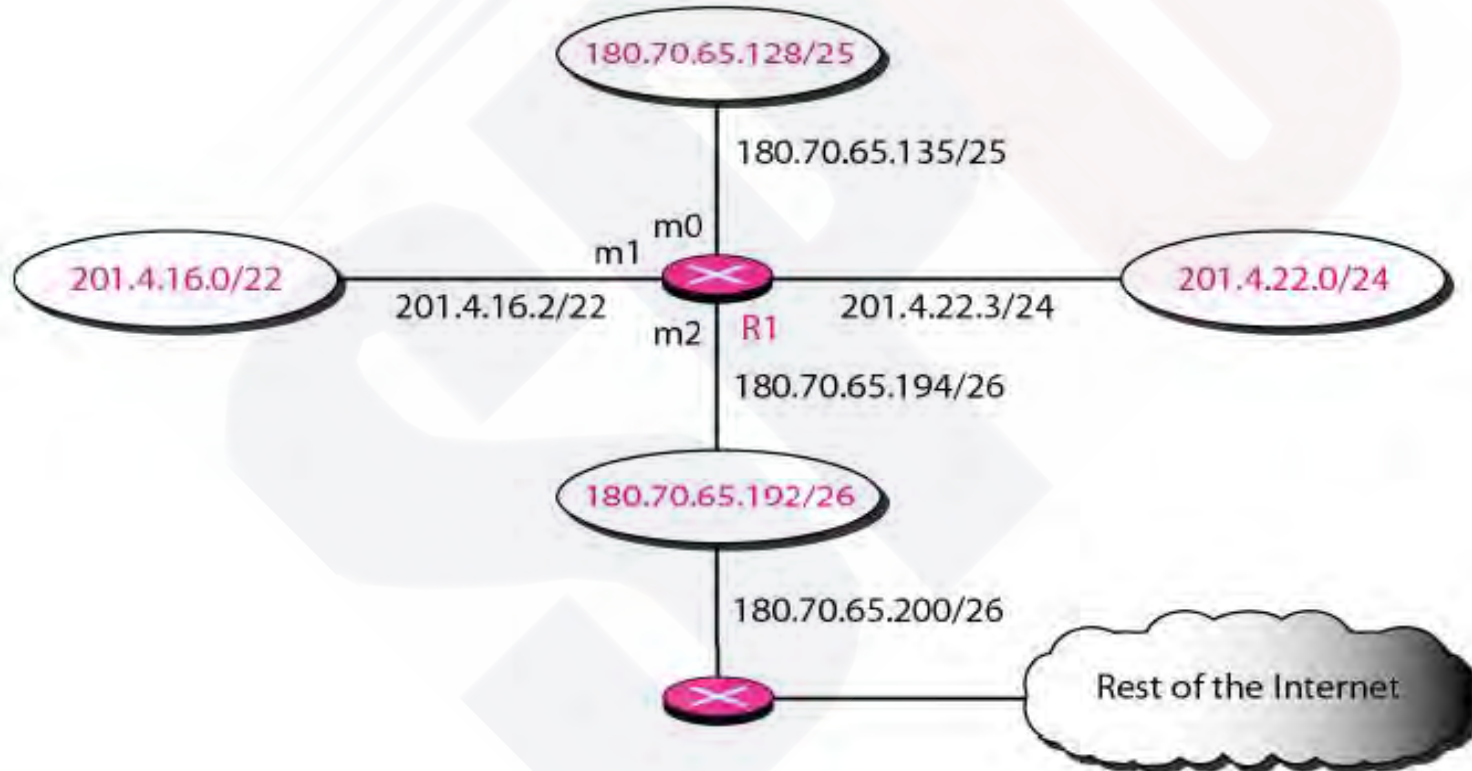
Solution

The router performs the following steps:

First step

The first mask (/26) is applied to the destination address.
The result is 180.70.65.128, which does not match the corresponding network address.

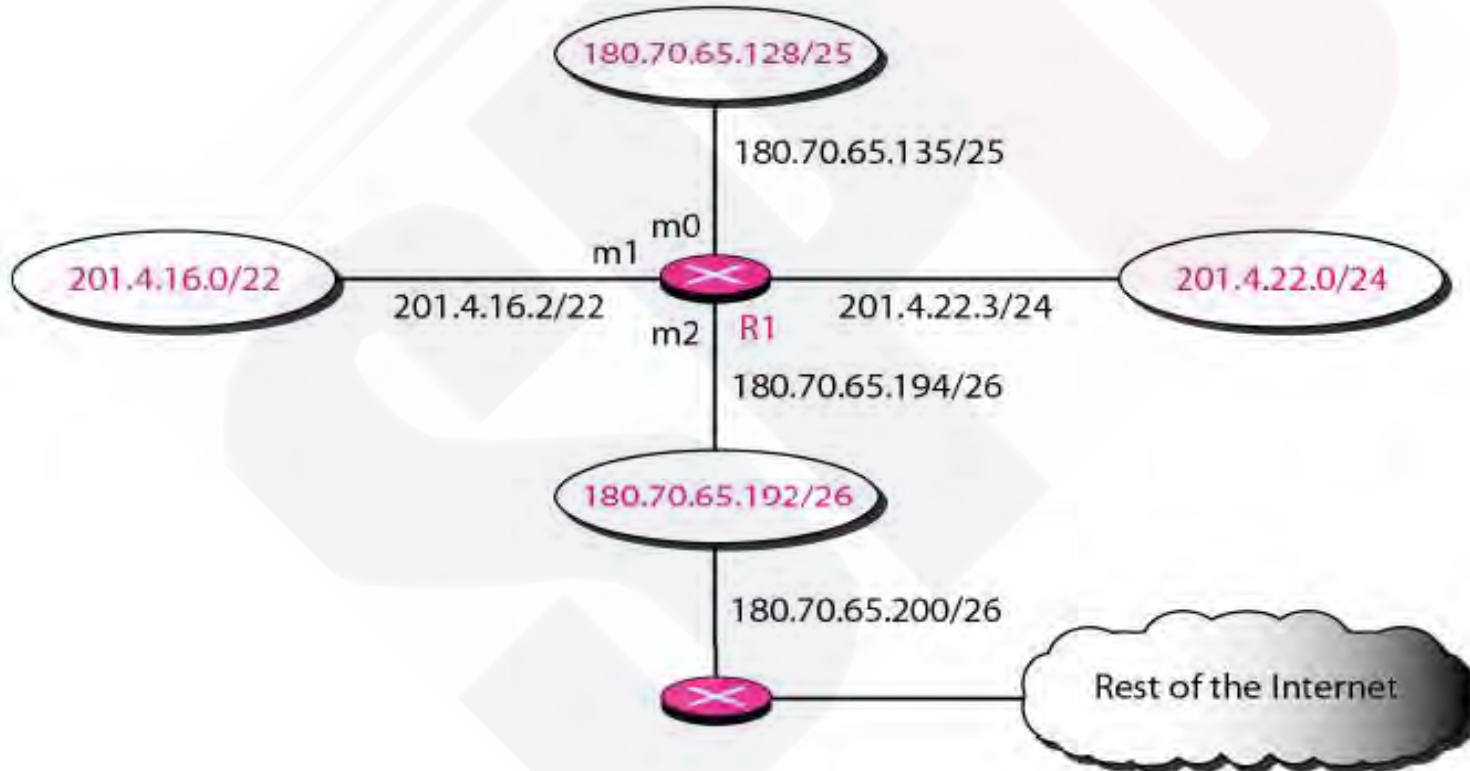| Mask	Network Address	Next Hop	Interface
/26	180.70.65.192	—	m2
/25	180.70.65.128	—	m0
/24	201.4.22.0	—	m3
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

Second step

The second mask (/25) is applied to the destination address.

The result is 180.70.65.128, which matches the corresponding network address.

The next-hop address and the interface number m0 are passed to ARP for further processing

Example3

Show the forwarding process if a packet arrives at R1 in Figure with the destination address 201.4.22.35.

The router performs the following steps:

First step

The first mask (/26) is applied to the destination address.
The result is 201.4.22.0, which does not match the corresponding network address.

Mask	Network Address	Next Hop	Interface
/26	180.70.65.192	—	m2
/25	180.70.65.128	—	m0
/24	201.4.22.0	—	m3
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

Second step

The second mask (/25) is applied to the destination address.

The result is 201.4.22.0, which does not match the corresponding network address.
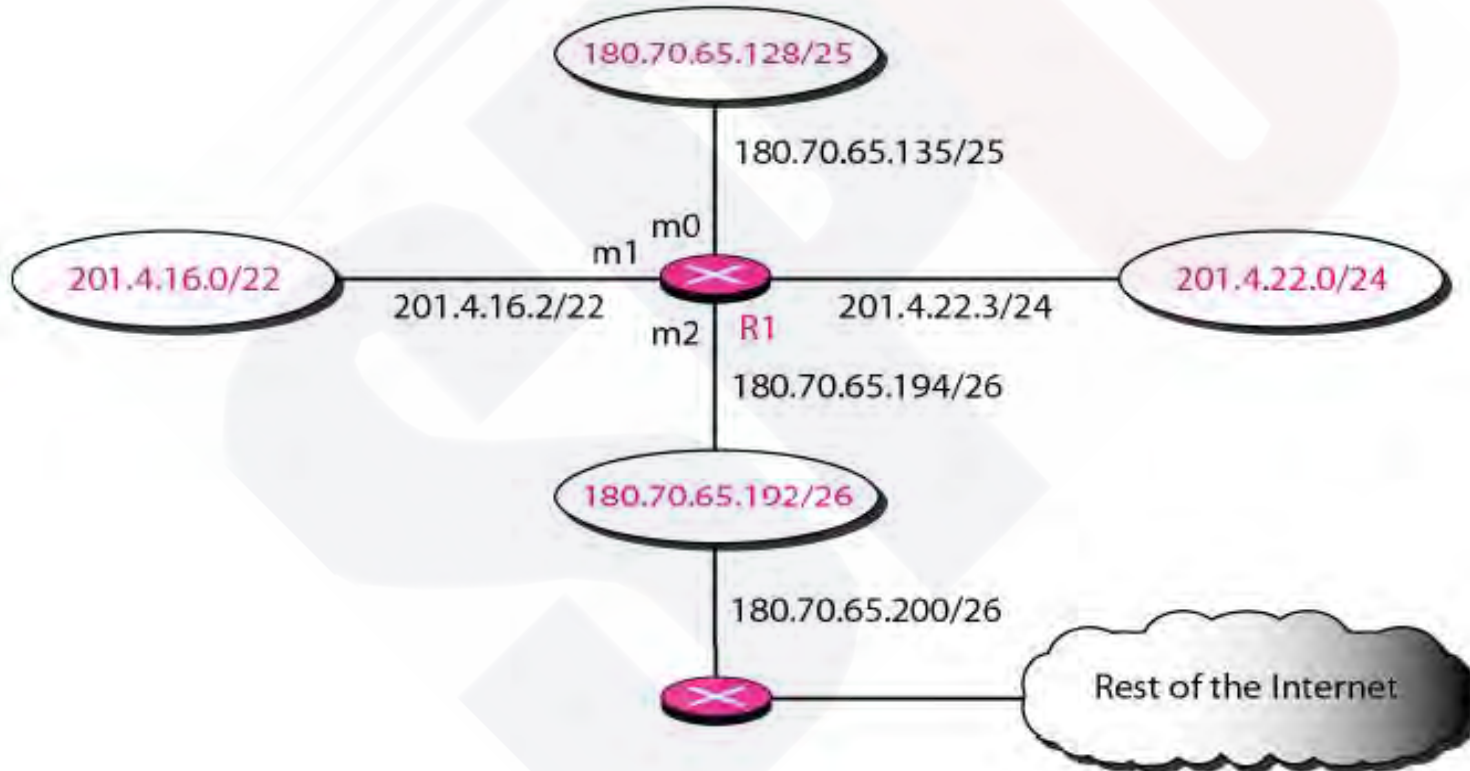
Third step

The third mask (/24) is applied to the destination address.

The result is 201.4.22.0, which matches the corresponding network address.

The next-hop address and the interface number m3 are passed to ARP for further processing

Example4

Show the forwarding process if a packet arrives at R1 in Figure with the destination address 18.24.32.78.

solution

This time all masks are applied, one by one, to the destination address, but no matching network address is found.
When it reaches the end of the table, the module gives the next-hop address 180.70.65.200 and interface number m2 to ARP.
This is probably an outgoing package that needs to be sent, via the default router, to someplace else in the Internet

ROUTING TABLE

A host or a router has a routing table with an entry for each destination, (or a combination of destinations), to route IP packet.
 The routing table can be either :
Static
dynamic

Static routing table:

A static routing table contains information entered manually.

The administrator enters the route for each destination into the table.

When a table is created, it cannot update automatically when there is a change in the Internet.

The table must be manually update by the administrator.

A static routing table can be used in a small internet that does not change very often

Dynamic routing table:

A dynamic routing table is updated periodically by using one of the dynamic routing protocols such as RIP, OSPF, or BGP.
 Whenever there is a change in the Internet, such as shutdown of a router or breaking of link, the dynamic routing protocols update all the tables in the routers automatically.

Common fields in a routing table

Mask	Network address	Next-hop address	Interface	Flags	Reference count	Use
....	....	....	....	....	....	....

Mask	Network address	Next-hop address	Interface	Flags	Reference count	Use
....	....	....	....	....	....	....

Mask: this field defines the mask applied for the entry

Network address: this field defines the network address to which the packet is finally delivered. In the case of host-specific routing, the field defines the address of the destination host

Next hop address: this field defines the address of the next-hop router to which the packet is delivered.

Interface: this field shows the name of the interface

Flags: this field defines up to five flags.

Flags are on/off switches that signify either presence or absence. These are:

U (up): indicates the router is up and running.
If this flag is not present, it means that the router is down.
The packet cannot be forwarded and is discarded.
G (gateway): means that the destination is in another network.
The packet is delivered to next-hop router for delivery.
When this flag is missing, it means the destination is in this network (direct delivery)
H (host-specific): indicates that the entry in the network address field is a host-specific address.
When it is missing, it means that the address is only the network address of the destination.
D (added by redirection): indicates that routing information for this destination has been added to the host routing table by redirection message from ICMP.
M (modified by redirection): indicates that routing information for this destination has been modified by redirection message from ICMP.

Mask	Network address	Next-hop address	Interface	Flags	Reference count	Use
....	....	....	....	....	....	....

Reference count: this field gives the number of users of this route at the moment.
Use: this field shows the number of packet transmitted through this router for the corresponding destination.