Network Layer

Routing

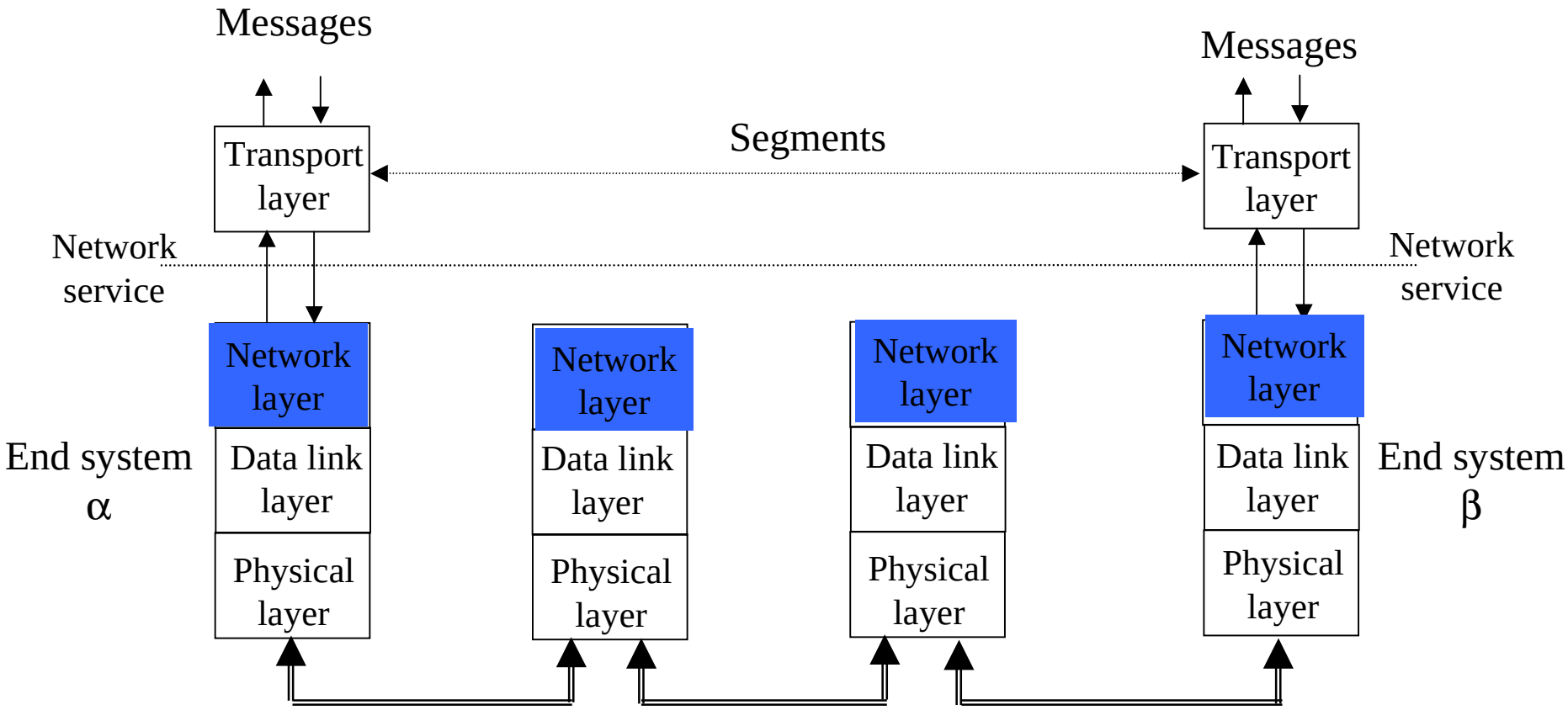
Network Layer

- Concerned with getting packets from source to destination.
- The network layer must know the topology of the subnet and choose appropriate paths through it.
- When source and destination are in *different networks*, the network layer **(IP)** must deal with these differences.

* **Key issue:** *what service does the network layer provide to the transport layer* (connection-oriented or connectionless).

Network Layer Design Goals

1. The services provided by the network layer should be independent of the subnet topology.
2. The Transport Layer should be shielded from the number, type and topology of the subnets present.
3. The network addresses available to the Transport Layer should use a uniform numbering plan (even across LANs and WANs).



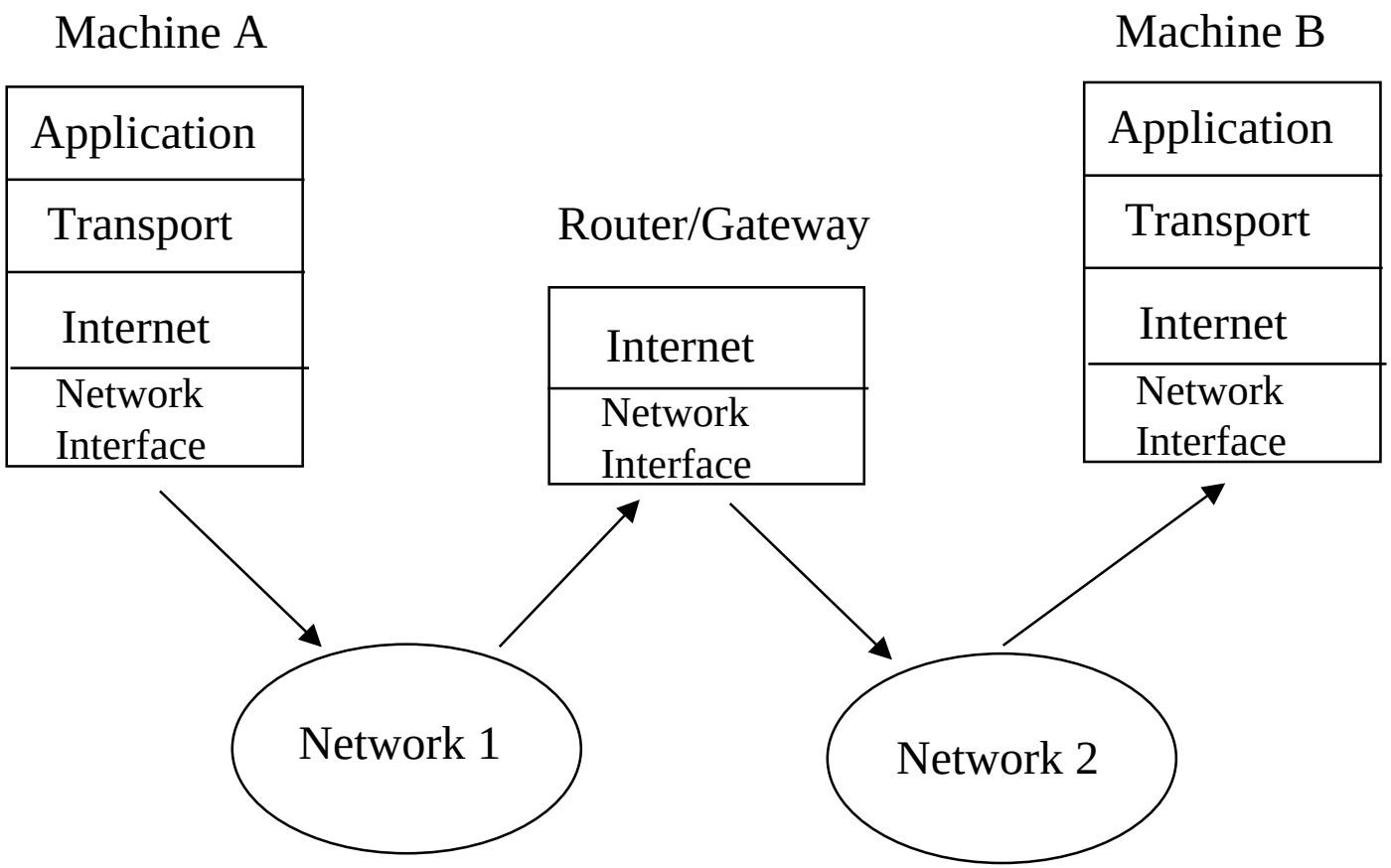
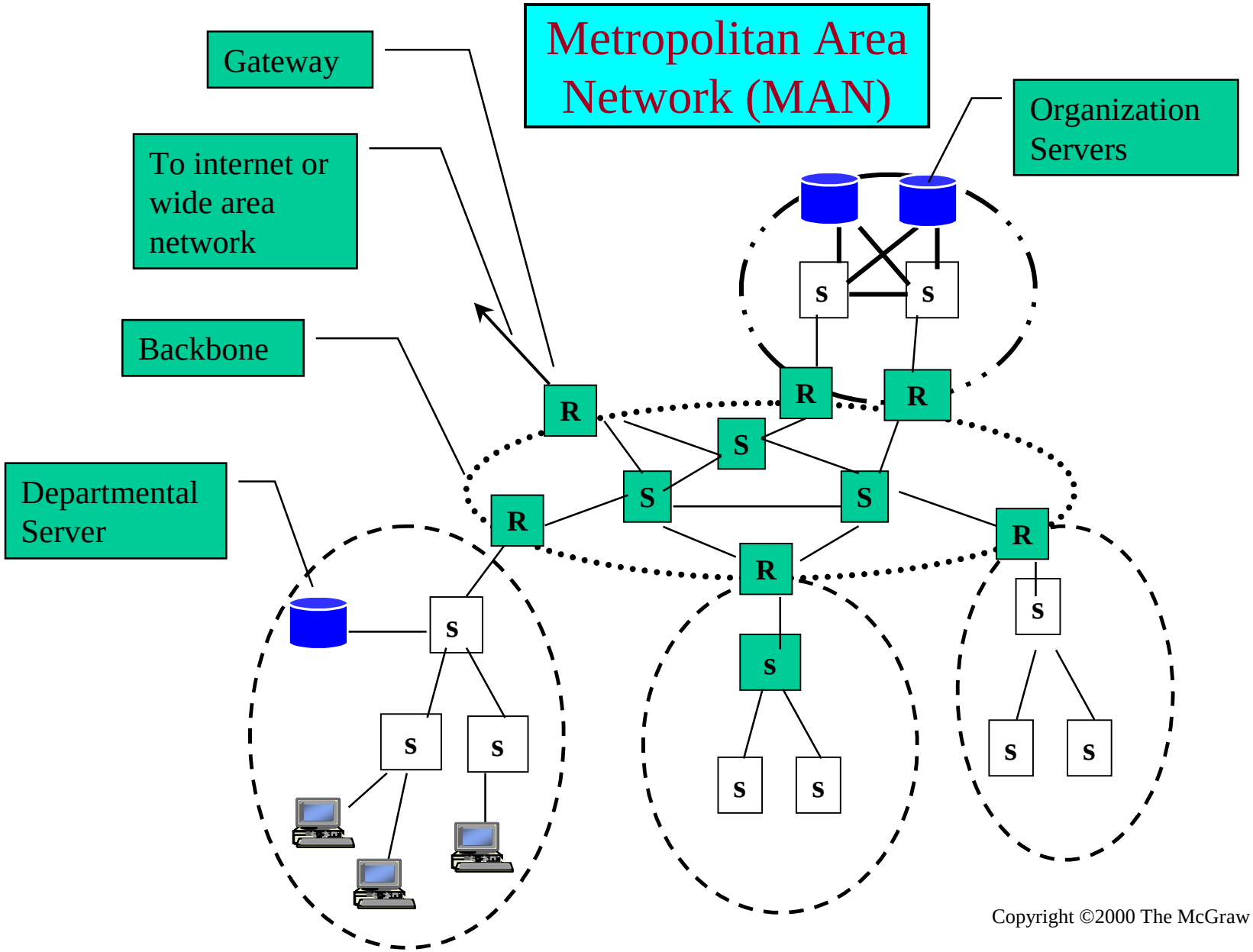
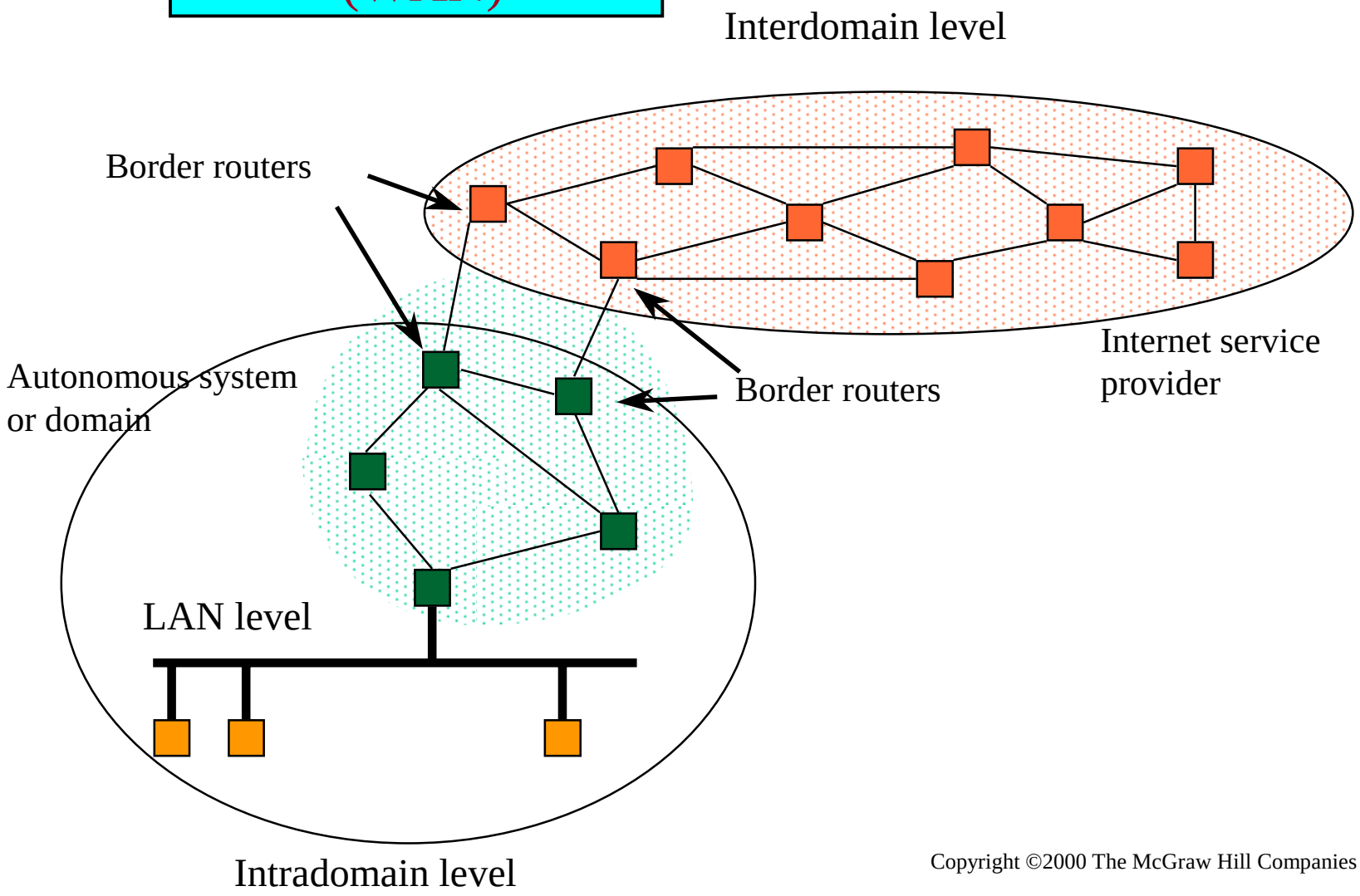
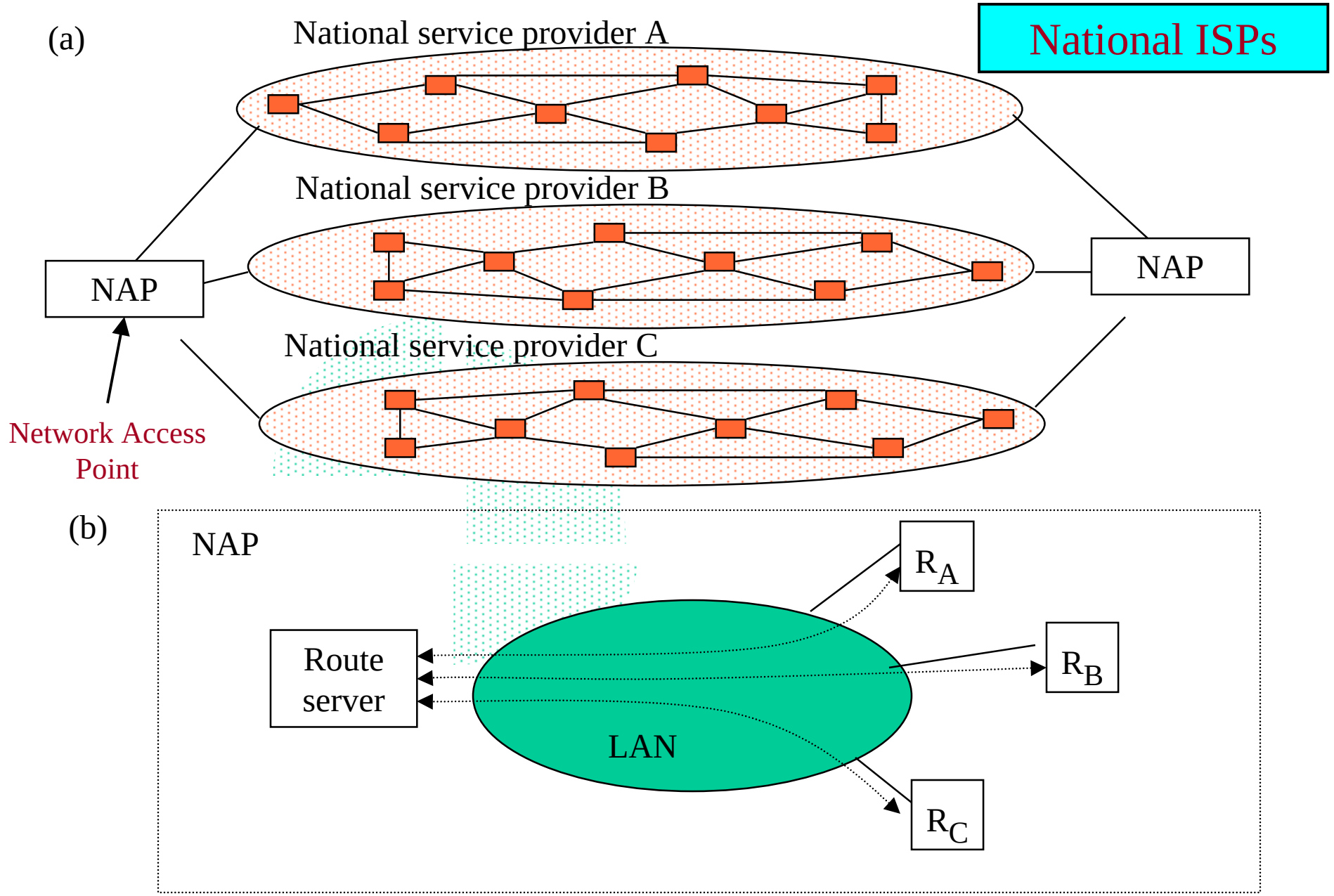

Machine A
Application
Transport
Internet
Network Interface
Router/Gateway
Internet
Network Interface
Machine B
Application
Transport
Internet
Network Interface
Network 1
Network 2

Figure 8.3

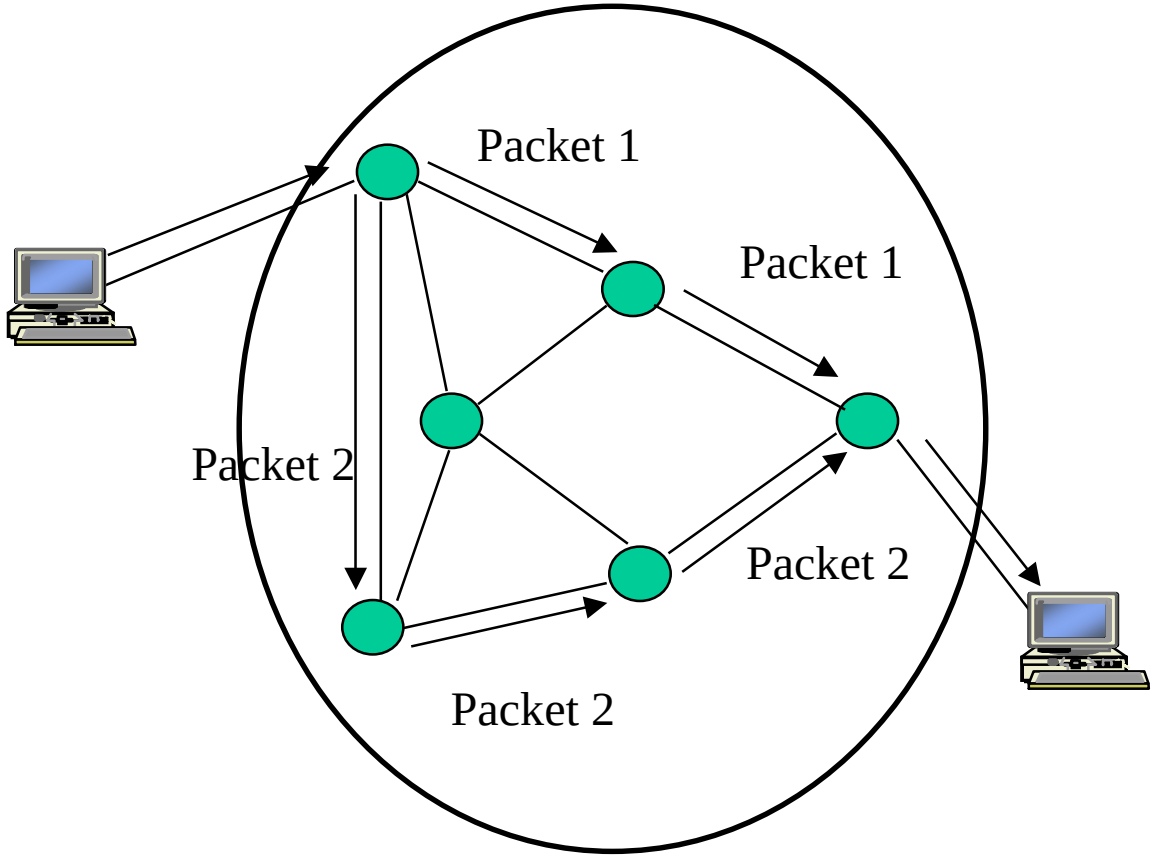


Wide Area Network (WAN)





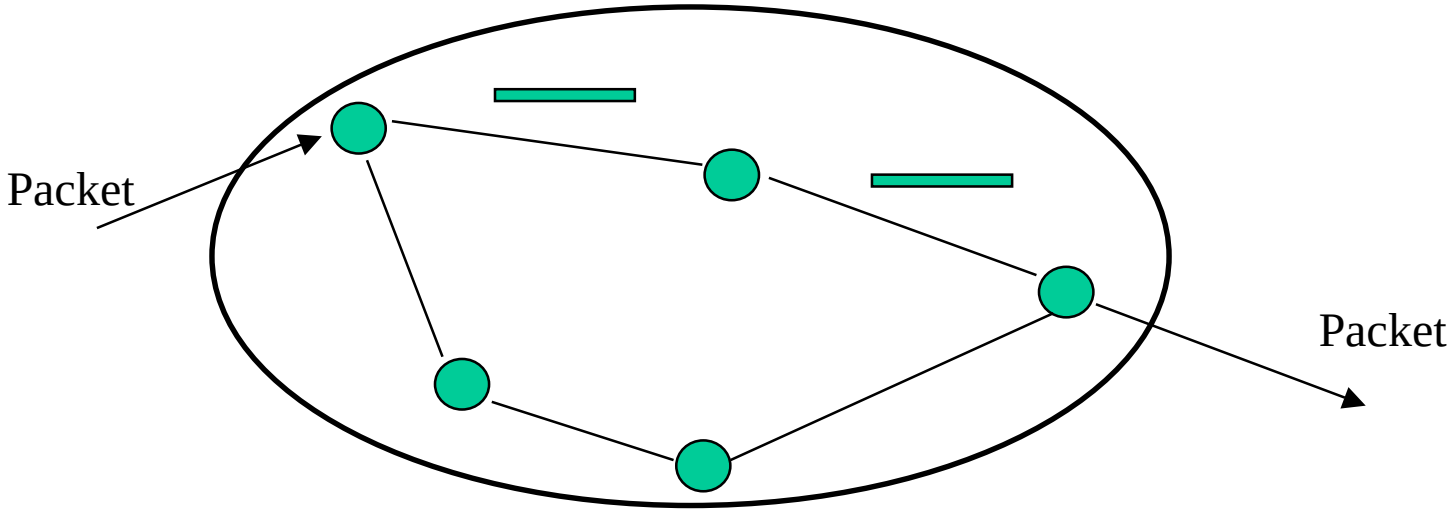
Datagram Packet Switching



Routing Table in Datagram Network

Destination address	Output port
0785	7
1345	12
1566	6
2458	12

Virtual Circuit Packet Switching



Routing Table in Virtual Circuit Network

Entry for packets with identifier 15 →

Identifier	Output port	Next identifier
12	13	44
15	15	23
27	13	16
58	7	34

Routing

Routing algorithm:: that part of the Network Layer responsible for deciding on which output line to transmit an incoming packet.

- Remember: For virtual circuit subnets the routing decision is made ONLY at set up.

Algorithm properties:: correctness, simplicity, robustness, stability, fairness, optimality, and scalability.

Routing Classification

Adaptive Routing

based on current measurements of traffic and/or topology.

1. centralized
2. isolated
3. distributed

Non-Adaptive Routing

1. flooding
2. static routing using shortest path algorithms

Shortest Path Routing

1. Bellman-Ford Algorithm [Distance Vector]
2. Dijkstra's Algorithm [Link State]

What does it mean to be the shortest (or optimal) route?

a. Minimize mean packet delay

b. Maximize the network throughput

c. Mininize the number of hops along the path

Dijkstra's Shortest Path Algorithm

Initially mark all nodes (except source) with infinite distance.

working node = source node

Sink node = destination node

While the working node is not equal to the sink

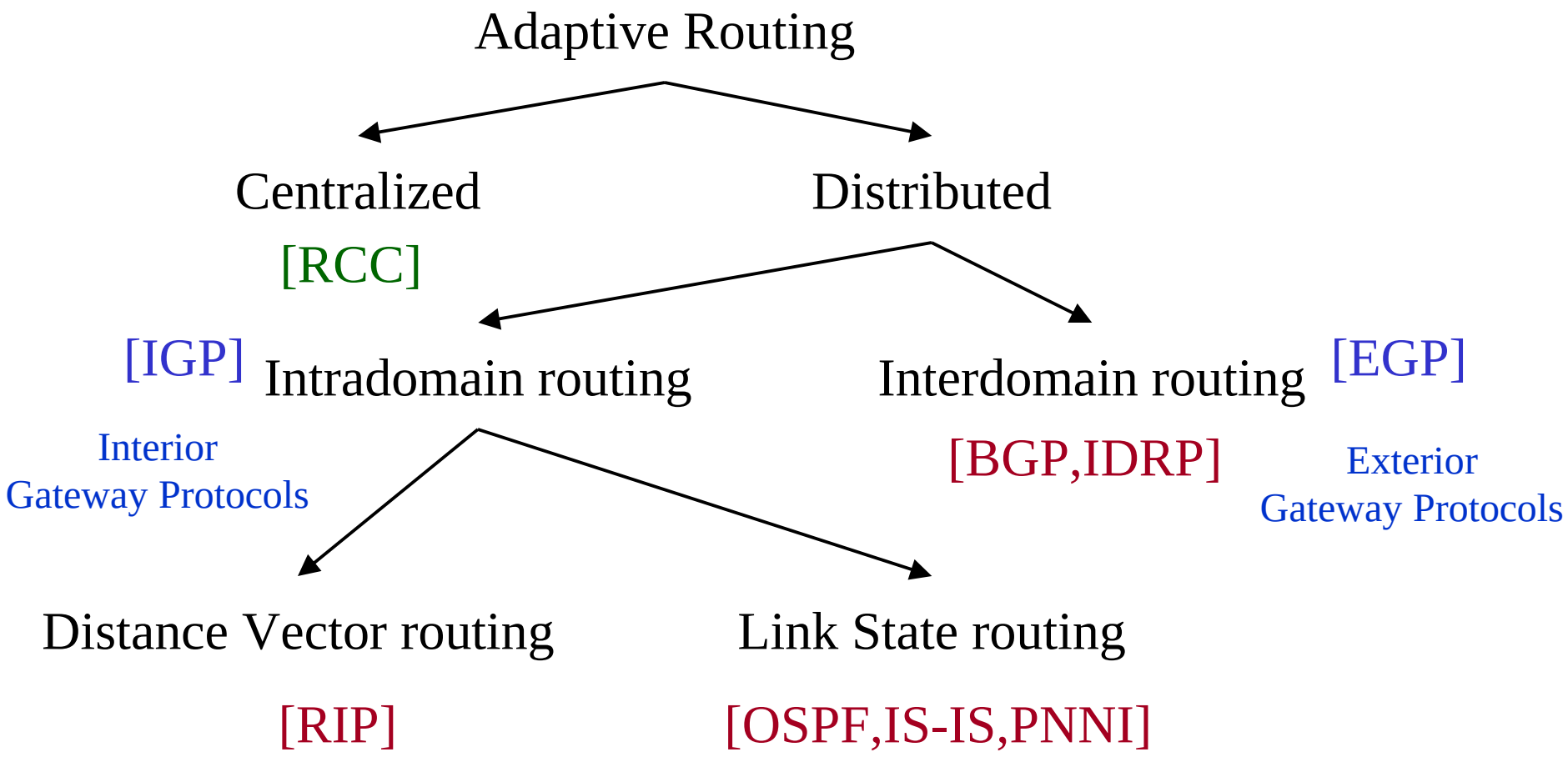
1. Mark the working node as permanent.
2. Examine all adjacent nodes in turn

   If the sum of label on working node plus distance from working node to adjacent node is less than current labeled distance on the adjacent node, this implies a shorter path. Relabel the distance on the adjacent node and label it with the node from which the probe was made.

3. Examine all tentative nodes (not just adjacent nodes) and mark the node with the smallest labeled value as permanent. This node becomes the new working node.

Reconstruct the path backwards from sink to source.

Internetwork Routing [Halsall]



Distance Vector Routing

- Historically known as the ***old*** ARPANET routing algorithm {or known as *Bellman-Ford algorithm*}.

Basic idea: each network node maintains a Distance Vector table containing the ***distance*** between itself and **ALL** possible destination nodes.

- Distances are based on a chosen metric and are computed using information from the **neighbors'** distance vectors.

Metric: *usually hops or delay*

Distance Vector Routing

Information kept by DV router

1. each router has an ID
2. associated with each link connected to a router, there is a link cost (static or dynamic) **the metric issue!**

Distance Vector Table Initialization

Distance to itself = 0

Distance to ALL other routers = infinity number

Distance Vector Algorithm [Perlman]

1. Router transmits its *distance vector* to each of its neighbors.
2. Each router receives and saves the most recently received *distance vector* from each of its neighbors.
3. A router **recalculates** its distance vector when:
   a. It receives a *distance vector* from a neighbor containing different information than before.
   b. It discovers that a link to a neighbor has gone down (i.e., a topology change).

- The DV calculation is based on minimizing the cost to each destination.

Distance Vector Routing

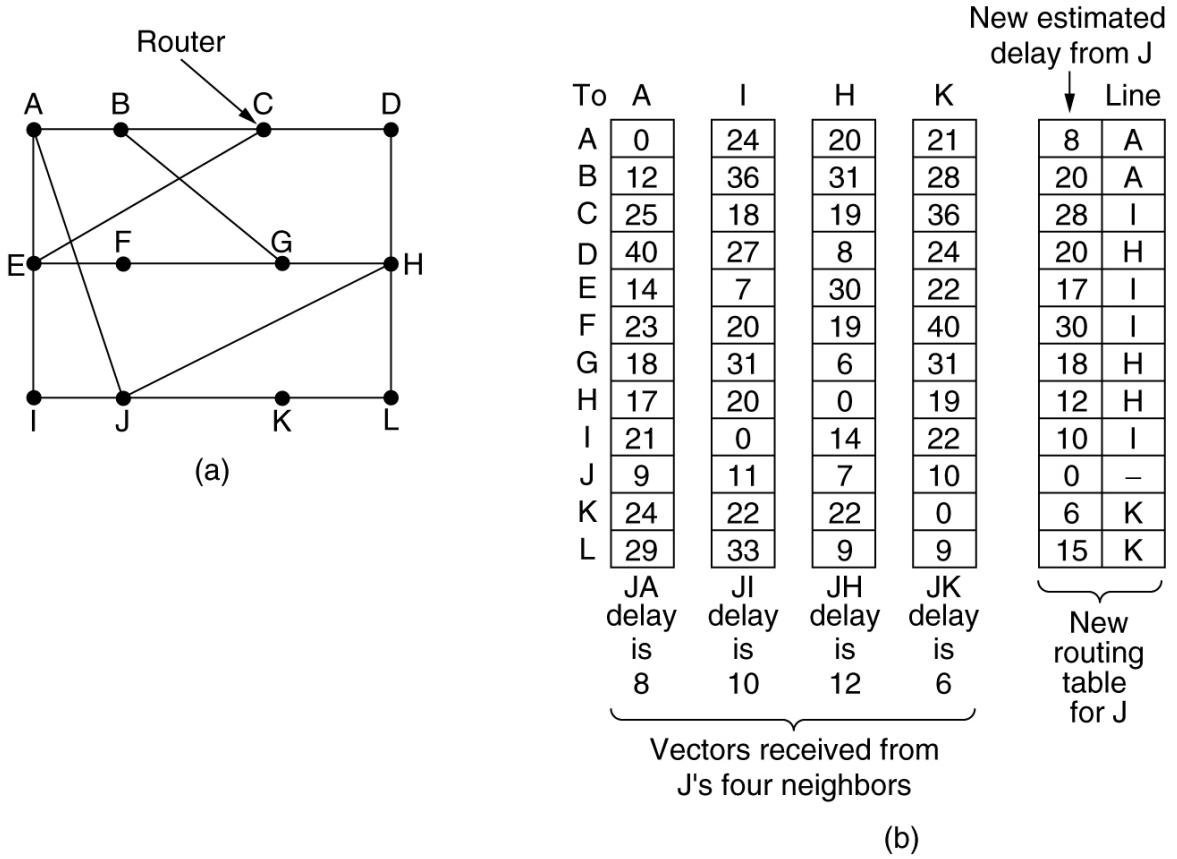


Figure 5-9.(a) A subnet. (b) Input from A, I, H, K, and the new routing table for J.

Routing Information Protocol (RIP)

- RIP had widespread use because it was distributed with BSD Unix in *"routed"*, *a router management daemon.*
- **RIP** is the most used Distance Vector protocol.
- RFC1058 in June 1988.
- Sends packets every 30 seconds or faster.
- Runs over UDP.
- Metric = hop count
- BIG problem is max. hop count =16

  ➔ RIP limited to running on small networks!!
- Upgraded to RIPv2

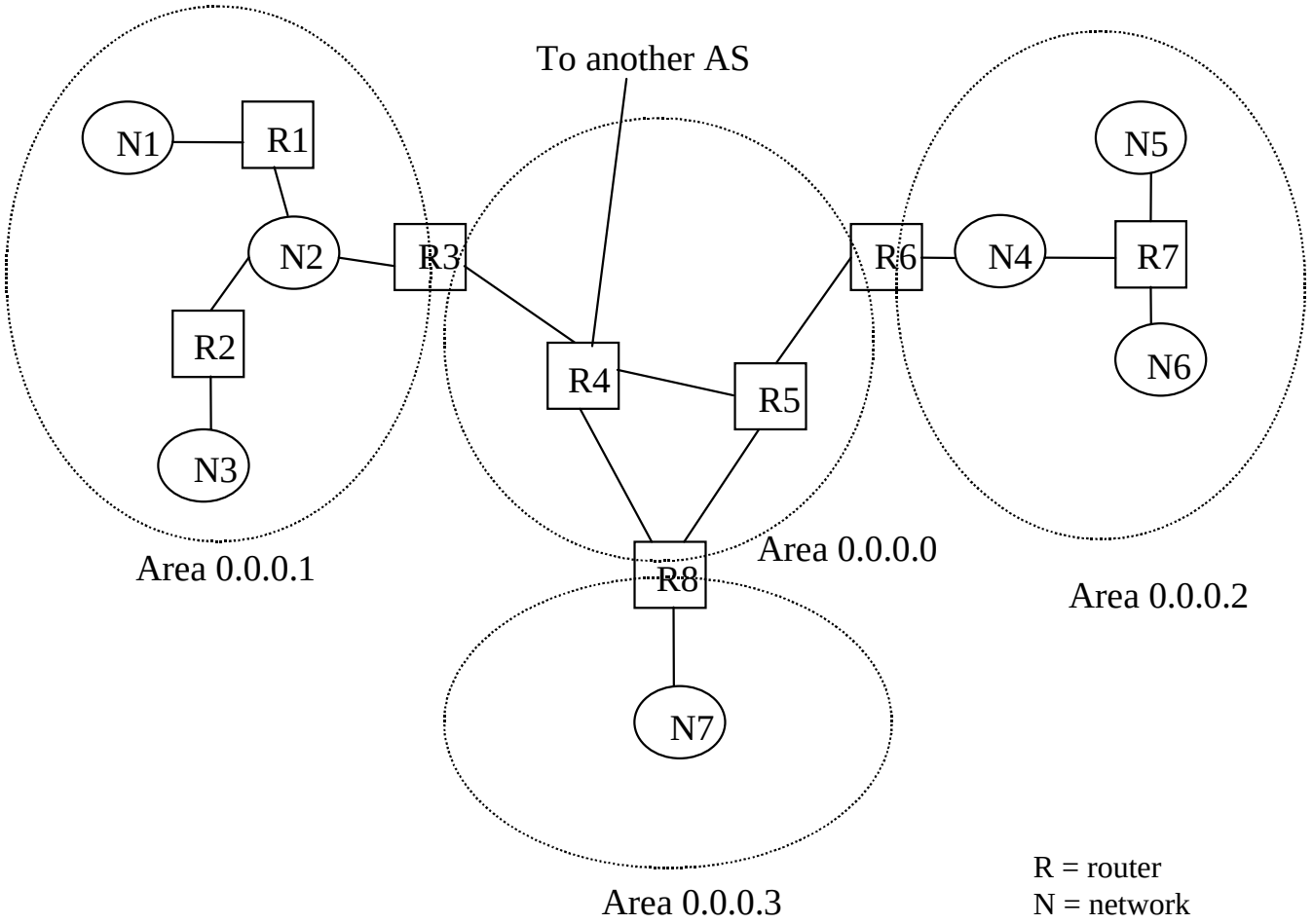
Link State Algorithm

1. Each router is responsible for meeting its neighbors and learning their names.
2. Each router constructs a link state packet (**LSP)** which consists of a list of names and cost to reach each of its neighbors.
3. The **LSP** is transmitted to ***ALL other routers***. Each router stores the most recently generated **LSP** from each other router.
4. Each router uses complete information on the network topology to compute the *shortest path route* to each destination node.

Open Shortest Path First (OSPF)

- OSPF runs *on top of* IP, i.e., an OSPF packet is transmitted with IP data packet header.
- Uses Level 1 and Level 2 routers
- Has: backbone routers, area border routers, and AS boundary routers
- LSPs referred to as **LSAs (Link State Advertisements)**
- Complex algorithm due to **five** distinct LSA types.

OSPF Areas



OSPF

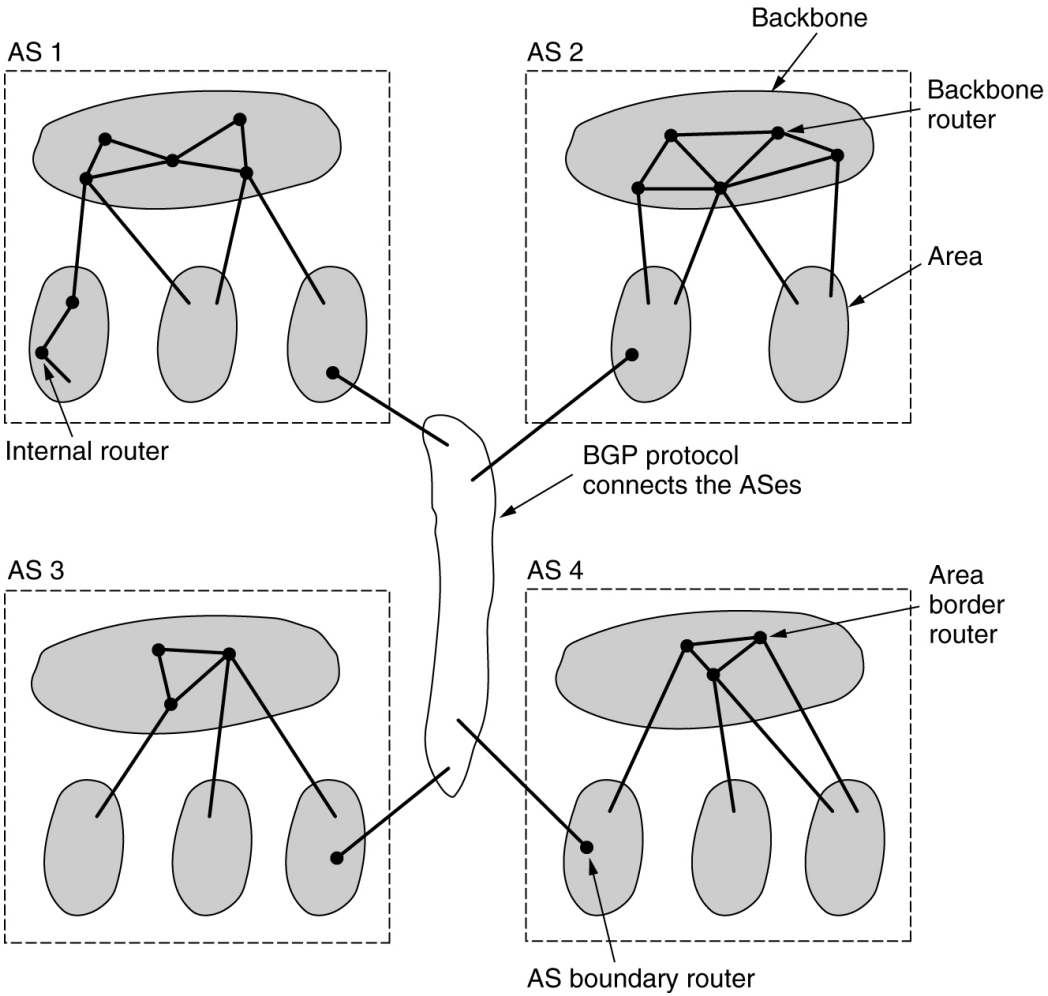


Figure 5-65.The relation between ASes, backbones, and areas in OSPF.

Border Gateway Protocol (BGP)

- The replacement for EGP is BGP. Current version is BGP-4.
- BGP assumes the Internet is an arbitrary interconnected set of AS's.
- In *interdomain* routing the goal is to find ANY path to the intended destination that is loop-free. The protocols are more concerned with **reachability** than optimality.