# Distance Vector Routing

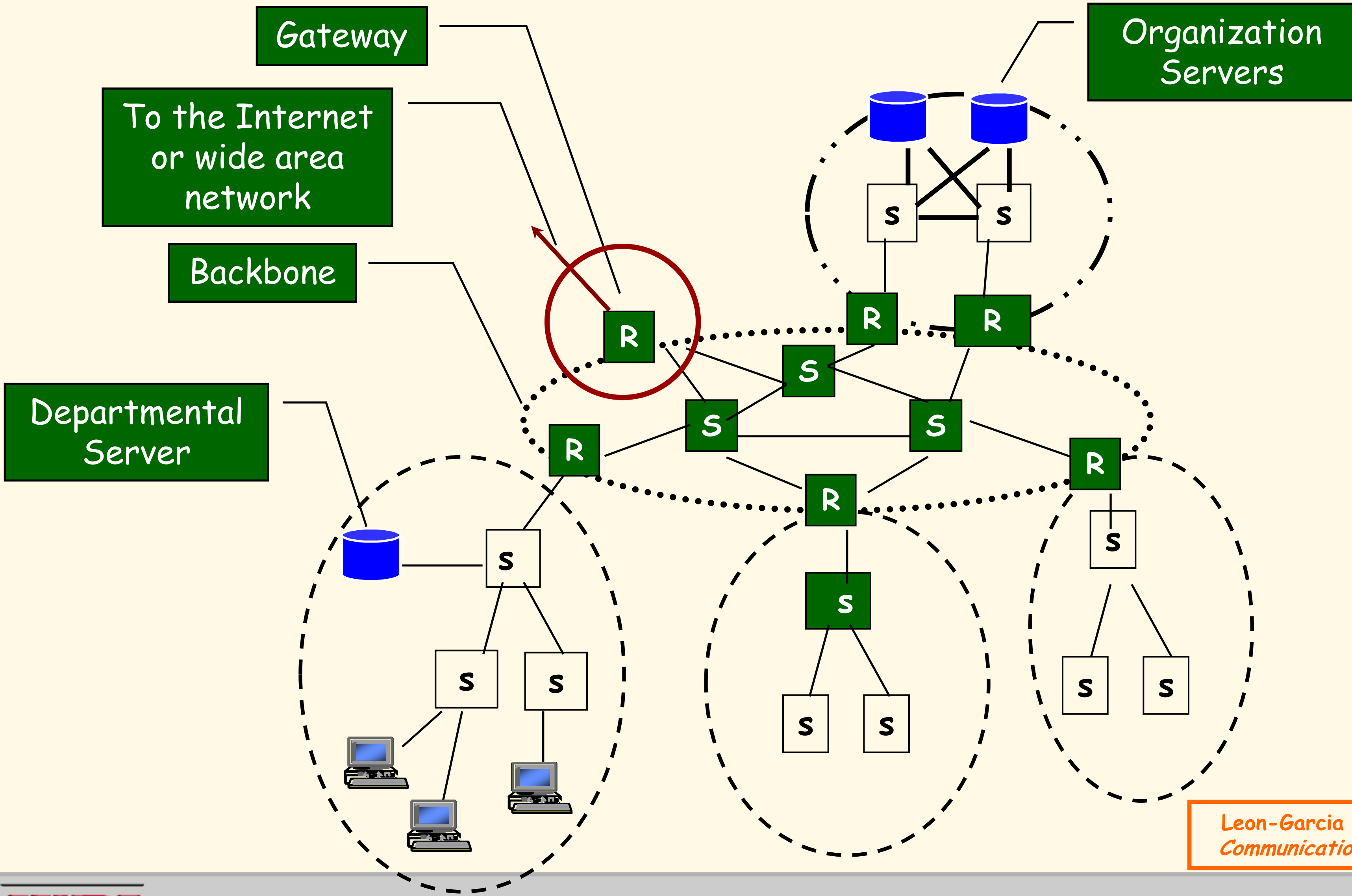
WPI

# DV Routing Outline

- Internet Context
- Network Layer Routing (**K&R slides)
- Quick Routing Overview
- Distance Vector Routing (my version)
  - Adapted from Tanenbaum & Perlman Texts
- Distance Vector Routing (K&R version)
- Summary

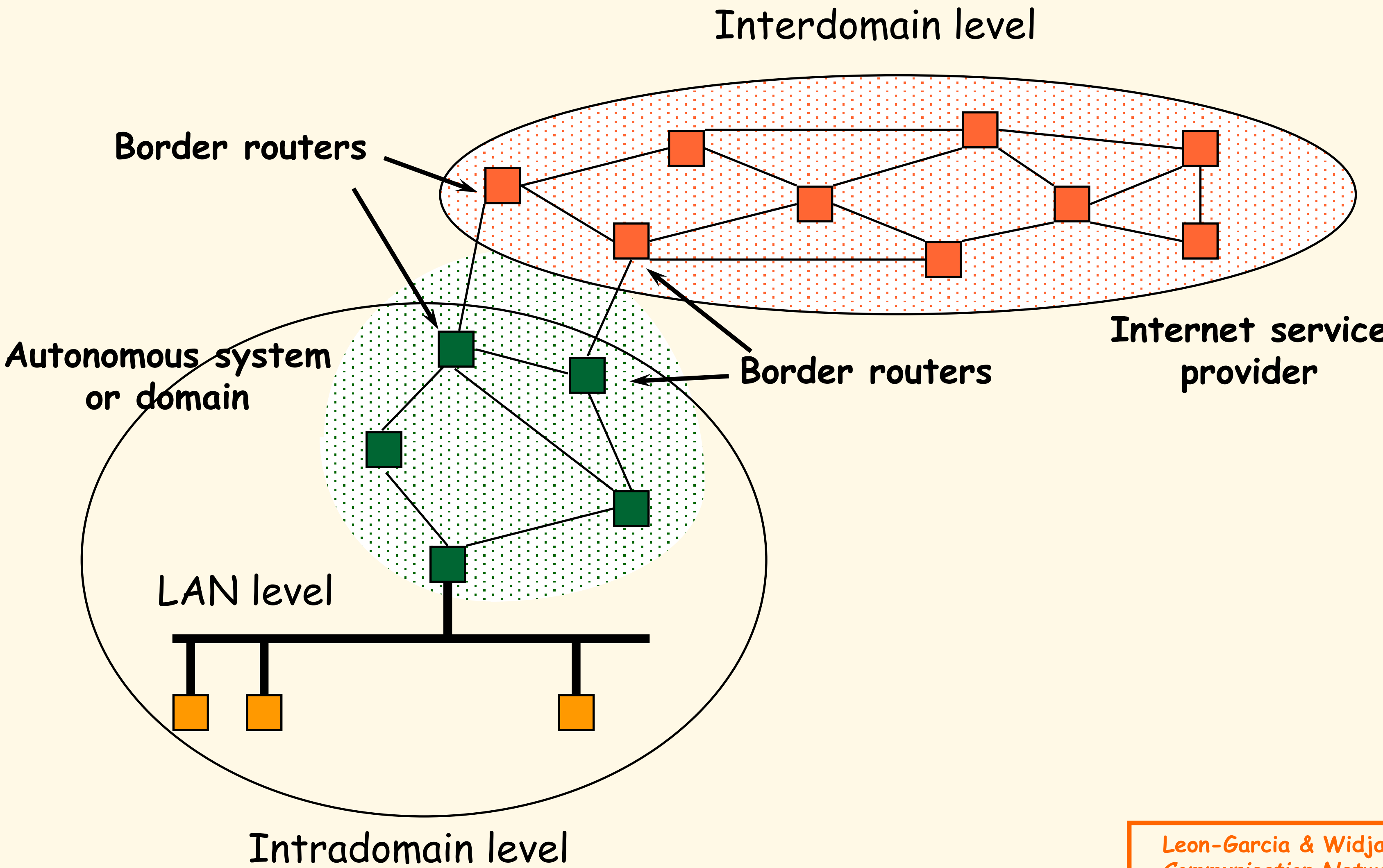
# Internet Context

# Metropolitan Area Network (MAN)




Leon-Garcia & Widjaja: *Communication Networks*

# Wide Area Network (WAN)

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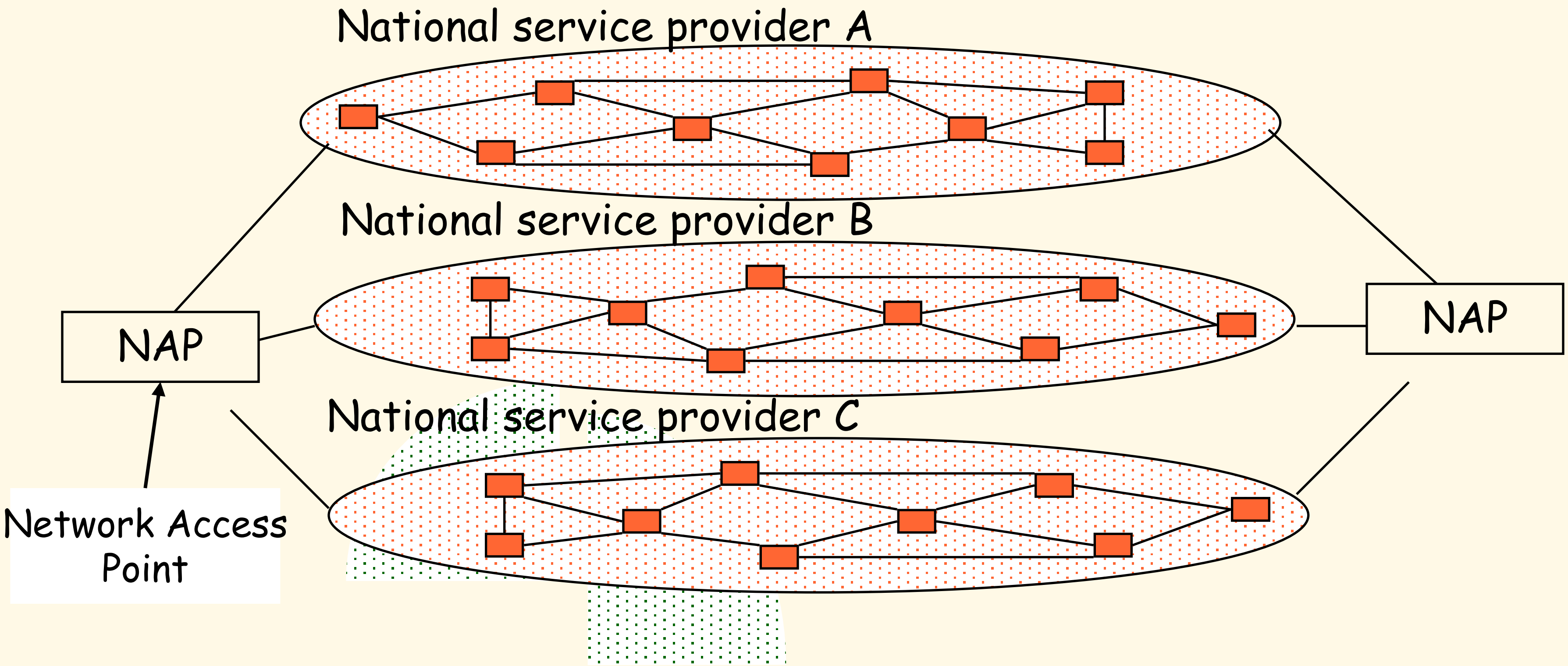
# Modern Internet Backbone




**National Internet Service Providers**

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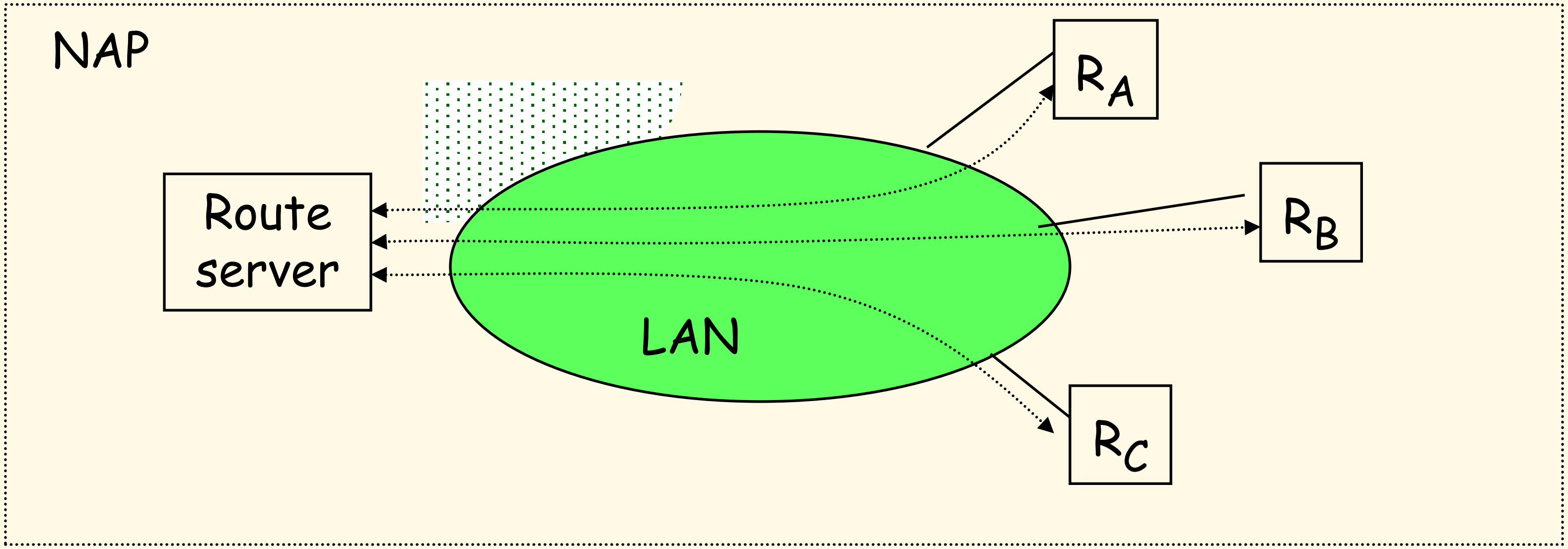
# Network Access Point

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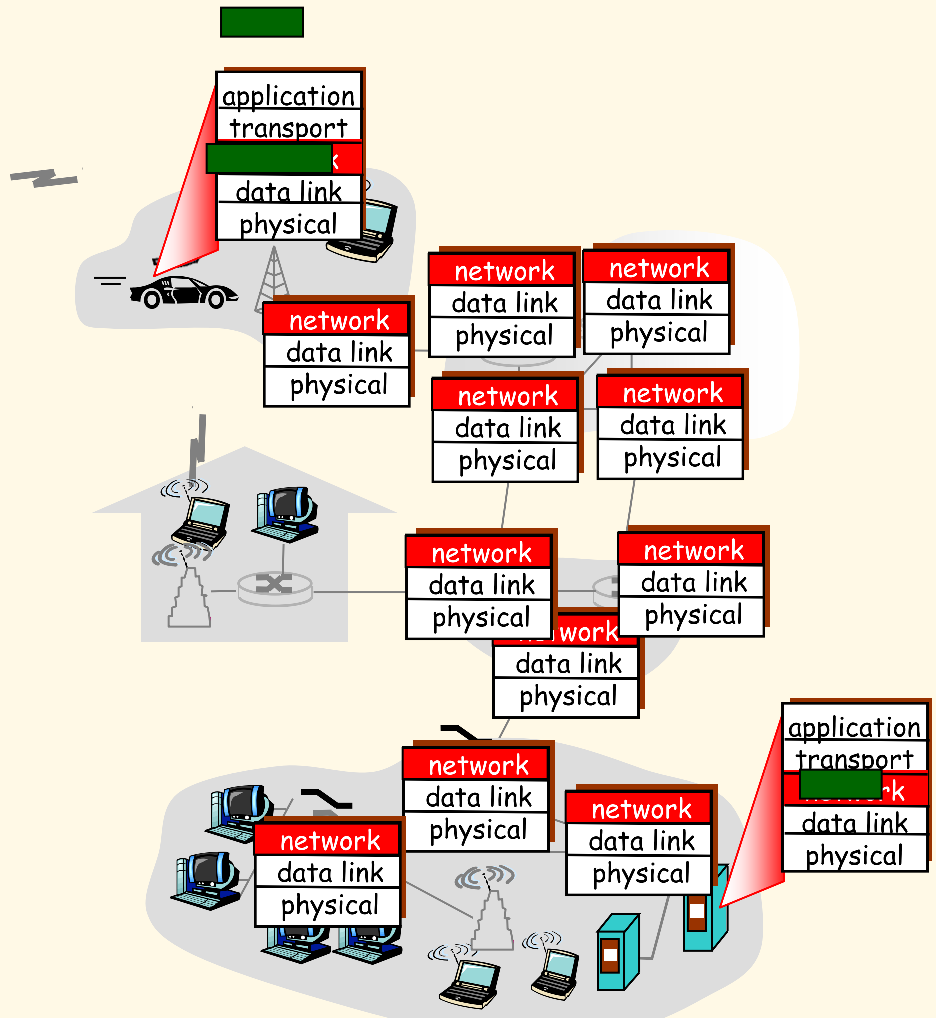
# Network Layer Routing

# Network Layer

- transport segment from sending to receiving host.
- on sending side, encapsulates segments into datagram packets.
- on receiving side, delivers segments to transport layer.
- network layer protocols in every host and router.
- router examines header fields in all IP datagrams passing through it.



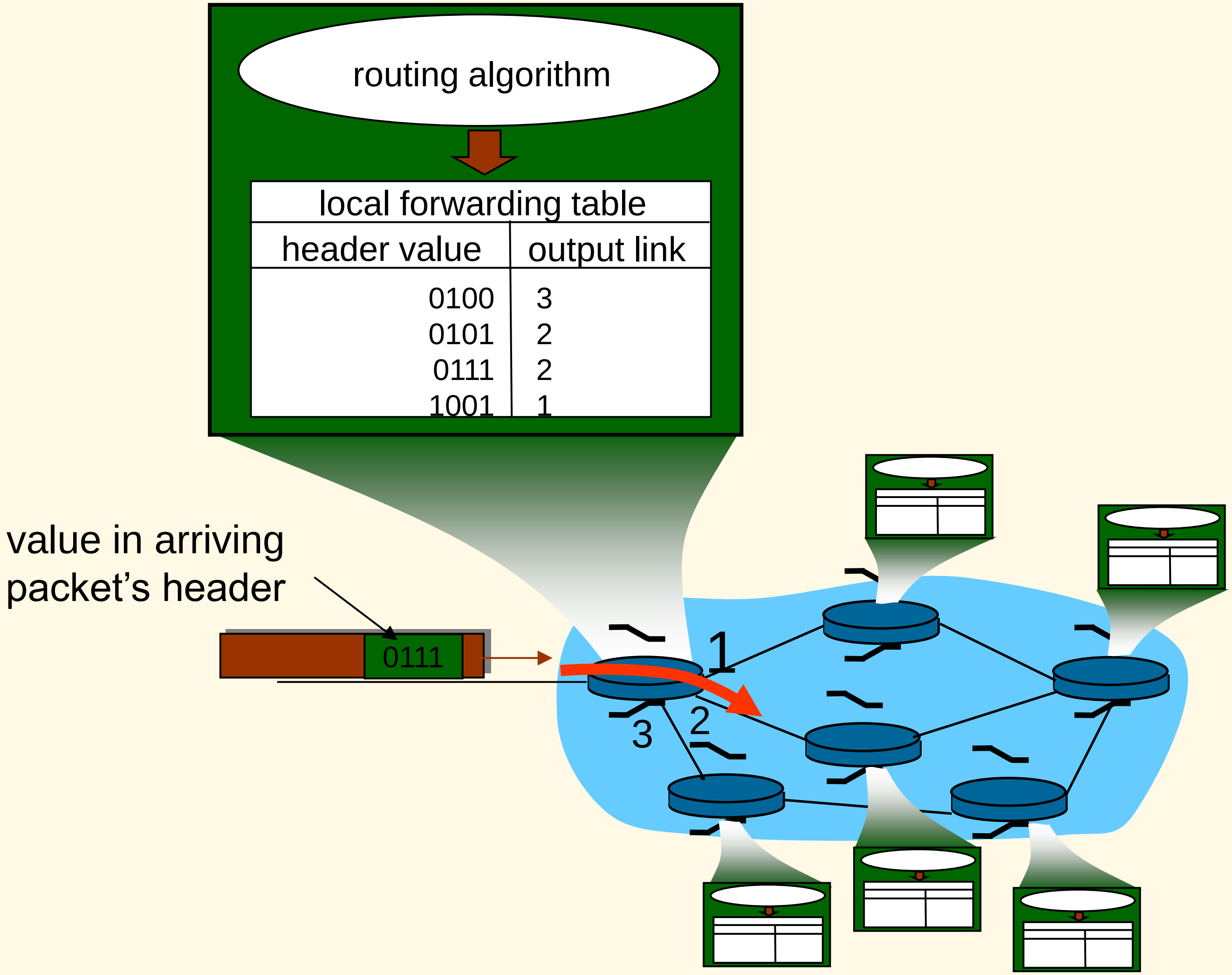
# Two Key Network Layer Functions

- *forwarding:* move packets from router's input to appropriate router output.
- *routing:* determine route taken by packets from source to destination.

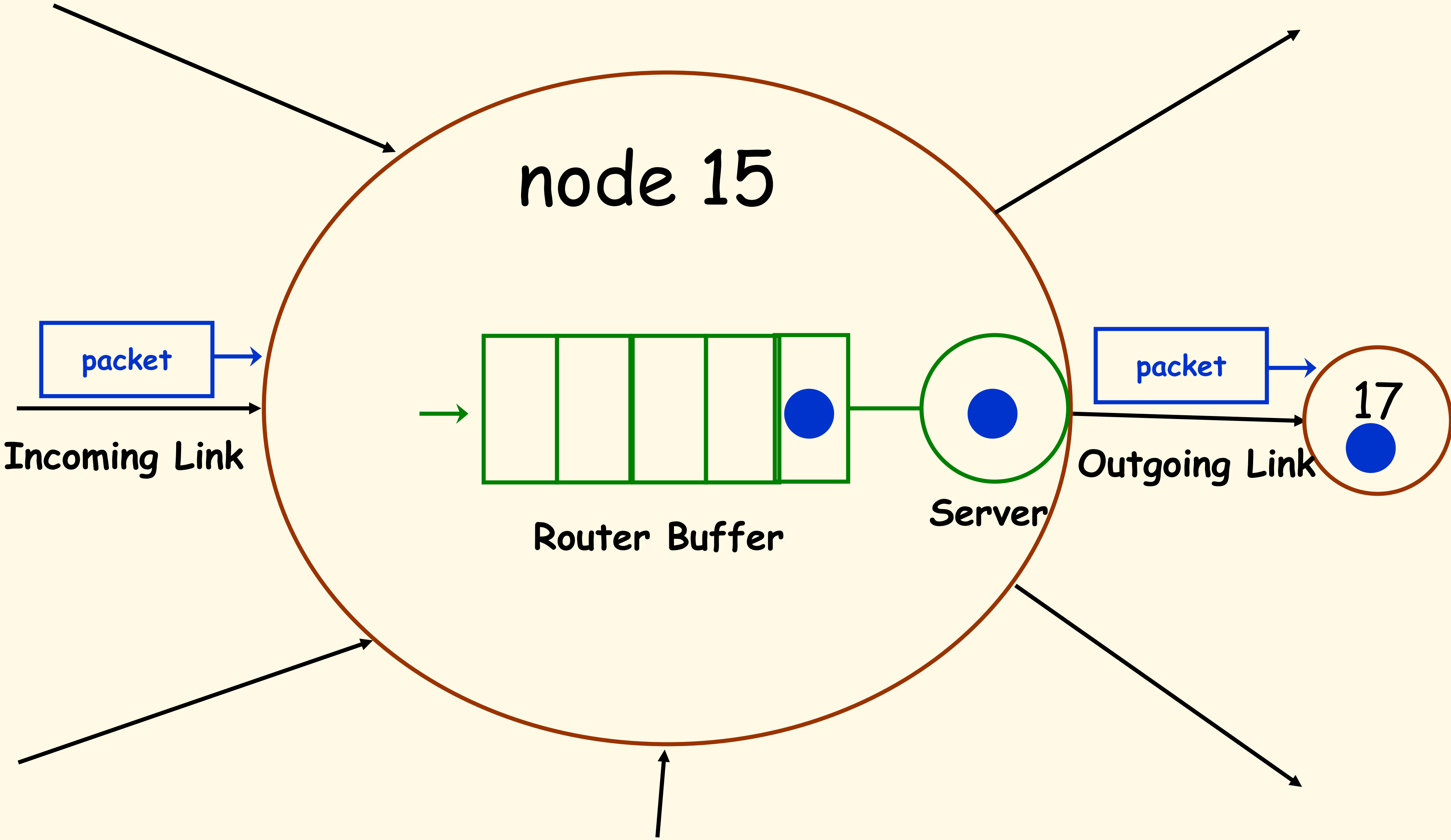
analogy:

- **routing:** process of planning trip from source to destination
- **forwarding:** process of getting through single interchange

# Interplay between Routing and Forwarding

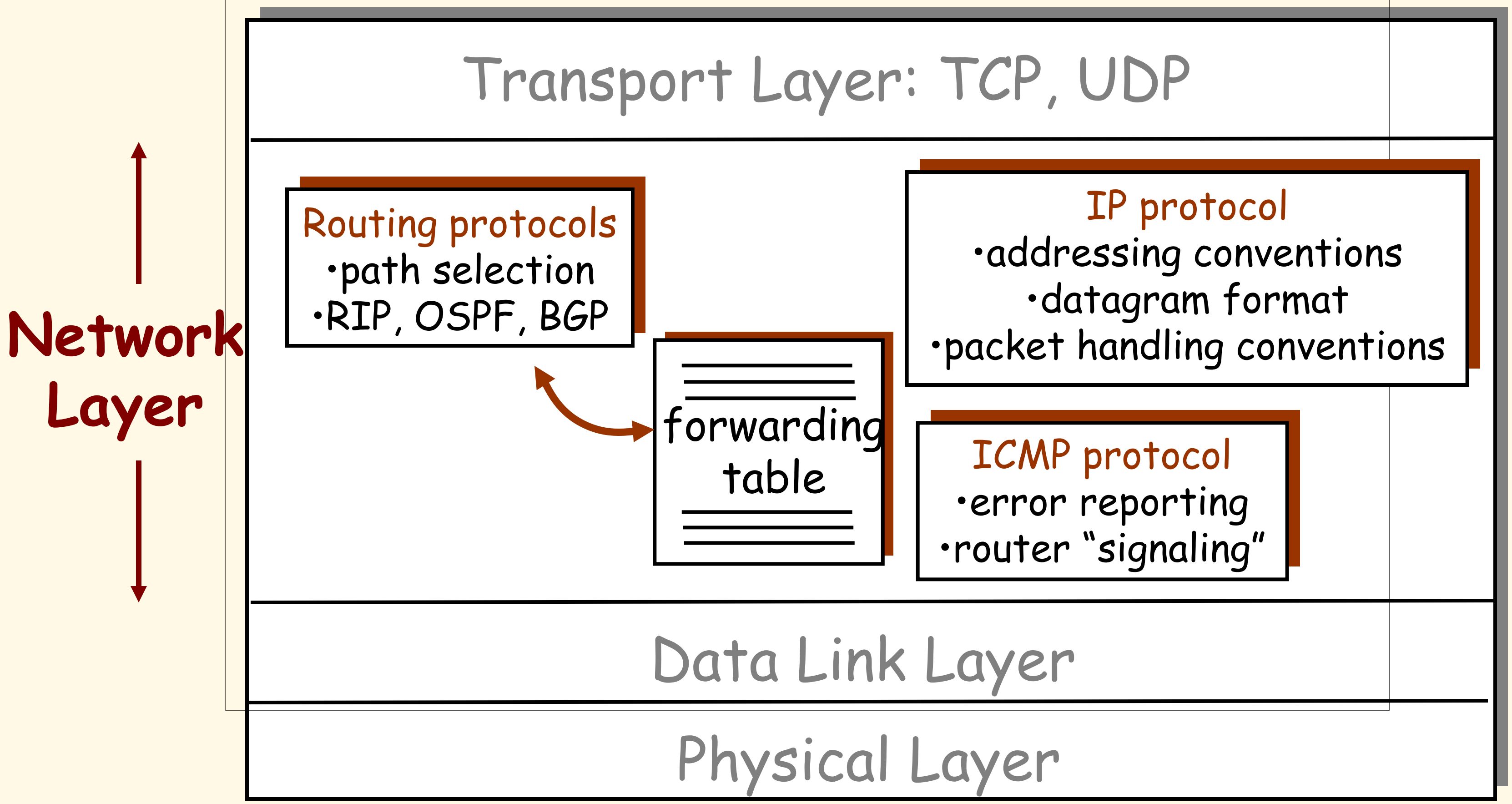


# Router Node


node 15
packet
Incoming Link
Router Buffer
Server
packet
Outgoing Link
17

# The Internet Network Layer

**Host, router network layer functions:**



# Quick Routing Overview

# 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.

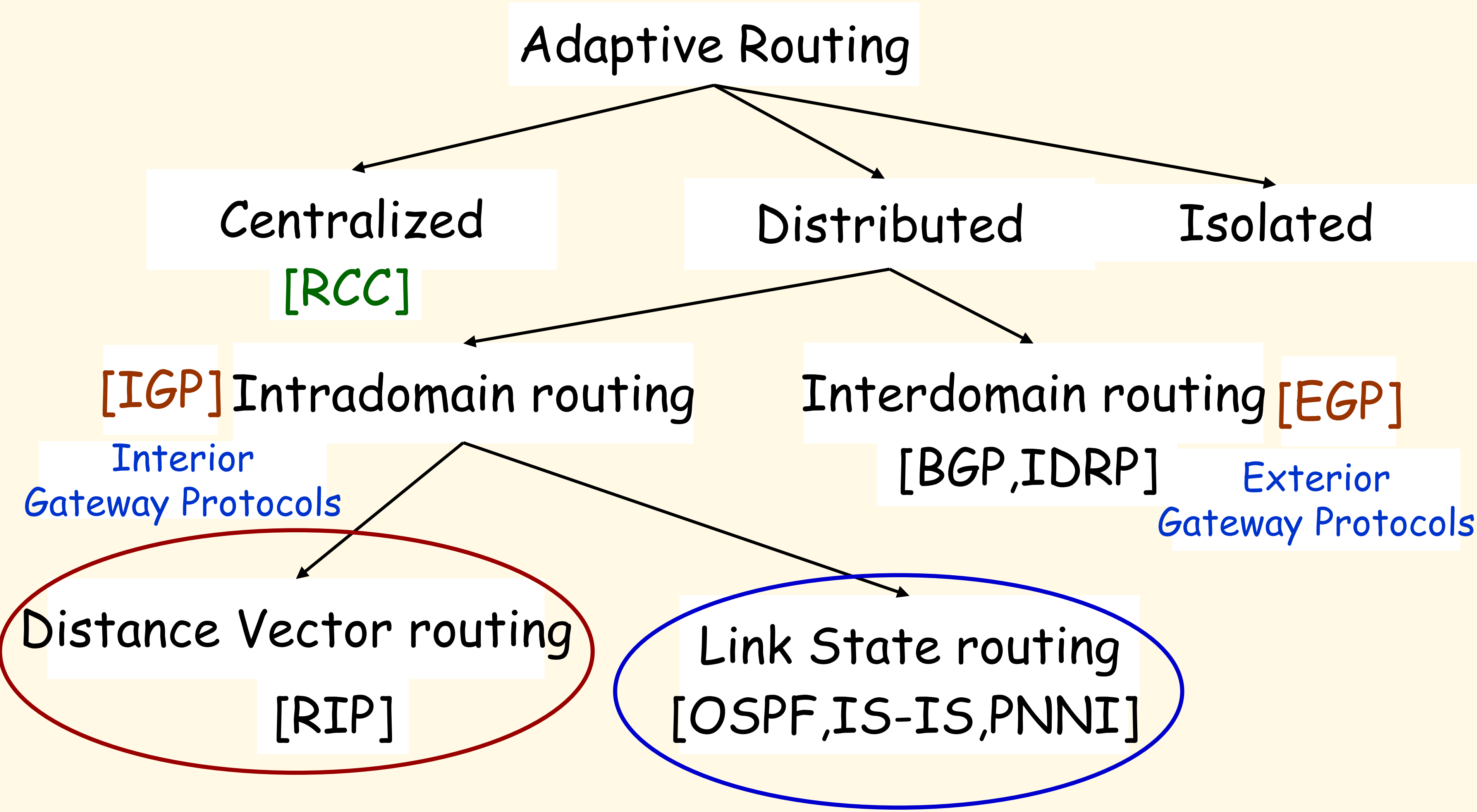
1. centralized
2. isolated
3. distributed

## Non-Adaptive Routing

routing computed in advance and off-line

1. flooding
2. static routing using shortest path algorithms

# Internetwork Routing [Halsall]



# Adaptive Routing Design

Design Issues:

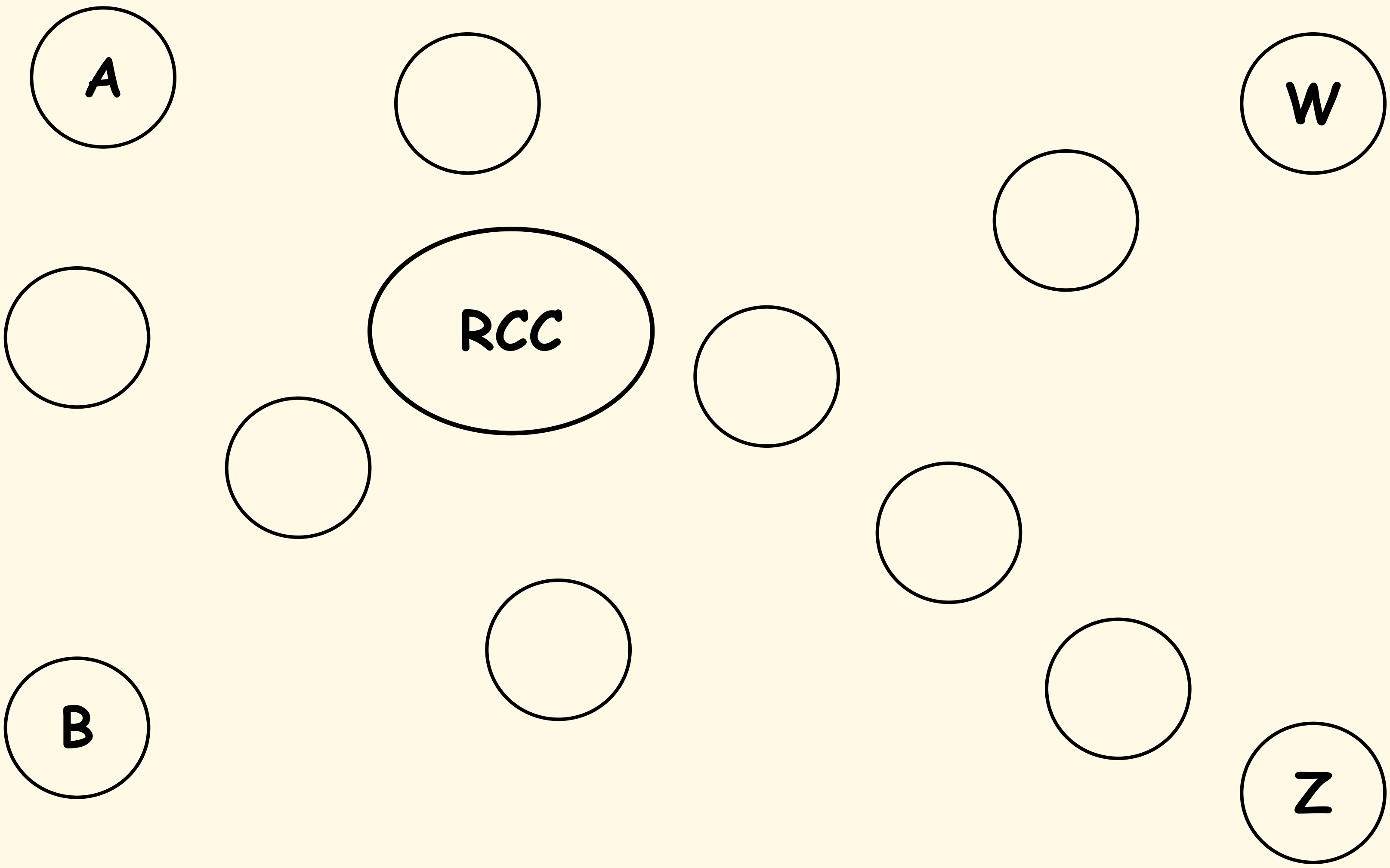
1. How much overhead is incurred due to gathering the routing information and sending *routing packets*?
2. What is the time frame (i.e, the frequency) for sending *routing packets* in support of adaptive routing?
3. What is the complexity of the routing strategy?

# Adaptive Routing

Basic functions:

1. Measurement of pertinent network data.
2. Forwarding of information to where the routing computation will be done.
3. Compute the routing tables.
4. Convert the routing table information into a routing decision and then dispatch the data packet.

# Centralized Routing



# Distance Vector Routing

## {Tanenbaum & Perlman version}

# Distance Vector Routing

- Historically known as the old ARPANET routing algorithm {or known as Bellman-Ford (BF) algorithm}.
- BF Basic idea: each router maintains a Distance Vector table containing the *distance* between itself and ALL possible destination nodes.
- Distances,based on a chosen metric, are computed using information from the neighbors' distance vectors.
- Distance 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).

## Distance Vector Table Initialization

Distance to itself = 0

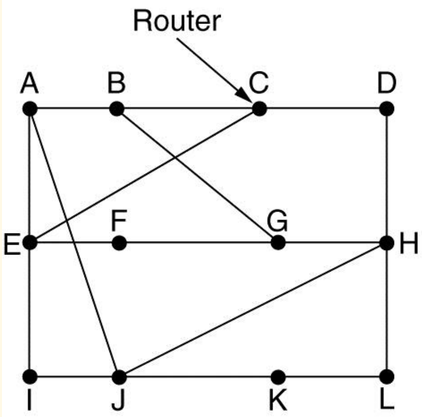
Distance to ALL other routers = infinity number

# Distance Vector Algorithm [Perlman]

1. A router transmits its distance vector to each of its neighbors in a routing packet.
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 Example




(a)

| To | A | I | H | K | New estimated delay from J | Line |
|---|---|---|---|---|---|---|
| A | 0 | 24 | 20 | 21 | 8 | A |
| B | 12 | 36 | 31 | 28 | 20 | A |
| C | 25 | 18 | 19 | 36 | 28 | I |
| D | 40 | 27 | 8 | 24 | 20 | H |
| E | 14 | 7 | 30 | 22 | 17 | I |
| F | 23 | 20 | 19 | 40 | 30 | I |
| G | 18 | 31 | 6 | 31 | 18 | H |
| H | 17 | 20 | 0 | 19 | 12 | H |
| I | 21 | 0 | 14 | 22 | 10 | I |
| J | 9 | 11 | 7 | 10 | 0 | – |
| K | 24 | 22 | 22 | 0 | 6 | K |
| L | 29 | 33 | 9 | 9 | 15 | K |
| | JA delay is 8 | JI delay is 10 | JH delay is 12 | JK delay is 6 | New routing table for J | |

Vectors received from J's four neighbors

(b)

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

Tanenbaum

# Distance Vector Routing

## {Kurose & Ross version}

# Distance Vector Algorithm

## Bellman-Ford Equation (dynamic programming)

Define

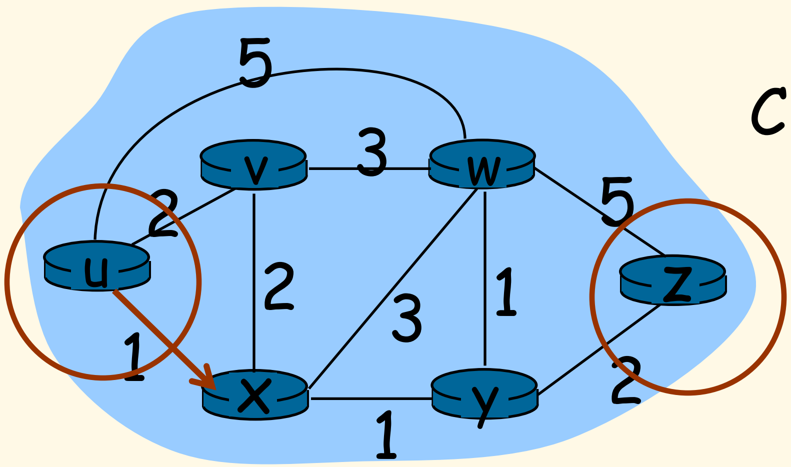
$d_x(y)$ := cost of least-cost path from x to y

Then

$$d_x(y) = \min_v \{c(x,v) + d_v(y)\}$$

where min is taken over all neighbors v of x.

# Bellman-Ford Example




Clearly, $d_v(z) = 5$, $d_x(z) = 3$, $d_w(z) = 3$

B-F equation says:

$$d_u(z) = \min \{ c(u,v) + d_v(z), \; c(u,x) + d_x(z), \; c(u,w) + d_w(z) \}$$
$$= \min \{2 + 5, \; 1 + 3, \; 5 + 3\} = 4$$

The node that achieves minimum is next hop in shortest path ➜ forwarding table.

Namely, packets from u destined for z are forwarded out link between u and x.

# Distance Vector Algorithm (3)

- $D_x(y)$ = estimate of least cost from x to y
- Node x knows cost to each neighbor v:

  $c(x,v)$

- Node x maintains distance vector

  $D_x = [D_x(y): y \in N]$

- Node x also maintains its neighbors' distance vectors
  - For each neighbor v, x maintains

    $D_v = [D_v(y): y \in N]$

# Distance Vector Algorithm (4)

DV Basic idea:

- From time-to-time, each node sends its own distance vector estimate to neighbors.
- Asynchronous
- When a node x receives a new DV estimate from any neighbor v, it saves v's distance vector and it updates its own DV using B-F equation:

$$D_x(y) \leftarrow \min_v\{c(x,v) + D_v(y)\} \quad \text{for each node } y \in N$$

- Under minor, natural conditions, the estimate $D_x(y)$ converges to the actual least cost $d_x(y)$.

# Distance Vector Algorithm (5)

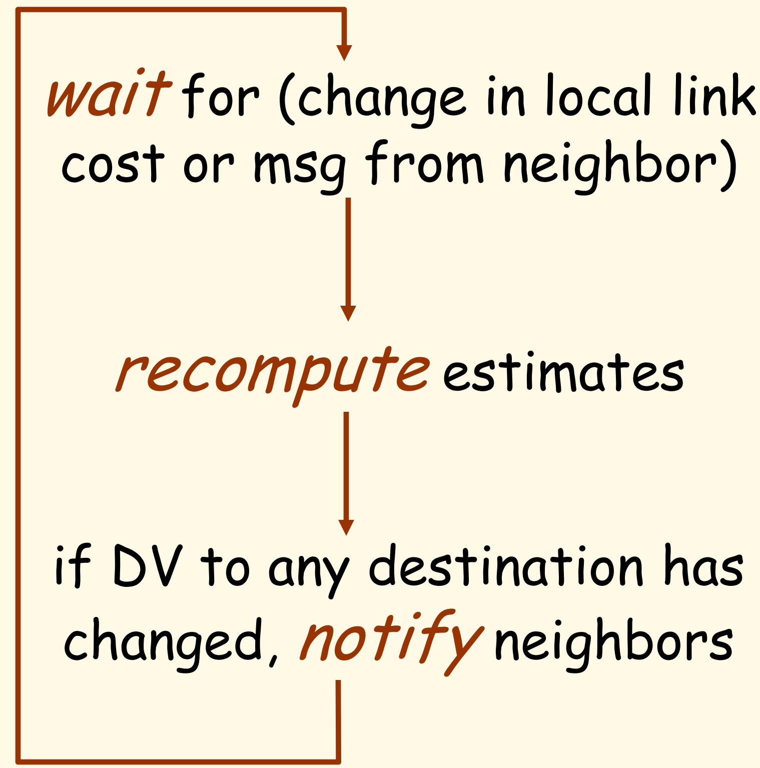
**Iterative, asynchronous:** each local iteration caused by:

- local link cost change
- DV update message from neighbor

**Distributed:**

- each node notifies neighbors only when its DV changes
  - neighbors then notify their neighbors if necessary.

**Each node:**



$D_x(y) = \min\{c(x,y) + D_y(y),\ c(x,z) + D_z(y)\}$
$= \min\{2+0\ ,\ 7+1\} = 2$

$D_x(z) = \min\{c(x,y) + D_y(z),\ c(x,z) + D_z(z)\}$
$= \min\{2+1\ ,\ 7+0\} = 3$

**node x table**

cost to

| from | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 7 |
| y | ∞ | ∞ | ∞ |
| z | ∞ | ∞ | ∞ |

cost to

| from | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 3 |
| y | 2 | 0 | 1 |
| z | 7 | 1 | 0 |

**node y table**

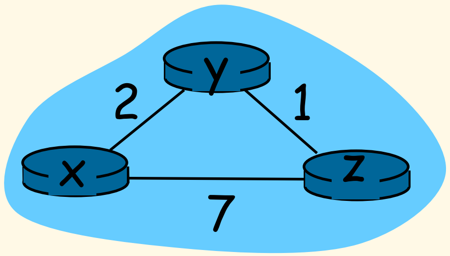
cost to

| from | x | y | z |
|---|---|---|---|
| x | ∞ | ∞ | ∞ |
| y | 2 | 0 | 1 |
| z | ∞ | ∞ | ∞ |

**node z table**

cost to

| from | x | y | z |
|---|---|---|---|
| x | ∞ | ∞ | ∞ |
| y | ∞ | ∞ | ∞ |
| z | 7 | 1 | 0 |




time

$D_x(y) = \min\{c(x,y) + D_y(y), c(x,z) + D_z(y)\}$
$= \min\{2+0 , 7+1\} = 2$

$D_x(z) = \min\{c(x,y) + D_y(z), c(x,z) + D_z(z)\}$
$= \min\{2+1 , 7+0\} = 3$

**node x table**

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 7 |
| y | ∞ | ∞ | ∞ |
| z | ∞ | ∞ | ∞ |

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 3 |
| y | 2 | 0 | 1 |
| z | 7 | 1 | 0 |

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 3 |
| y | 2 | 0 | 1 |
| z | 3 | 1 | 0 |

**node y table**

| from \ cost to | x | y | z |
|---|---|---|---|
| x | ∞ | ∞ | ∞ |
| y | 2 | 0 | 1 |
| z | ∞ | ∞ | ∞ |

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 7 |
| y | 2 | 0 | 1 |
| z | 7 | 1 | 0 |

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 3 |
| y | 2 | 0 | 1 |
| z | 3 | 1 | 0 |

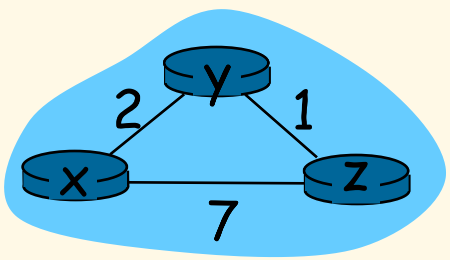
**node z table**

| from \ cost to | x | y | z |
|---|---|---|---|
| x | ∞ | ∞ | ∞ |
| y | ∞ | ∞ | ∞ |
| z | 7 | 1 | 0 |

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 7 |
| y | 2 | 0 | 1 |
| z | 3 | 1 | 0 |

| from \ cost to | x | y | z |
|---|---|---|---|
| x | 0 | 2 | 3 |
| y | 2 | 0 | 1 |
| z | 3 | 1 | 0 |

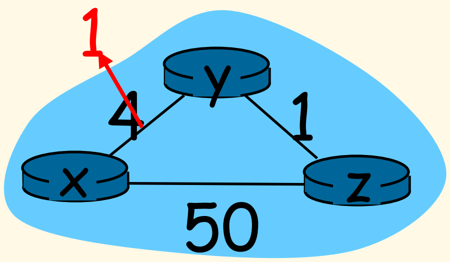
time →



# Distance Vector: Link Cost Changes

Link cost changes:

- node detects local link cost change.
- updates routing info, recalculates distance vector.
- if DV changes, it notifies neighbors




“good news travels fast”

At time $t_0$, *y* detects the link-cost change, updates its DV, and informs its neighbors.

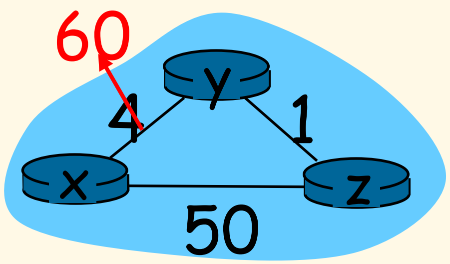
At time $t_1$, *z* receives the update from *y* and updates its table. It computes a new least cost to *x* and sends its neighbors its DV.

At time $t_2$, *y* receives *z*'s update and updates its distance table. *y*'s least costs do not change and hence *y* does *not* send any message to *z*.

# Distance Vector: Link Cost Changes

## Link cost changes:

- good news travels fast
- bad news travels slow - "count to infinity" problem!
- 44 iterations before algorithm stabilizes: see text!




## Poisoned reverse:

- If Z routes through Y to get to X :
  - Z tells Y its (Z's) distance to X is infinite (so Y won't route to X via Z)
- will this completely solve count to infinity problem?

# Distance Vector Summary

The Network Layer is responsible for routing and forwarding.

The routing process is used to build forwarding lookup tables.

Forwarding uses the lookup table to move an incoming packet to the correct outgoing link queue.

Routing algorithms use link cost metrics such as hops or delay.

Distance Vector (DV) is an intradomain adaptive routing algorithm that does not scale well.

# Distance Vector Summary

DV (originally the old ARPA algorithm) employs the Bellman-Ford shortest path algorithm and currently is used in the RIP, RIP-2, BGP, ISO IDRP and Novell IPX protocols.

DV routers:

- keep distances to ALL intranet routers in a distance vector which is periodically updated and transmitted to each of its neighbors.
- reacts to changes in its neighbors' distance vectors and to topology changes (i.e., nodes and/or links coming up or going down).

In distance vector routing "bad news travels slowly and good news travels quickly".