Chapter- L2 & L3 Routing

Topic- Layer 3(L3) Routing

TOPIC COVERED IN THIS LECTURE

- Layer 3 operations
- Routing/Forwarding
- Router
- Routing Table
- Need of layer 3 Routes
- Layer 3 routing topologies
- Routing Metrics and Costs
- How are Routing Tables populated?
- Routing table look up

Layer 3 operations

Network layer is majorly focused on getting packets from the source to the destination, routing error handling and congestion control.

- **Addressing**
  Maintains the address at the frame header of both source and destination and performs addressing to detect various devices in network.
- **Packeting**
  This is performed by Internet Protocol. The network layer converts the packets from its upper layer.
- **Routing**
  It is the most important functionality. The network layer chooses the most relevant and best path for the data transmission from source to destination.
- **Inter-networking**
  It works to deliver a logical connection across multiple devices.

Routing/Forwarding

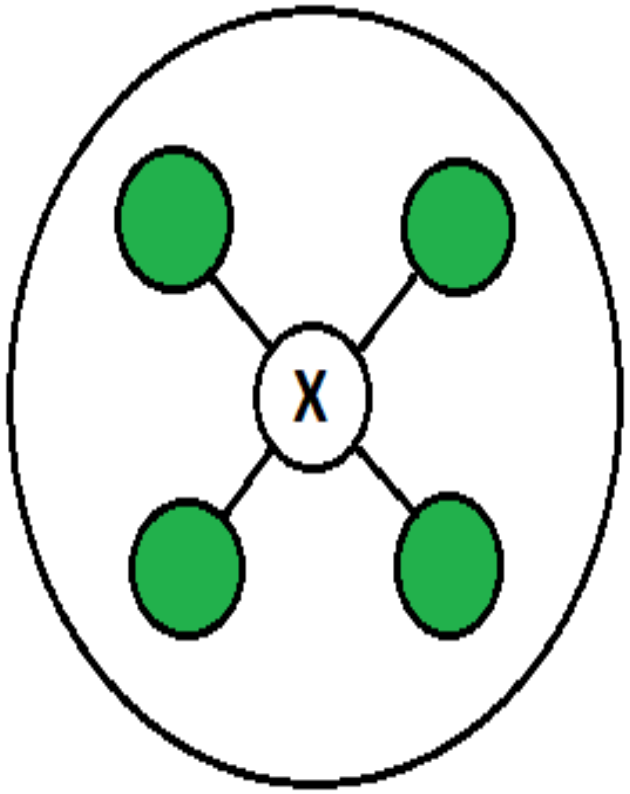
- Routing is a process which is performed by layer 3 (or network layer) devices in order to deliver the packet by choosing an optimal path from one network to another.
  - Routing decides in which direction to send the packets.
  - Routing is the process of populating routing or forwarding table.
  - Routers exchange messages about the networks they can reach.

- Forwarding is the process of sending a packet on its way
  - 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.

Router

- A Router is a networking device that forwards data packets between computer network.
- This device is usually connected to two or more different networks.
- When a packet arrives at a Router, it examines destination IP address of a received packet and make routing decisions accordingly.
- Routers use *Routing Tables* to determine out which interface the packet will be sent.
- Each router's routing table is unique and stored in the RAM of the device.



Routing Table

- A routing table is a set of rules, often viewed in table format, that is used to determine where data packets traveling over an Internet Protocol (IP) network will be directed.

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

Entries of an IP Routing Table

Each entry in the routing table consists of the following entries:

- **Network ID:**
  The network ID or destination corresponding to the route.
- **Subnet Mask:**
  The mask that is used to match a destination IP address to the network ID.
- **Next Hop:**
  The IP address to which the packet is forwarded
- **Outgoing Interface:**
  Outgoing interface the packet should go out to reach the destination network.
- **Metric:**
  A common use of the metric is to indicate the *minimum number of hops* (routers crossed) to the network ID.

Need of layer 3 Routes

- Path derived from information received from a routing protocol
- Several alternative paths may exist
  - best next hop stored in forwarding table
- Decisions are updated periodically or as topology changes (event driven)
- Decisions are based on:
  - topology
  - policies
  - metrics (hop count, filtering,delay, bandwidth, etc.)

Layer 3 routing topologies

- Global (centralized) vs. Decentralized
  - Global: All routers have complete topology
  - Decentralized: Only know neighbours and share information from them

- Intra-domain vs Inter-domain routing
  - Intra: All routers operates under the same administrative control
  - Inter: Decentralized, scale to Internet

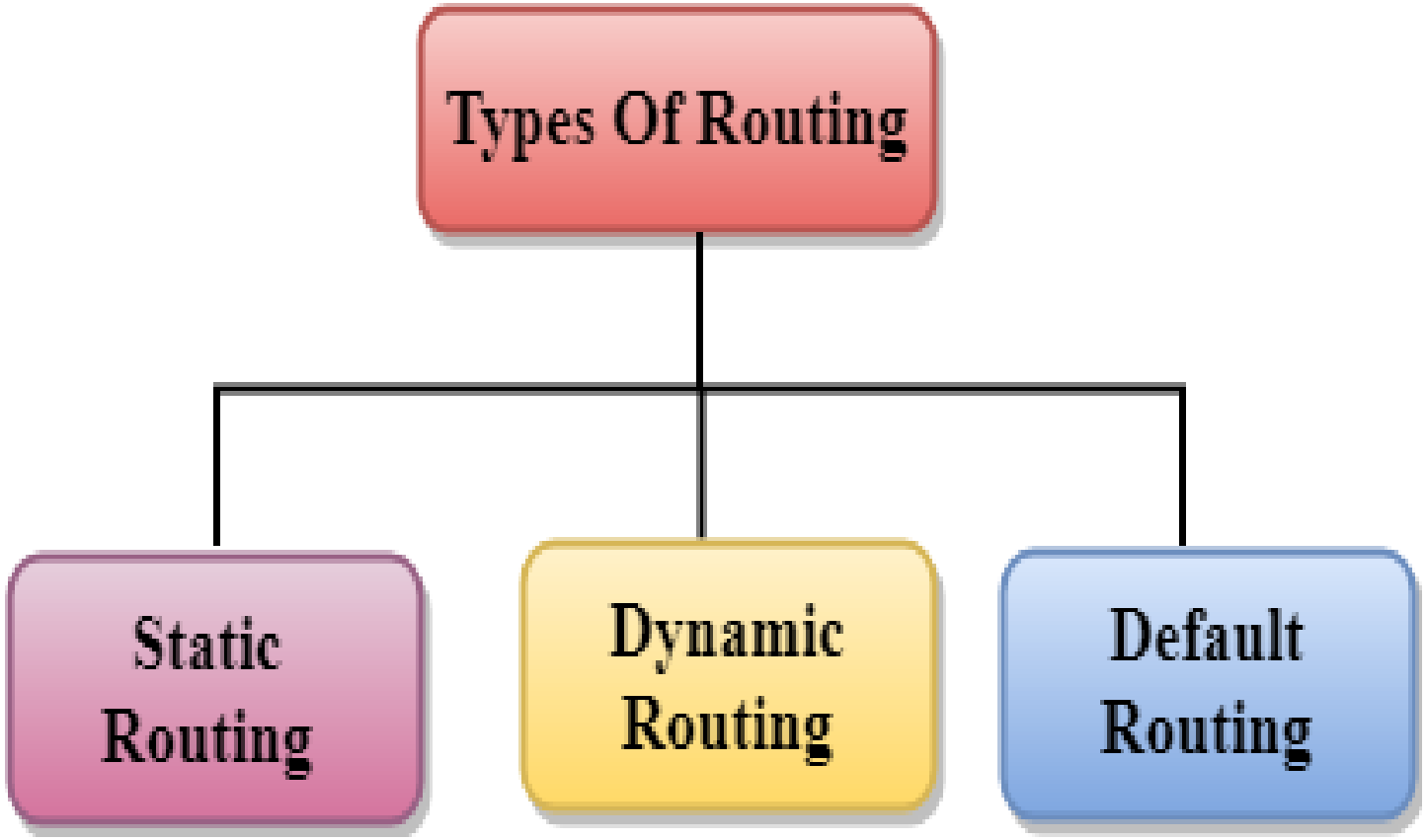
Routing Metrics and Costs

- **Hop count:** Hop count is defined as a metric that specifies the number of passes through internetworking devices such as a router, a packet must travel in a route to move from source to the destination.
- **Delay:** It is a time taken by the router to process, queue and transmit a datagram to an interface.
- **Bandwidth:** The capacity of the link is known as a bandwidth of the link.
- **Load:** Load refers to the degree to which the network resource such as a router or network link is busy.
- **Reliability:** Reliability is a metric factor that measures which networks go down more often than others.

How are Routing Tables populated?

There are three ways to maintain Routing Table:

- Static Routing.
- Dynamic Routing.
- Default Routing.



Static routing

Static routing is a process in which we have to manually add routes in routing table.

Advantages –

- No routing overhead for router CPU which means a cheaper router can be used to do routing.
- It adds security because only administrator can allow routing to particular networks only.
- No bandwidth usage between routers.

Disadvantage –

- For a large network, it is a hectic task for administrator to manually add each route for the network in the routing table on each router.
- The administrator should have good knowledge of the topology. If a new administrator comes, then he has to manually add each route so he should have very good knowledge of the routes of the topology.

Dynamic Routing

- Dynamic routing makes automatic adjustment of the routes according to the current state of the route in the routing table.
- Dynamic routing uses protocols to discover network destinations and the routes to reach it.
- Automatic adjustment will be made to reach the network destination if one route goes down.

A dynamic protocol have following features:

- The routers should have the same dynamic protocol running in order to exchange routes.
- When a router finds a change in the topology then router advertises it to all other routers.

Advantages –

- Easy to configure.
- More effective at selecting the best route to a destination remote network and also for discovering remote network.

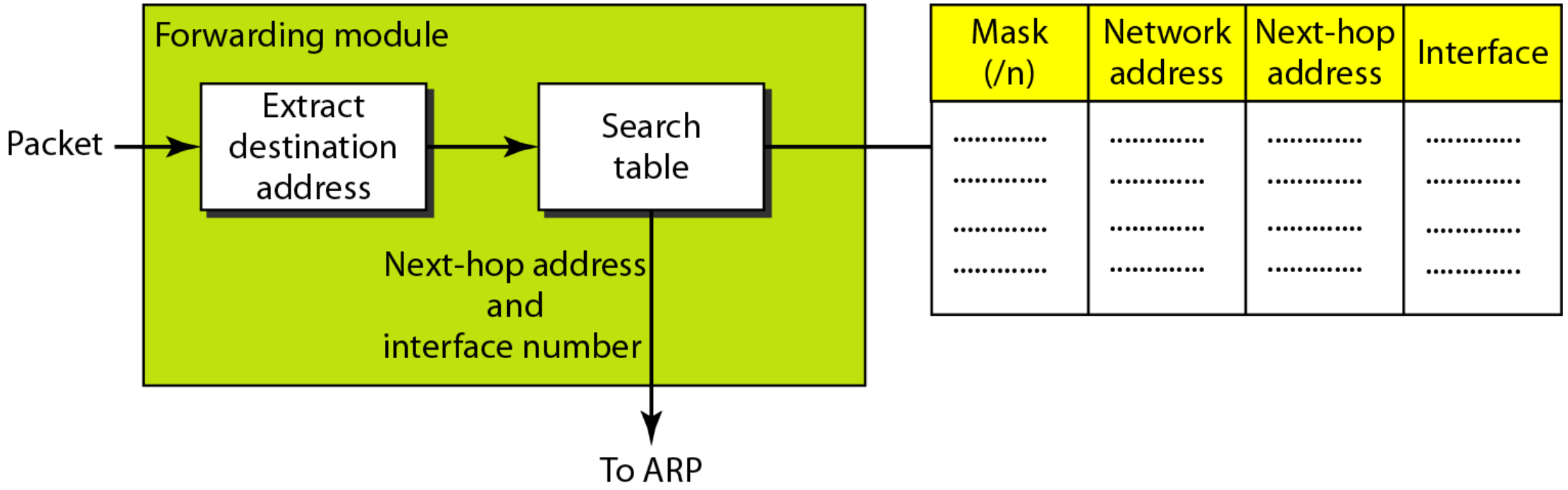
Disadvantage –

- Consumes more bandwidth for communicating with other neighbors.
- Less secure than static routing.

Default Routing

- This is the method where the router is configured to send all packets towards a single router (next hop).
- It doesn’t matter to which network the packet belongs, it is forwarded out to router which is configured for default routing.
- It is generally used with stub routers. A stub router is a router which has only one route to reach all other networks.

Routing Table Look up or Route Determination Process



Routing Table Look up or Route Determination Process

- To find its right subnet (subnet ID), router performs the bitwise ANDing of destination IP Address mentioned on the data packet and all the subnet masks one by one.

- If there occurs only one match, router forwards the data packet on the corresponding interface.

- If there occurs more than one match, router forwards the data packet on the interface corresponding to the longest subnet mask.

- If there occurs no match, router forwards the data packet on the interface corresponding to the default entry.

Routing Table Look up or Route Determination Process

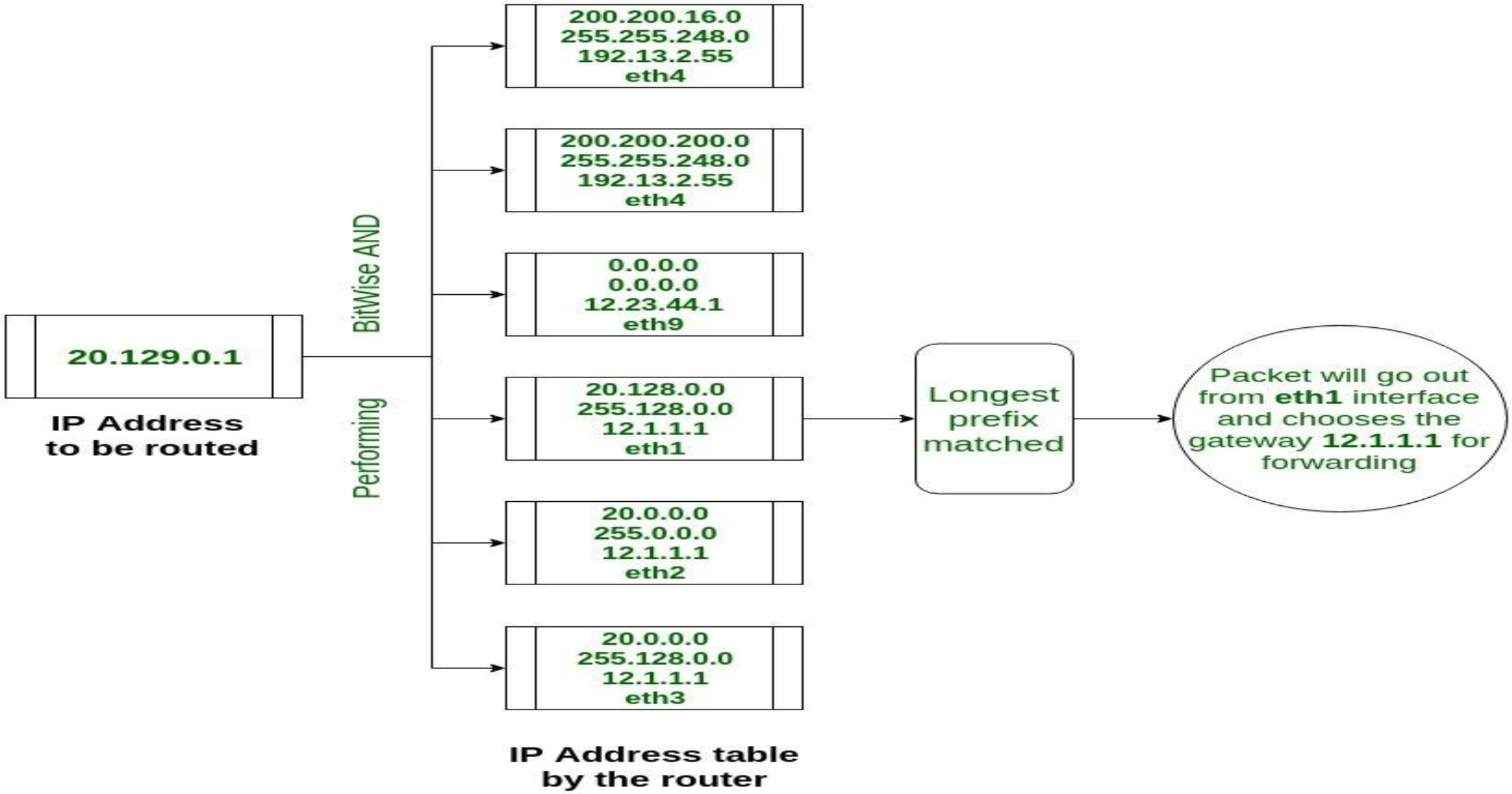
- Suppose there is a packet with IP address "**20.129.0.1**" and the **routing table** has following entries:

Network's IP Address	**Subnet Mask**	**Gateway's IP Address**	**Interface Name**
200.200.16.0	255.255.248.0	192.13.2.55	eth4
200.200.200.0	255.255.248.0	192.13.2.55	eth4
0.0.0.0	0.0.0.0	12.23.44.1	eth9
20.128.0.0	255.128.0.0	12.1.1.1	eth1
20.0.0.0	255.0.0.0	12.1.1.1	eth2
20.0.0.0	255.128.0.0	12.1.1.1	eth3

Routing Table Look up or Route Determination Process

- So when packet goes to the kernel of the system to find gateway and interface, it will first perform bitwise AND operation with subnet mask of each entry to find Longest prefix match.
- The result of the bitwise AND operation is then compared with the network's IP address. So it will return the correspondent IP address of gateway and interface's name through which packet can go out.
- Binary representation of 20.129.0.1 is 00010100.10000001.00000000.00000001. It then performs bitwise AND operation with subnet mask for each and every entry of routing table.
- In this table that entry number is 4(i.e. 20.128.0.0, 255.128.0.0, 12.1.1.1, eth1) which gives the longest prefix match for this packet. So packet will go out from eth1 interface and chooses the gateway 12.1.1.1 for forwarding.

Routing Table Look up or Route Determination Process



Forwarding Techniques

- Route method versus next-hop method

a. Routing tables based on route

Destination	Route
Host B	R1, R2, host B

Routing table for host A

Destination	Route
Host B	R2, host B

Routing table for R1

Destination	Route
Host B	Host B

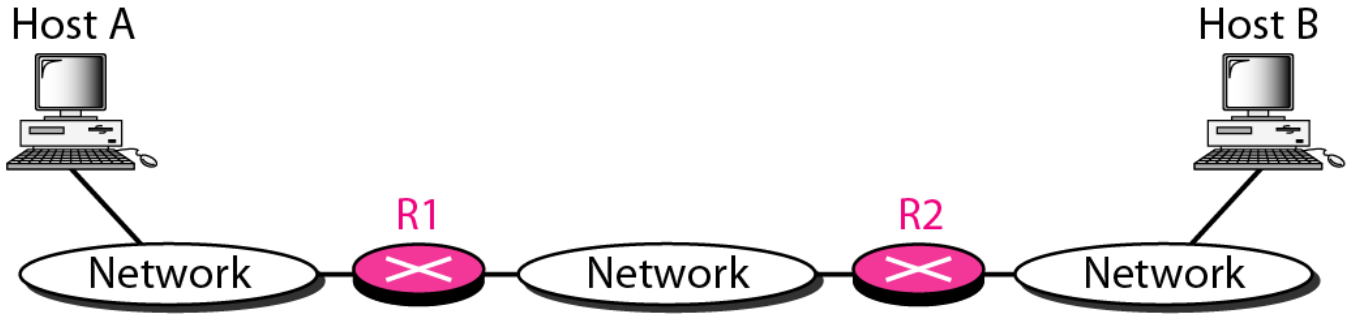
Routing table for R2

b. Routing tables based on next hop

Destination	Next hop
Host B	R1

Destination	Next hop
Host B	R2

Destination	Next hop
Host B	---



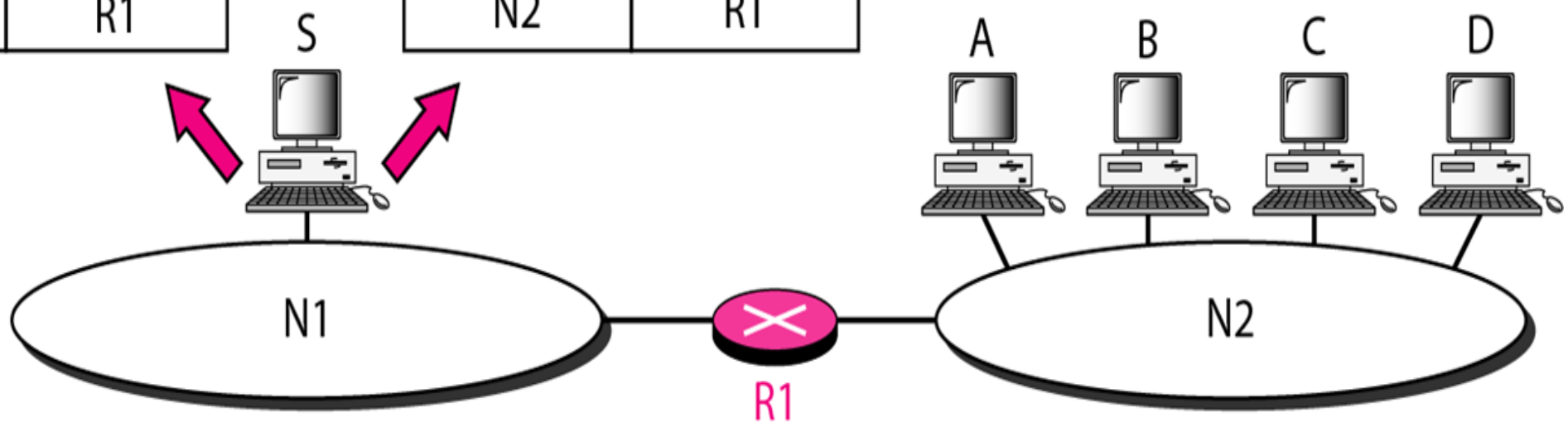
Host-specific versus network-specific method

Routing table for host S based on host-specific method

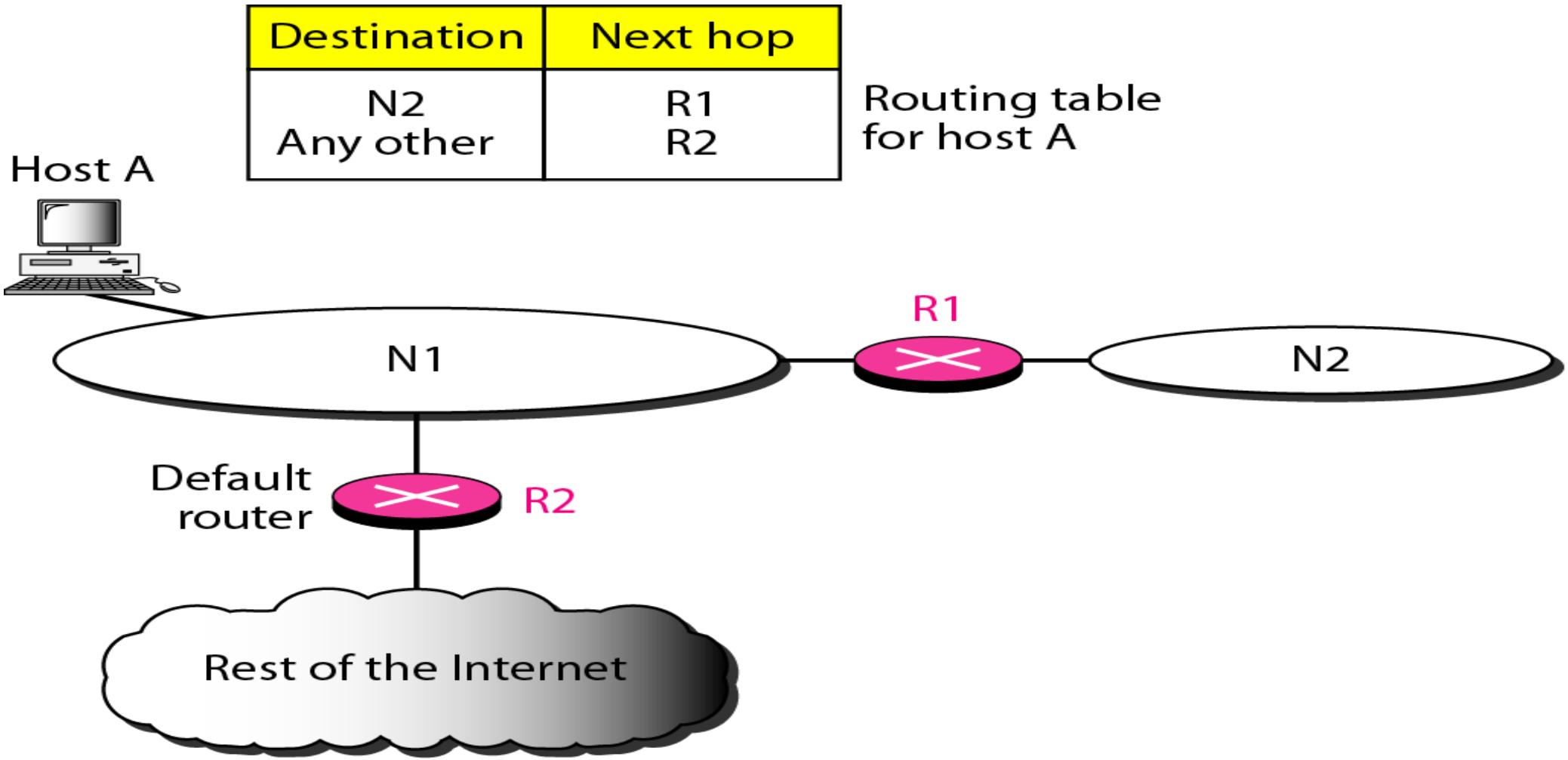
Destination	Next hop
A	R1
B	R1
C	R1
D	R1

Routing table for host S based on network-specific method

Destination	Next hop
N2	R1



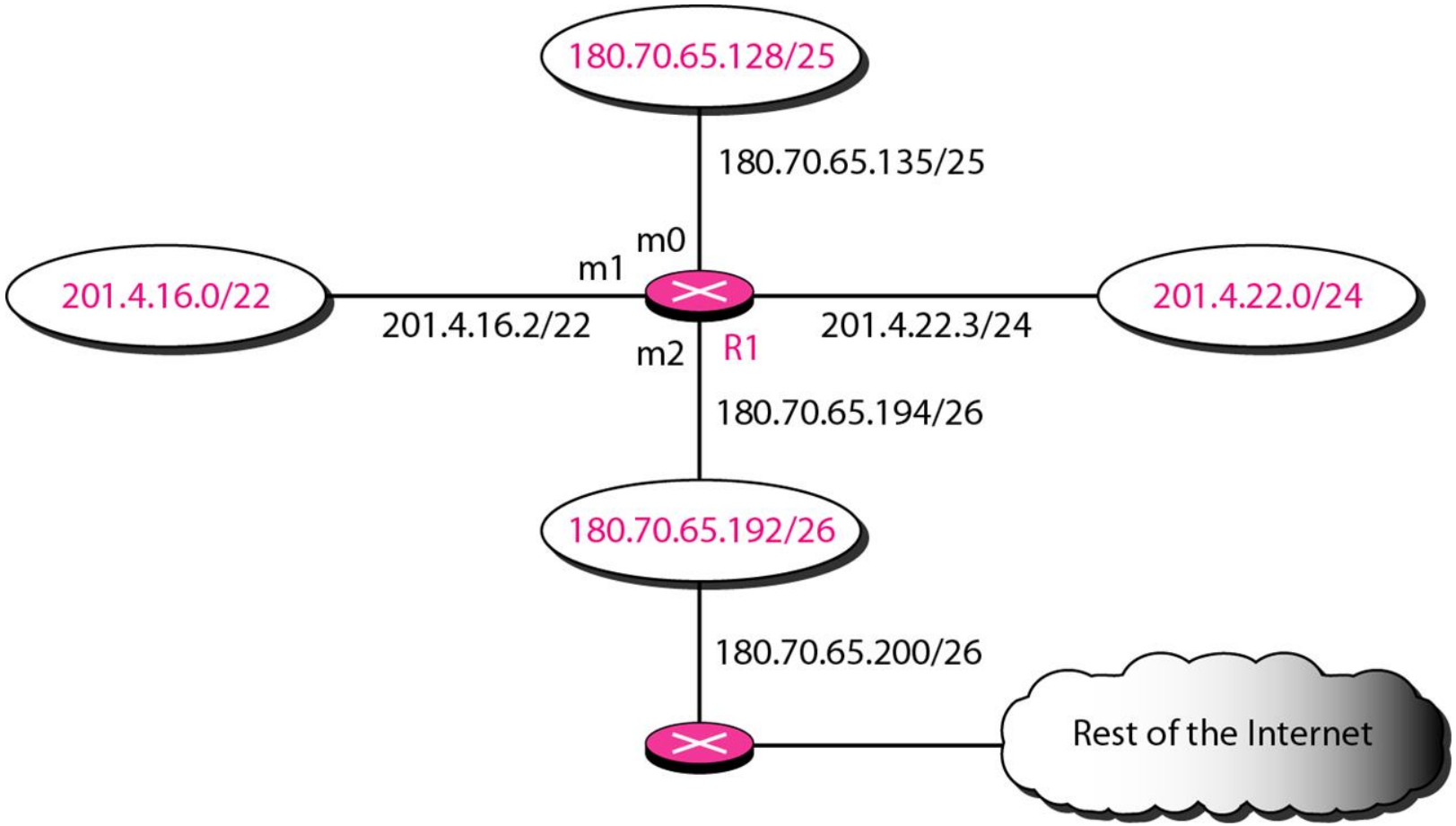
Default method



Note

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

Construct routing table for given network



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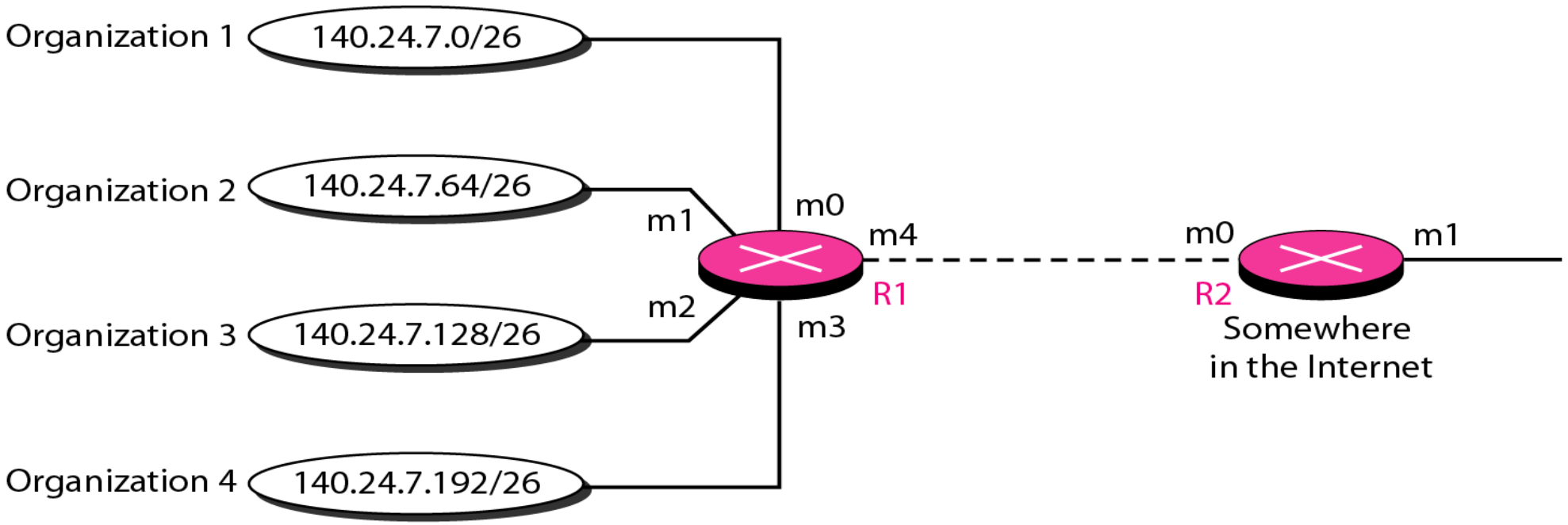
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

Address aggregation



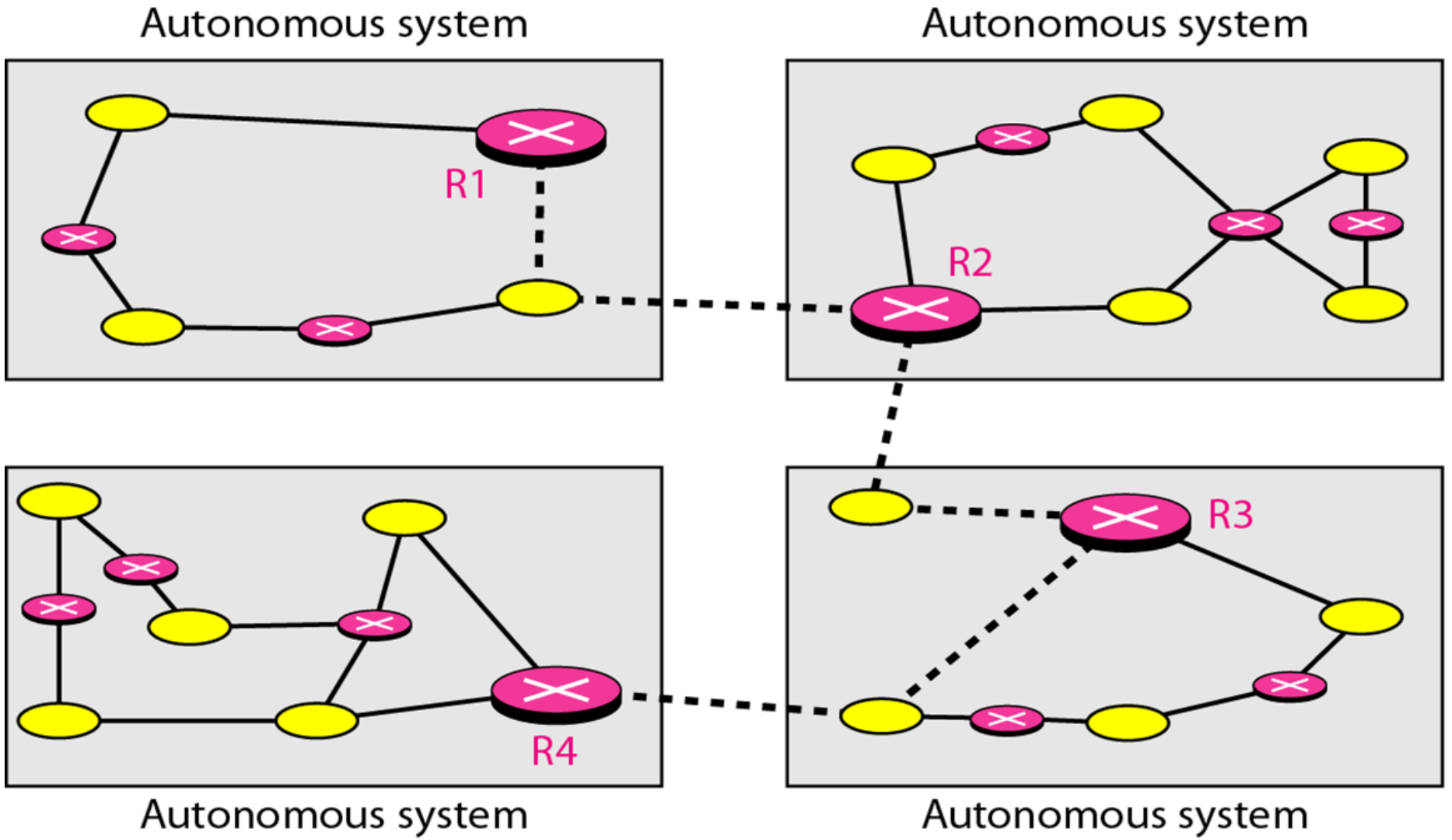
Mask	Network address	Next-hop address	Interface
/26	140.24.7.0	----------	m0
/26	140.24.7.64	----------	m1
/26	140.24.7.128	----------	m2
/26	140.24.7.192	----------	m3
/0	0.0.0.0	Default	m4

Routing table for R1

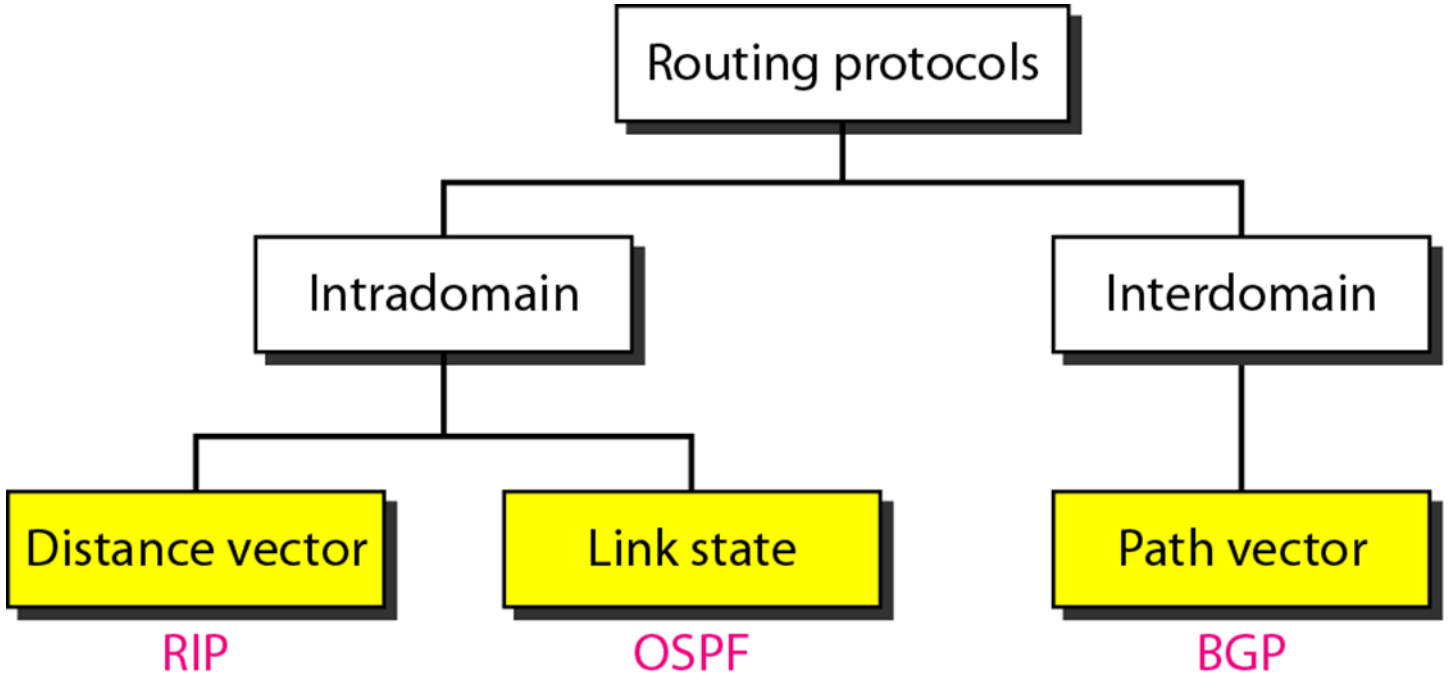
Mask	Network address	Next-hop address	Interface
/24	140.24.7.0	----------	m0
/0	0.0.0.0	Default	m1

Routing table for R2

Autonomous systems



Popular routing protocols



- When we send a packet destined to a remote machine, What is the IP address we should specify as Source and Destination IP address ?

- If A wants to send data to machine B, What should be src ip address to be specified in IP hdr of the packet ?
  10.18.1.2 Or 11.18.5.1
- If A wants to send a data to router B, what should be dest IP address to be specified in the packet ?
  192.168.1.2 Or 192.168.5.1