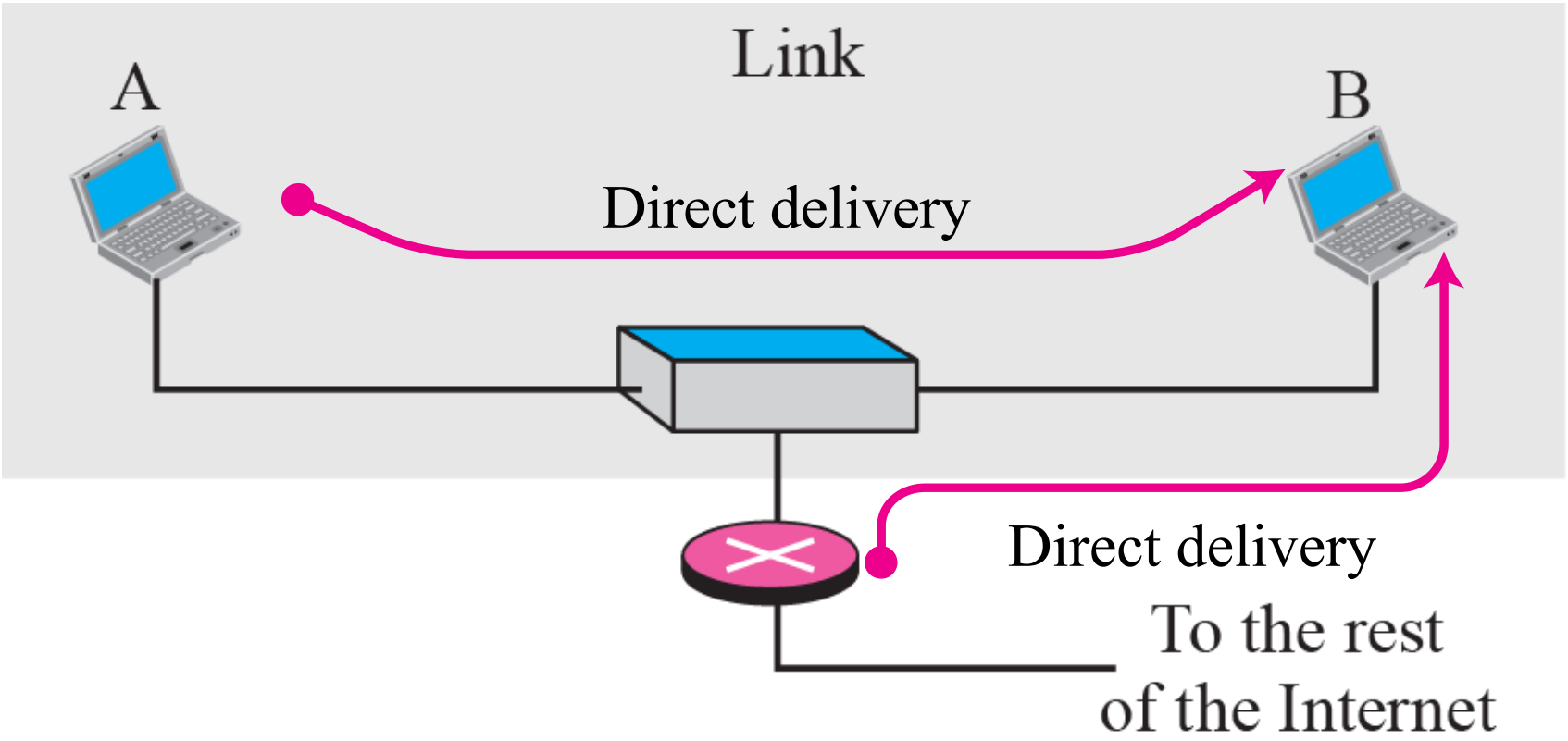
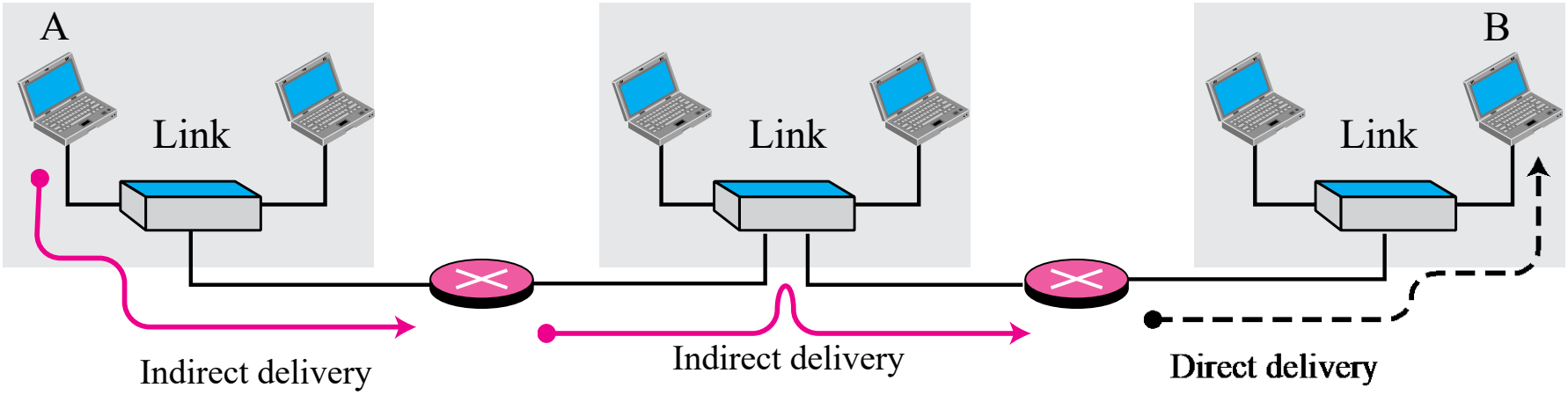
Network Layer: Delivery, Forwarding, and Routing

DELIVERY

- Delivery refers to the way a packet is handled by the underlying networks under the control of the network layers.
- The delivery of a packet to its final destination is accomplished using two different methods of delivery: direct and indirect.



Indirect delivery



FORWARDING

- Forwarding refers to the way a packet is delivered to the next station
- Forwarding requires a host or a router to have a routing table.
- Routing refers the way routing table are created to help in forwarding
- Several techniques can make the size of the routing table
  - ✓ Next hop method vs route method
  - ✓ Network specific method vs host specific method
  - ✓ Default method

Figure *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

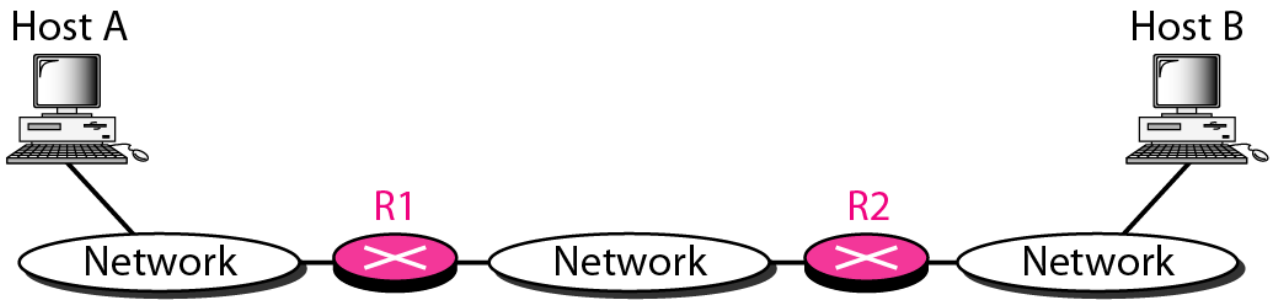
Routing table for R2

b. Routing tables based on next hop

Destination	Next hop
Host B	R1

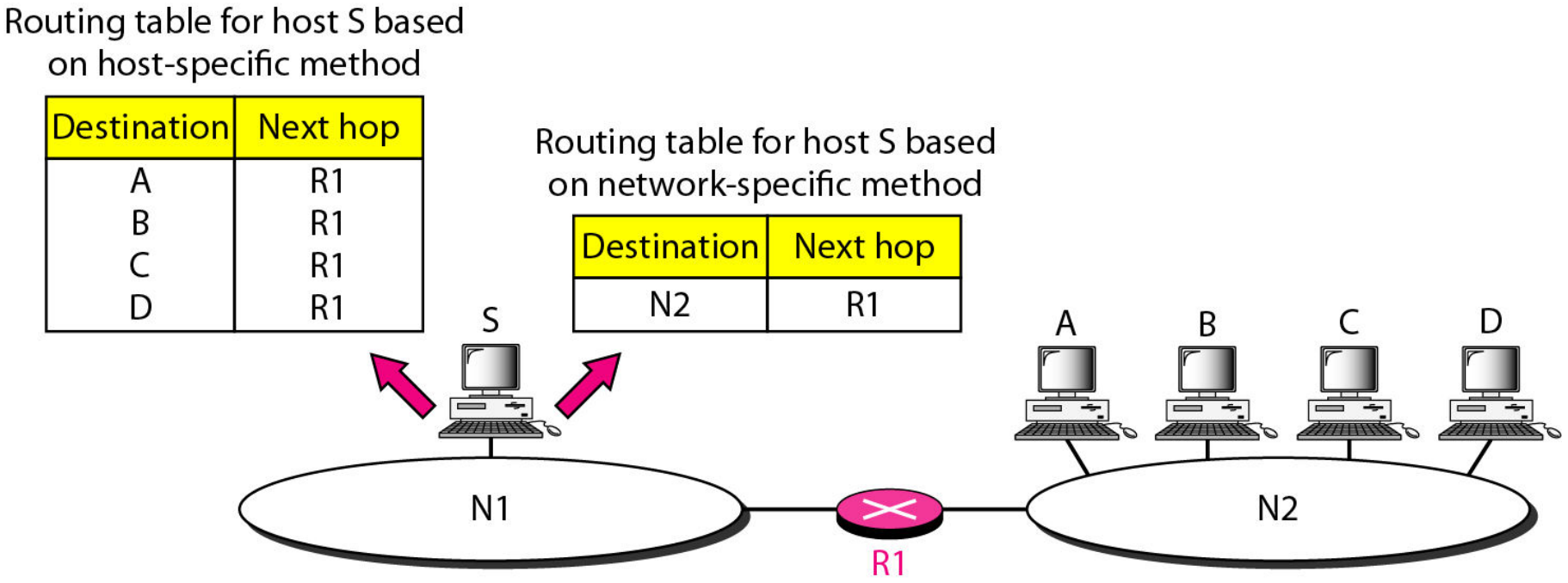
Destination	Next hop
Host B	R2

Destination	Next hop
Host B	---



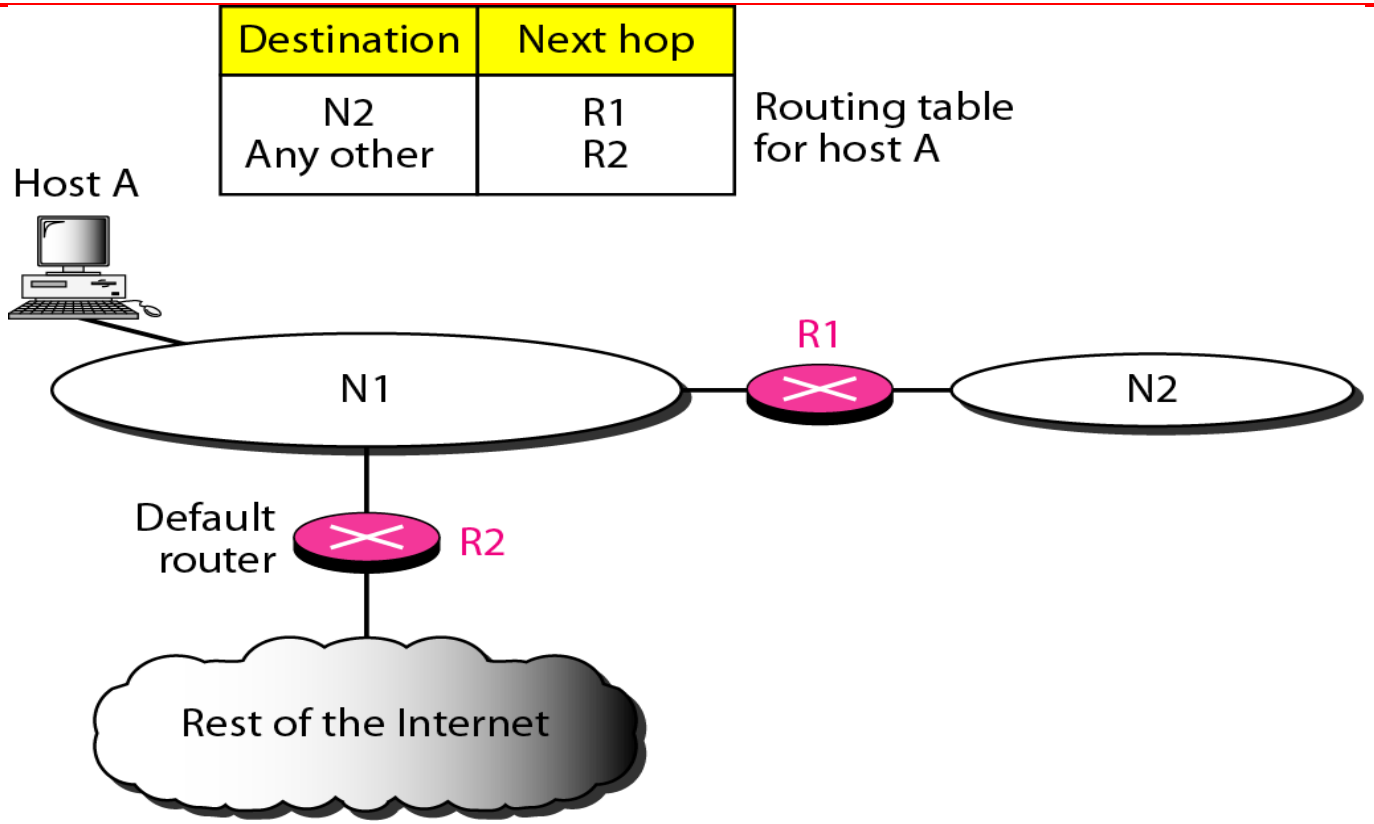
In next-hop routing, Routing table holds the information (IP address) that leads to the next hop (router) instead of holding information about the complete path

Figure *Host-specific versus network-specific method*



Instead of having entry for each host connected to the same network, the table contains only a single entry for the address of the network itself

Figure *Default method*



Default router is used if the destination network address is not found in the routing table

Routing (IP routing)

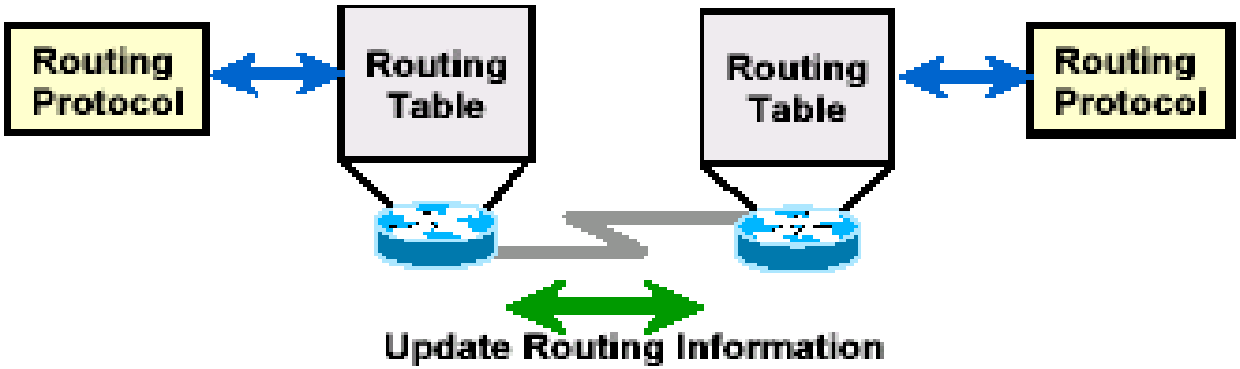
- **Routing Protocol:** determines the **best path** (route) that the packets should follow to arrive to the desired destination
- Routing Protocols: A **software** in the network layer that implements **routing algorithms** and responsible for:
  - Filling and updating routing tables (by finding the shortest paths from each source to each destination) This part is called **Routing**
  - Deciding which output interface an incoming packet should be transmitted on (by referring to the routing table). This part is called **Forwarding**

Routing Algorithms Classifications

- Static
  - Information entered manually
  - Shortest paths are precompiled offline by a special computer running the routing algorithm
  - Resulted information is entered manually by the administrator into the routing tables
  - **Can not** update automatically if there is a change in the network or failure
  - Used in **small** networks
- Dynamic (adaptive)
  - Each router or host learns the state of the network by communicating with its **neighbours.**
  - Based on the collected information, each node can fill its routing table
  - More complexity is added to the router

Routing algorithm: Dynamic Route operation

- Routing protocol maintains and distributes routing information



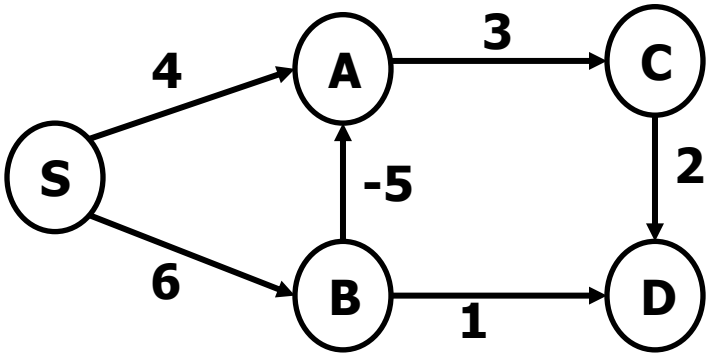
Shortest Path Routing

- Algorithms used to determine the shortest path between two nodes according to some cost condition.
- The shortest path is the path with the ***least cost*** (the sum of the cost of the links on the path is minimum over all possible paths between the source and destination)
- Two main algorithms to find the shortest path between any two nodes
  - Distance Vector (**Bellman-Ford** Algorithm)
  - Link State – (**Dijkstra's Algorithm**)

Distance Vector (DV) Routing

- The distance vector routing algorithm, also called a **Bellman-Ford algorithm** after two of its inventors, is one where routes are selected based on the distance between networks.
- Basic idea: each network node maintains a Distance Vector (DV) table containing the ***distances from*** itself to **ALL** possible destination nodes.
- Distances are based on a chosen metric (Metric: *usually number of hops, bandwidth, delay)*
- Router transmits its *distance vector table* to each of its **neighbors (directly connected to it) periodically** (every 30 sec)
- A router **recalculates** its distance vector when:
  - It receives a *distance vector table* from a neighbor containing different information than before.
  - It discovers that a link to a neighbor has gone down or up (i.e., a topology changes).
- Distances to all destinations are computed using information from the **neighbors'** distance vectors.
- The DV calculation is based on minimizing the cost to each destination.
- From its DV, a router can directly derive its **routing table**.

Bellman-Ford Algorithm



	S	A	B	C	D
Initial	0	∞	∞	∞	∞
1	0	1	6	7	7
2	0	1	6	4	6
3	0	1	6	4	6
4	0	1	6	4	6

Edges: SA, SB, AC, BA, BD, CD
Number of Iteration: V-1 =5-1= 4

Shortest Path tree:
S -> B -> A -> C ->D

Distance vector protocols example: RIP (Routing Information Protocol), EIGRP (Enhanced Interior Gateway Routing Protocol)

- **RIP follows Bellman-Ford Algorithm**
- **EIGRP follows Diffusing Update Algorithm (DUAL)**

Routing Information Protocol

- RIPv1
  - -A classful distance vector routing protocol
  - -Does not support discontiguous subnets
  - -Does not support VLSM
  - -Does not send subnet mask in routing update
  - -Routing updates are broadcast
  - -Maximum hop count of 15, 16 is unreachable
- RIPv2
  - -A classless distance vector routing protocol that is an enhancement of RIPv1's features.
  - -Next hop address is included in updates
  - -Routing updates are multicast
  - -The use of authentication is an option
  - - Maximum hop count of 15, 16 is unreachable

RIP Vs EIGRP

Factors	RIP	EIGRP
Class	V1 is classful and V2 is classless	Classless
Proprietary	Open standard	CISCO proprietary Protocol
AD Value	120	90(Internal), 170(External)
Best Path Algorithm	Bellmen	DUAL
Hop Counts	15	By default 100, Max 255
Network Types	Small	Large
Hello Time	Every 30 Secs	Every 5 Sec

Link State Routing

- Each router measures the cost (in delay, Bandwidth) between itself and its neighbour routers (directly connected)
- The router builds a packet containing all these costs.
- Each router distributes these packets using **flooding** to **ALL** other routers in **the routing area**
- Information is sent when **there a change** in the link between the router and its neighbours (to reduce traffic)
- Each router builds map of the **entire network**, uses a **shortest-path algorithm** (usually Dijkstra algorithm) to compute a shortest path between itself and any other node in the area (creates the routing table)
- **OSPF** (Open Shortest Path first is an Example)

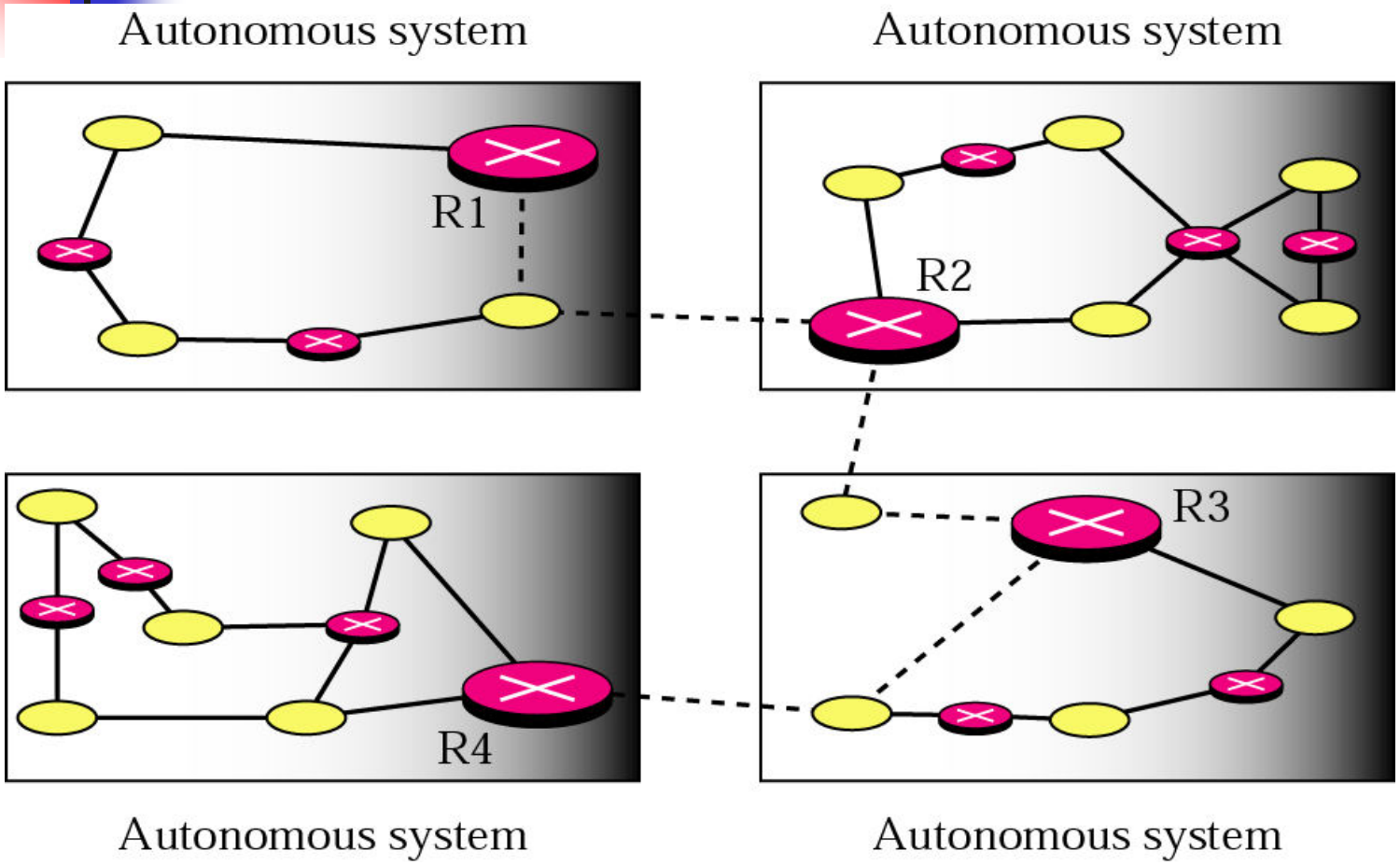
Comparison between distance vector & Link state

Distance Vector Routing	Link State Routing
Bandwidth required is less due to local sharing, small packets and no flooding.	Bandwidth required is more due to flooding and sending of large link state packets.
Based on local knowledge, since it updates table based on information from neighbors.	Based on global knowledge, it have knowledge about entire network.
Make use of Bellman Ford Algorithm.	Make use of Dijakstra's algorithm.
Traffic is less.	Traffic is more.
Converges slowly, good news spread fast and bad news spread slowly.	Converges faster.
Count of infinity problem.	No count of infinity problem.
Practical implementation is RIP	Practical implementation is OSPF

Autonomous systems (AS)

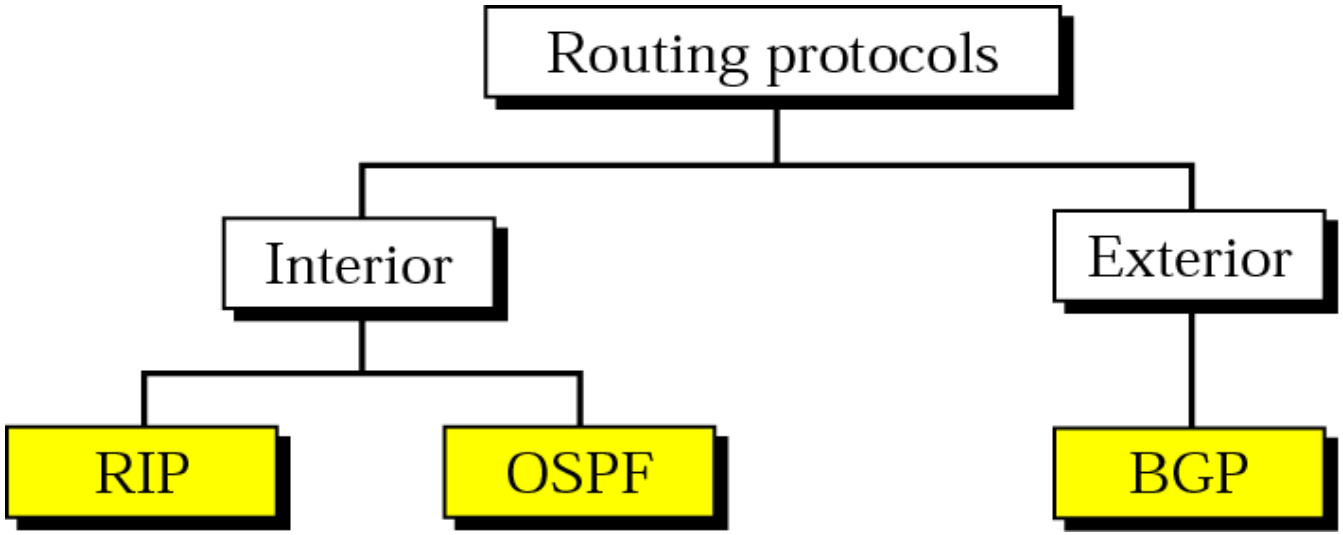
- On the Internet, Autonomous system (AS) is either a **single network** or a **group of networks** that is controlled by a common network administrator
- An autonomous system is assigned a globally unique number, sometimes called an Autonomous System Number (ASN).
- AS systems are connected by special routers called **boarder routers or gateways routers.**
- Routers in **same** AS run **same** routing protocol this is called "intra-AS" (interior) routing protocol
- Routing between autonomous systems is called **inter-AS** or **exterior routing**
- Gateways routers (boarder routers) are special routers in AS that run intra-AS" routing protocol and also responsible for routing to destinations outside AS by running inter-AS (exterior) routing protocol with other gateway (boarder) routers

Figure 21.3 Autonomous systems



- **Routers R1,R2,R3,R4 are designated as border gateway routers**
- **These routers run both interior and exterior routing protocols**

Figure 21.2 *Popular routing protocols*



- **Interior routing (RIP, OSPF): between routers inside a single AS**
- **Exterior routing (BGP): between routers connecting several AS**
  - **BGP stands for Border Gateway Protocol Routing**