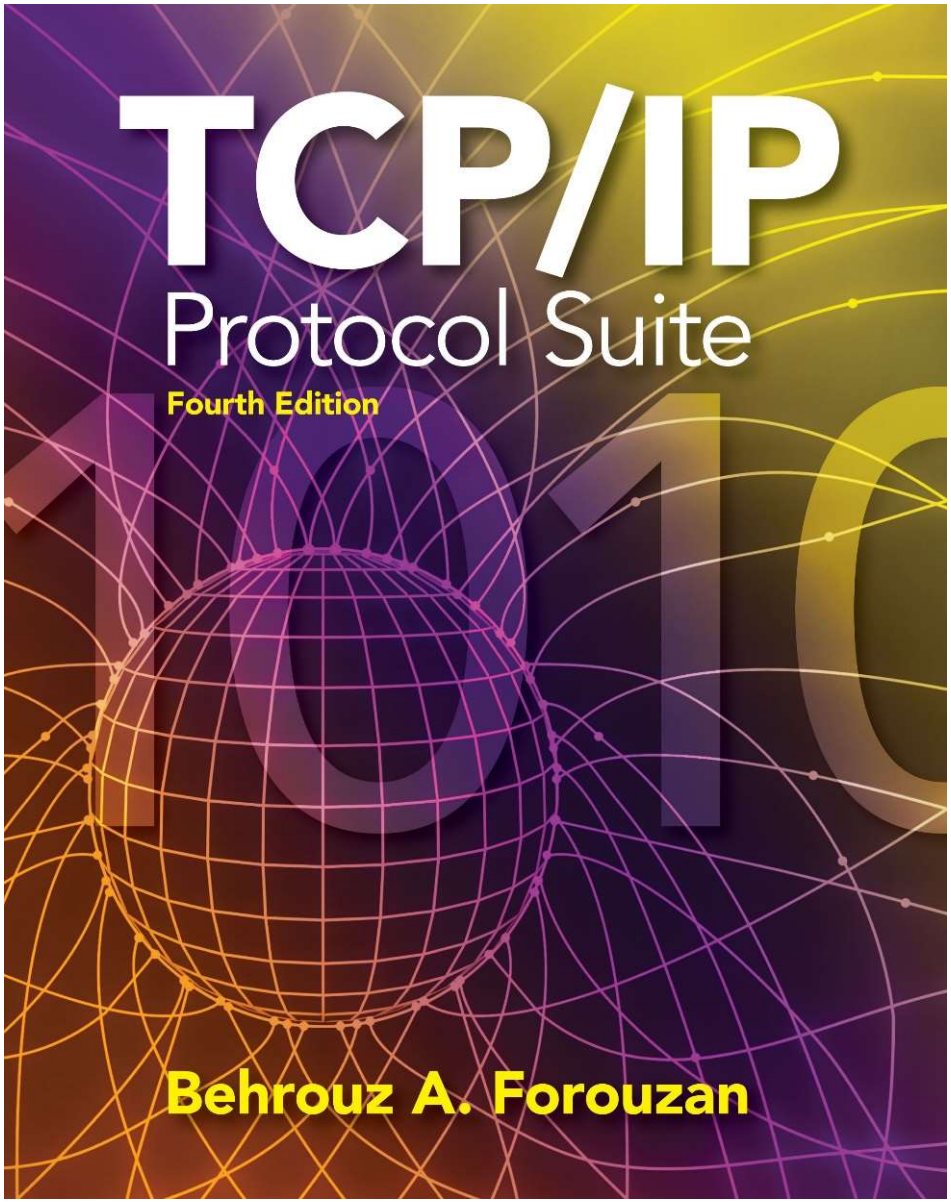
Chapter 11

Unicast Routing Protocols



OBJECTIVES:

- To introduce the idea of autonomous systems (ASs) that divide the Internet into smaller administrative regions.
- To discuss the idea of distance vector routing and the RIP that is used to implement the idea.
- To discuss the idea of link state routing as the second intra-AS routing method and OSPF that is used to implement the idea.
- To discuss the idea of path vector routing as the dominant inter-AS routing method and BGP that is used to implement the idea.

Chapter Outline

11-1 INTRODUCTION

An internet is a combination of networks connected by routers. When a datagram goes from a source to a destination, it will probably pass through many routers until it reaches the router attached to the destination network.

11-2 INTER- AND INTRA-DOMAIN ROUTING

Today, an internet can be so large that one routing protocol cannot handle the task of updating the routing tables of all routers. For this reason, an internet is divided into autonomous systems.

An autonomous system (AS) is a group of networks and routers under the authority of a single administration. Routing inside an autonomous system is called intra-domain routing. Routing between autonomous systems is called inter-domain routing

Each autonomous system is assigned a globally unique number called an Autonomous System Number (ASN) by The Internet Assigned Numbers Authority (IANA) .

India ASN Summary

The report below shows ASNs assigned to India, ranked by the total number of IP addresses currently active on each network. Click on the ASN for full IP address information, whois details and more. You can also view our hosting report to see the networks ranked by how many domain names they host.

ASN	NAME	NUM IPS
AS9829	National Internet Backbone	5,419,776
AS55836	Reliance Jio Infocomm Limited	4,175,616
AS45609	Bharti Airtel Ltd. AS for GPRS Service	3,842,560
AS24560	Bharti Airtel Ltd., Telemedia Services	3,489,536
AS9498	BHARTI Airtel Ltd.	2,045,184

https://ipinfo.io/countries/in

Figure 11.1 *Autonomous systems*

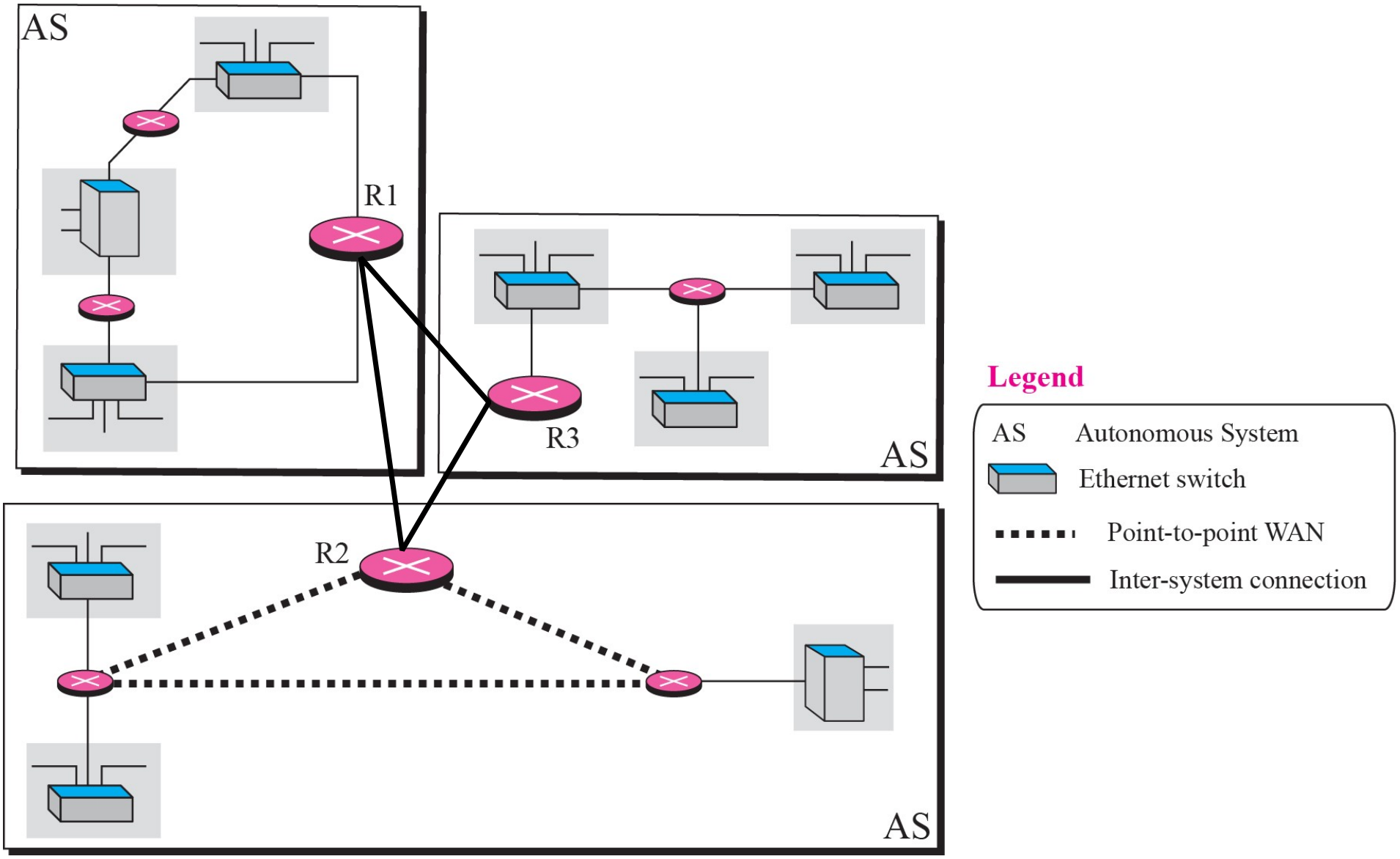
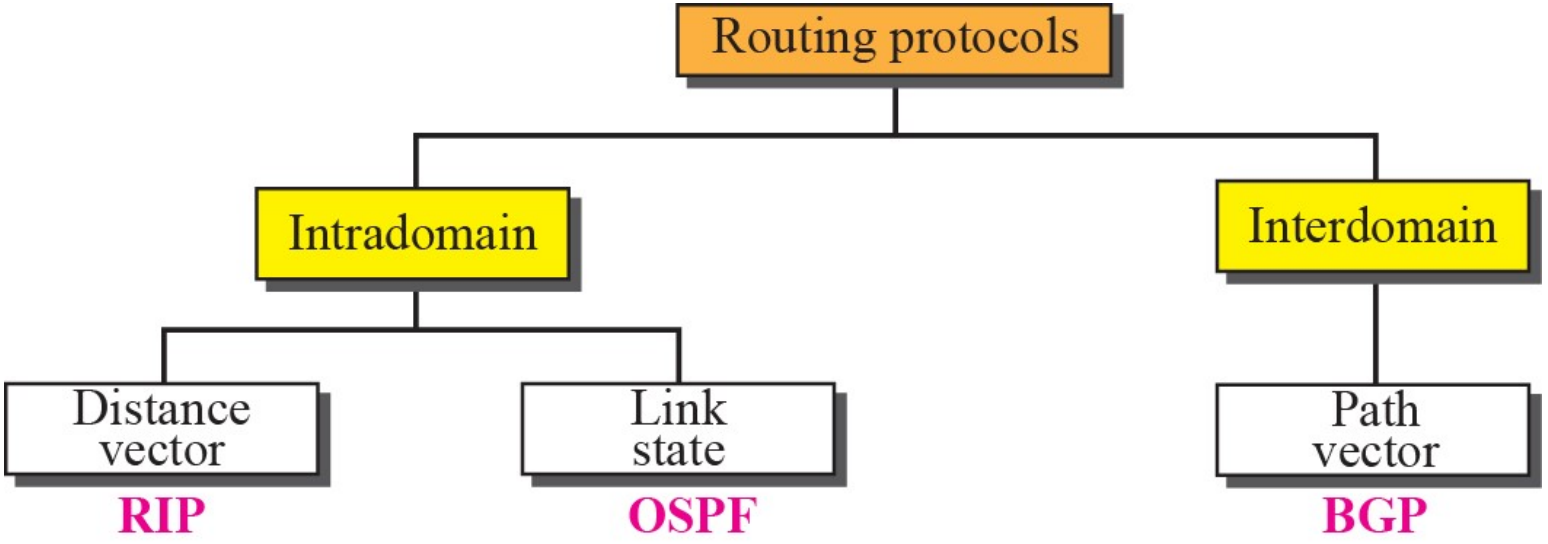


Figure 11.2 *Popular routing protocols*



11-3 DISTANCE VECTOR ROUTING

Today, an internet can be so large that one routing protocol cannot handle the task of updating the routing tables of all routers. For this reason, an internet is divided into autonomous systems. An

autonomous system (AS) is a group of networks and routers under the authority of a single administration. Routing inside an autonomous system is called intra-domain routing. Routing between autonomous systems is called inter-domain routing

Topics Discussed in the Section

- ✓ **Bellman-Ford Algorithm**
- ✓ **Distance Vector Routing Algorithm**
- ✓ **Count to Infinity**

Shortest Paths Problem

- Many possible paths connect any given source and to any given destination
- Routing involves the selection of the path to be used to accomplish a given transfer
- Typically it is possible to attach a cost or distance to a link connecting two nodes
- Routing can then be posed as a shortest path problem

Routing Metrics

Means for measuring desirability of a path

- Path Length = sum of costs or distances
- Possible metrics
  - Hop count: rough measure of resources used
  - Reliability: link availability; BER
  - Delay: sum of delays along path; complex & dynamic
  - Bandwidth: "available capacity" in a path
  - Load: Link & router utilization along path
  - Cost: $$$

Shortest Path Protocols

Distance Vector Protocols

- Neighbors exchange list of distances to destinations
- Best next-hop determined for each destination
- **Bellman-Ford** (distributed) shortest path algorithm

Link State Protocols

- Link state information flooded to all routers
- Routers have complete topology information
- Shortest path (& hence next hop) calculated
- **Dijkstra** (centralized) shortest path algorithm

6.3.1 Distance Vector

Do you know the way to San Jose?

Distance Vector

Local Signpost

- Direction
- Distance

Routing Table

For each destination list:

- Next Node
- Distance

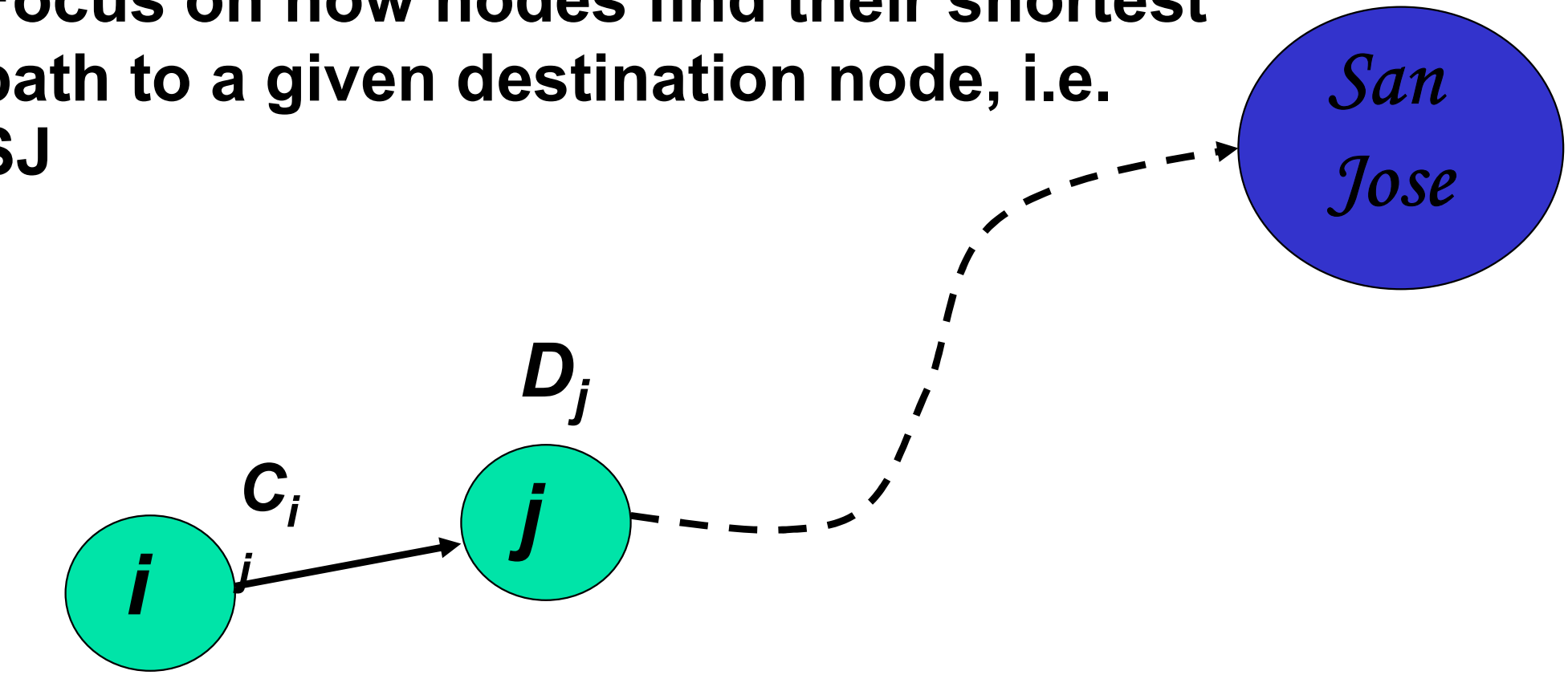
dest	next	dist

Table Synthesis

- Neighbors exchange table entries
- Determine current best next hop
- Inform neighbors
  - Periodically
  - After changes

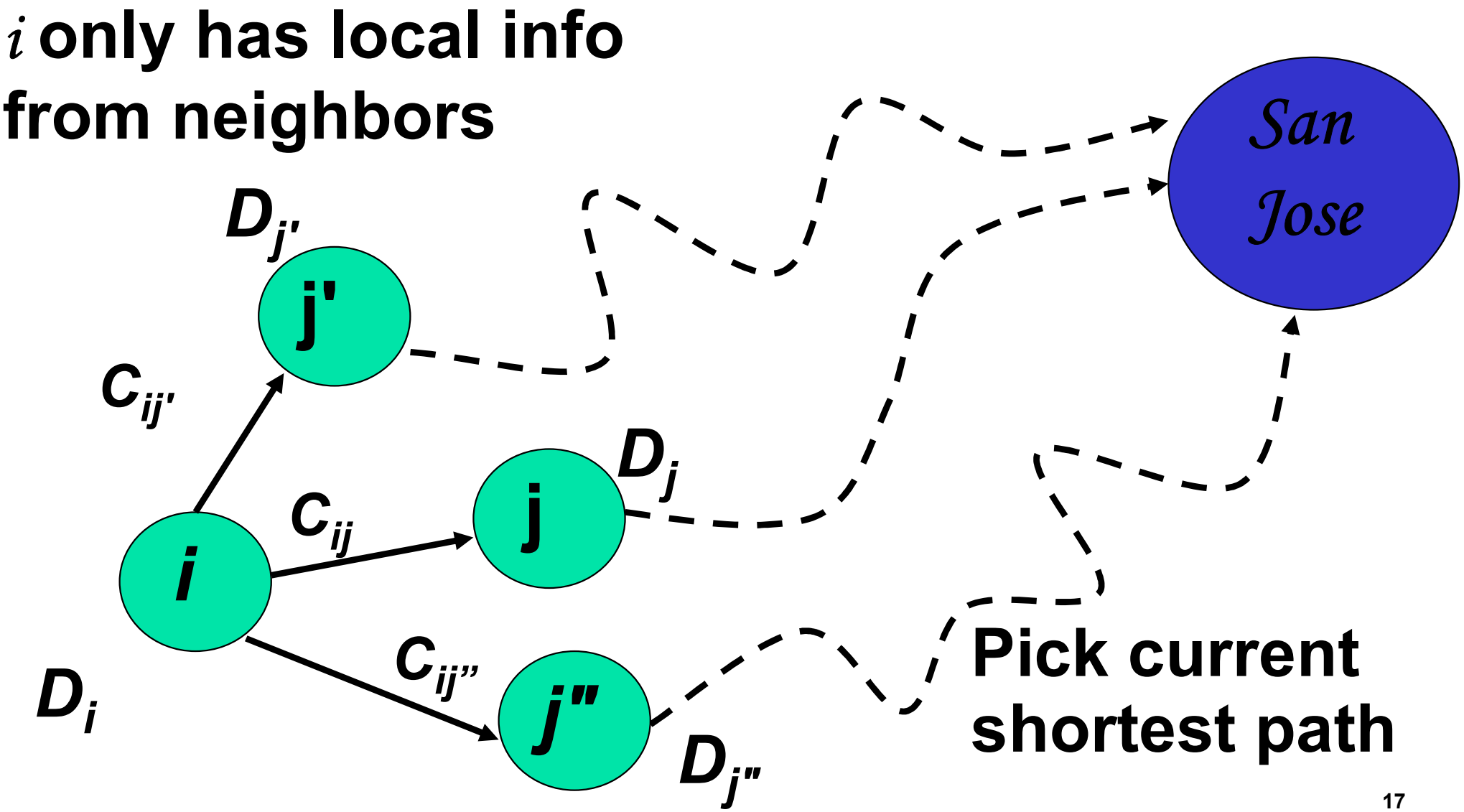
Shortest Path to SJ

Focus on how nodes find their shortest path to a given destination node, i.e. SJ

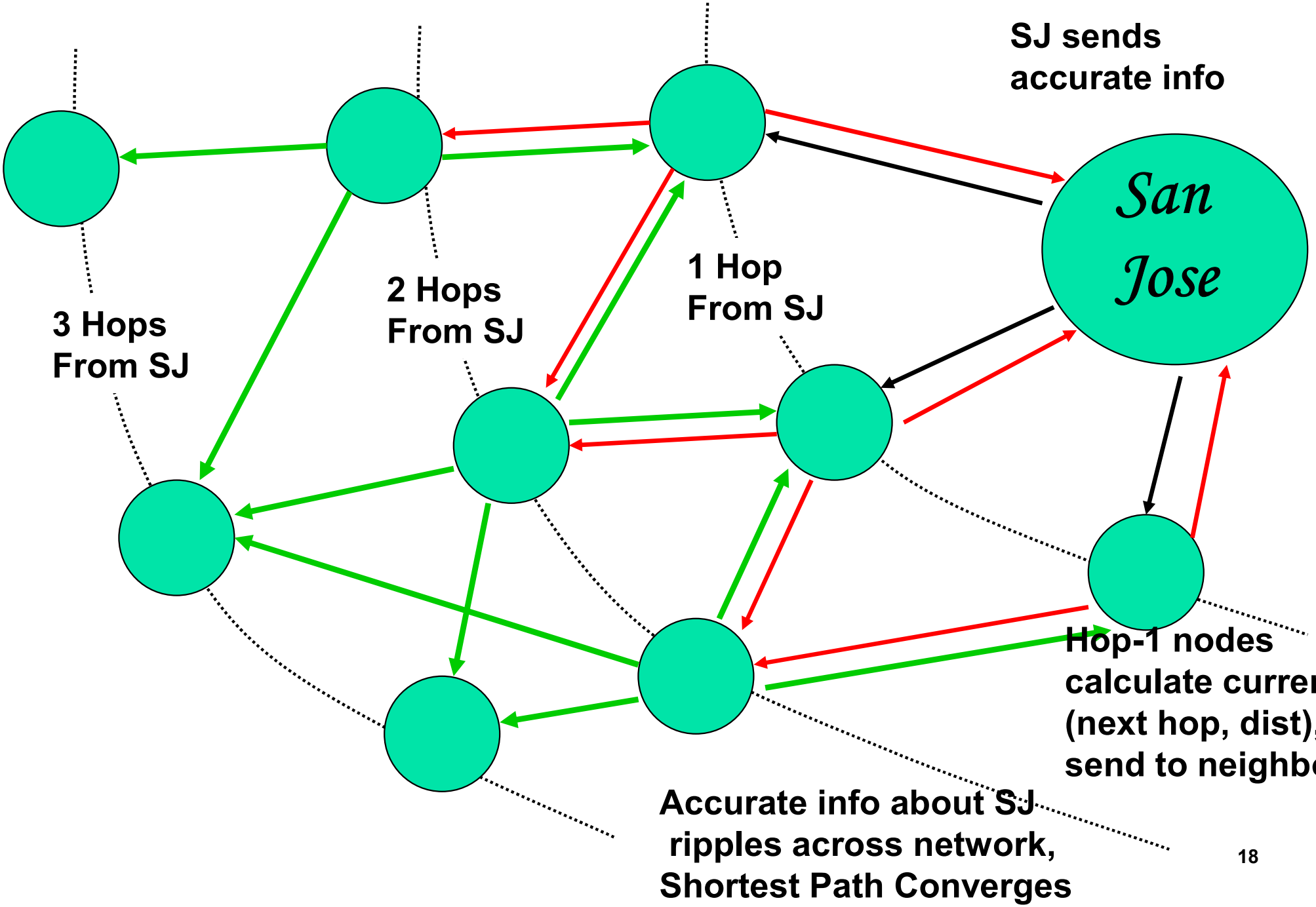


If D_i is the shortest distance to SJ from *i* and if *j* is a neighbor on the shortest path, then $D_i = C_{ij} + D_j$

But we don't know the shortest paths



Why Distance Vector Works

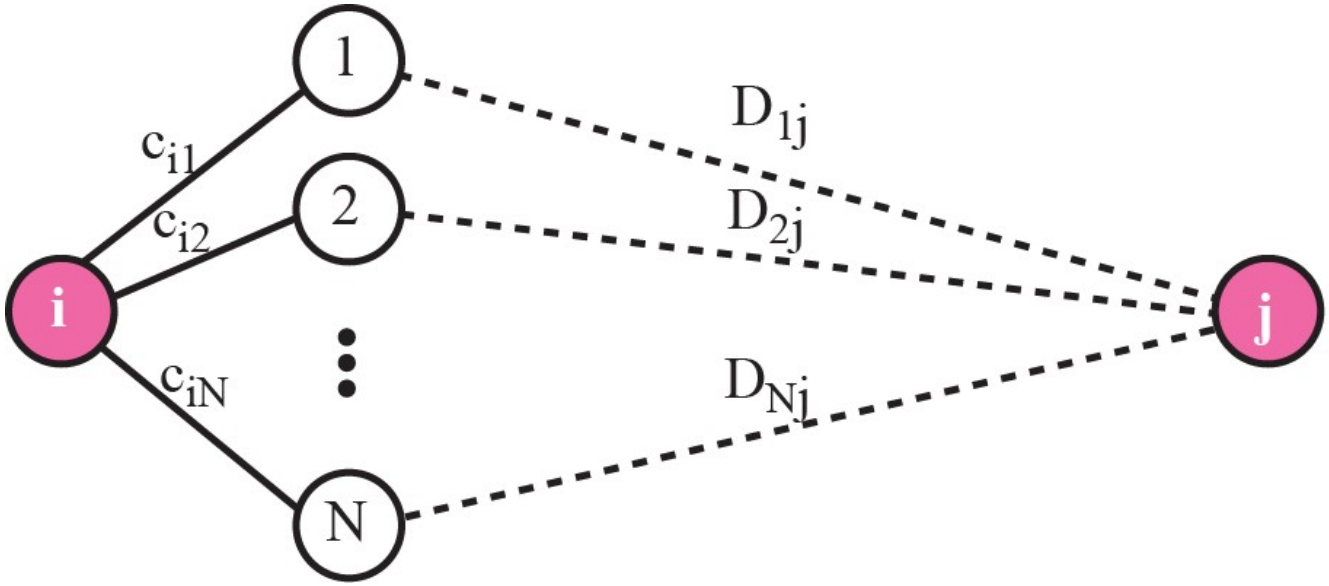


Bellman-Ford Algorithm

- *Consider computations for one destination d*
- ***Initialization***
  - Each node table has 1 row for destination *d*
  - Distance of node *d* to itself is zero: $D_d=0$
  - Distance of other node *j* to *d* is infinite: $D_j=\infty$, for $j \neq d$
  - Next hop node n_j = -1 to indicate not yet defined for $j \neq d$
- ***Send Step***
  - Send new distance vector to immediate neighbors across local link
- ***Receive Step***
  - At node *j*, find the next hop that gives the minimum distance to *d*,
    - $Min_j \{ C_{ij} + D_j \}$
    - Replace old $(n_j, D_j(d))$ by new $(n_j^*, D_j^*(d))$ if new next node or distance
  - Go to send step
  - Similar, *parallel computations for all destinations d.*

Figure 11.4 *The fact behind Bellman-Ford algorithm*

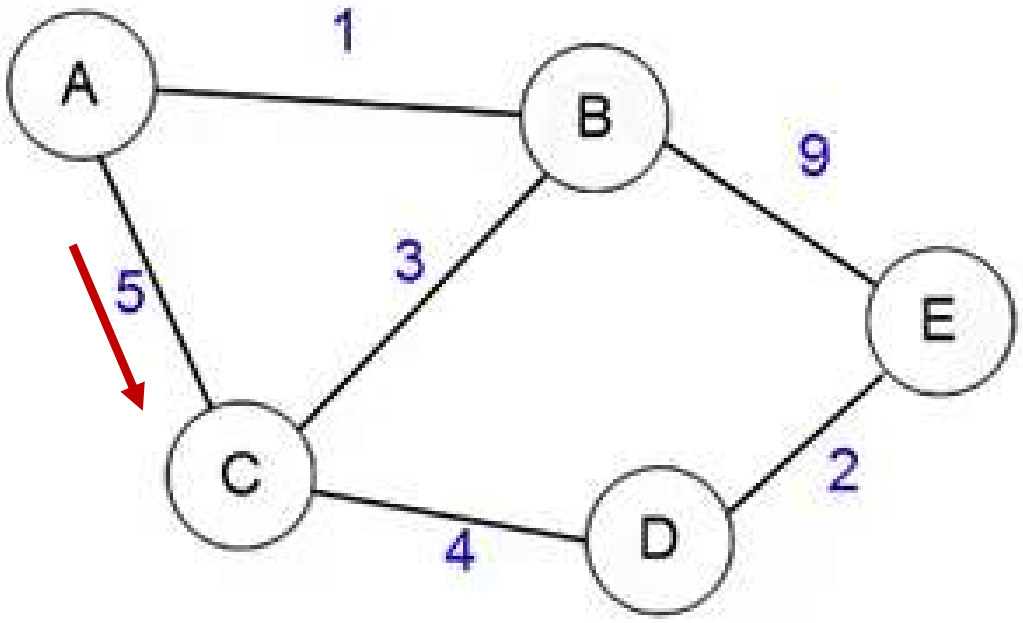
$$D_{ij} = \text{minimum } \{(c_{i1} + D_{1j}), (c_{i2} + D_{2j}), \ldots (c_{iN} + D_{Nj})$$



Legend

D_{ij} Shortest distance between i and j
c_{ij} Cost between i and j
N Number of nodes

Building Routing Table for Node -C



Initial-C Node

D	C	H
A	∞	-1
B	∞	-1
D	∞	-1
E	∞	-1

Reference Node C

D	C	H
A	5	A
B	3	B
D	4	D

Routing Table of C

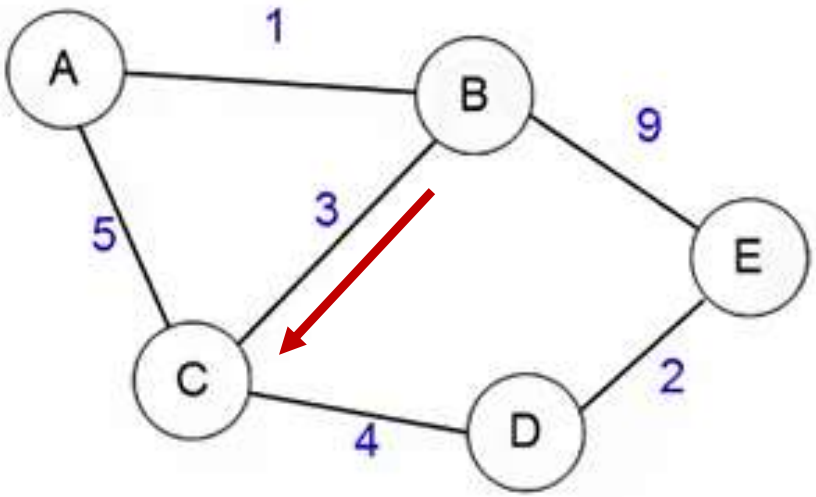
(1)

To	A
A	0
B	1
C	5

Message from A
C to A: C = 5

D	C	H
A	5	A
B	3	B
D	4	D

Routing Table of C



Old Dist. (C to A)=5

New Dist.(C to B via A) = Dist. (C to B) + Dist. (B to A)

=3+1=3

New Dist. < Old Dist.

Update 3 as New Dist.

D	C	H
A	5	A
B	3	B
D	4	D

Routing Table of C

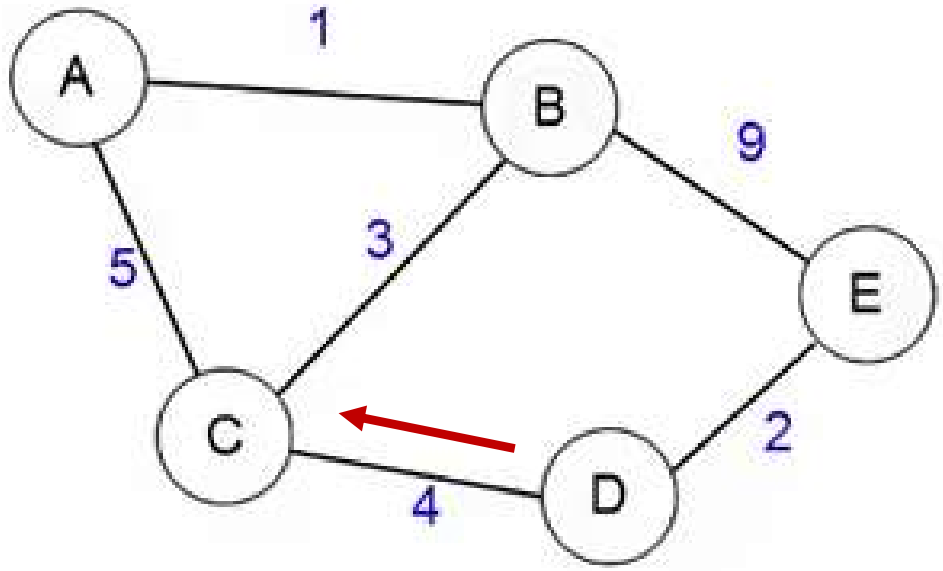
(2)

To	B
A	1
B	0
C	3
E	9

Message from B
C to B: C = 3

D	C	H
A	4	B
B	3	B
D	4	D
E	12	B

Routing Table of C



D	C	H
A	4	B
B	3	B
D	4	D
E	12	B

Routing Table of C

(3)

To	D
C	4
D	0
E	2

Message from D

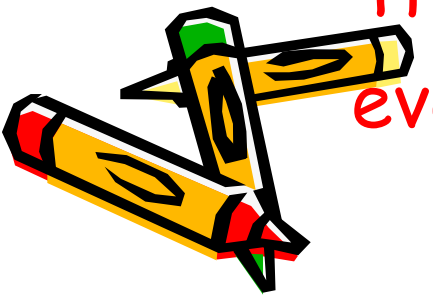
C to D: C = 4

D	C	H
A	4	B
B	3	B
D	4	D
E	6	D

Routing Table of C

Updating Routing Table

- If the next-node entry is different
  - The receiving node chooses the row with the smaller cost
  - If there is a tie, the old one is kept
- If the next-node entry is the same
  - i.e. the sender of the new row is the provider of the old entry
  - The receiving node chooses the new row, even though the new value is infinity.



When to Share

- Periodic Update
  - A node sends its routing table, normally 30 seconds, in a periodic update
- Triggered Update
  - A node sends its routing table to its neighbors any time when there is a change in its routing table
    - 1. After updating its routing table, or
    - 2. Detects some failure in the neighboring links

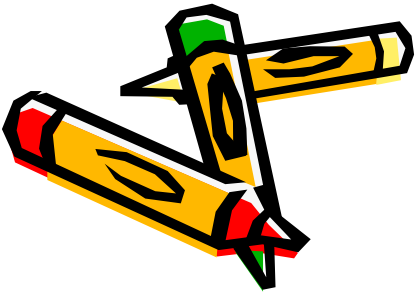
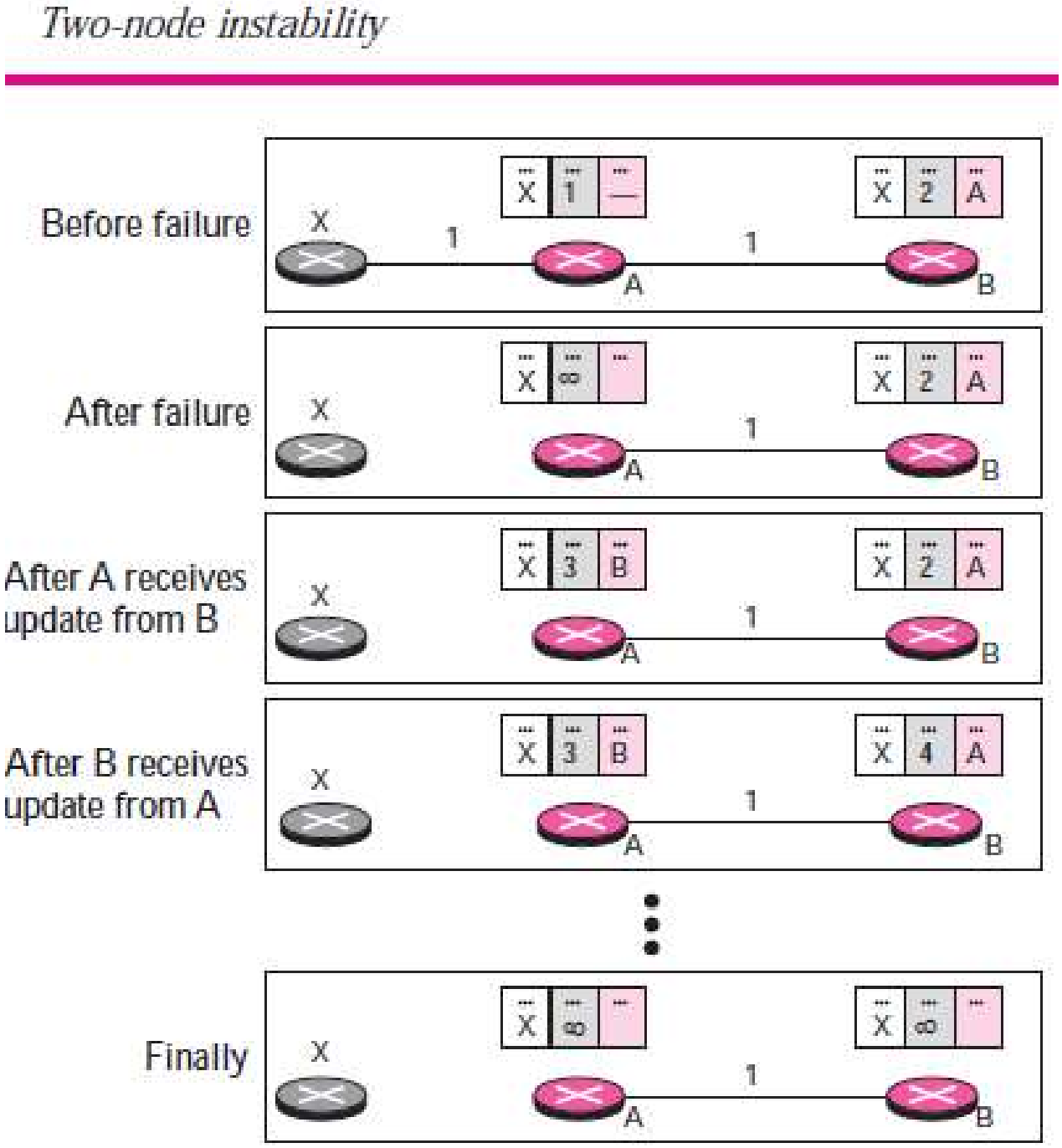


Figure 11.8 *Two-node instability*



Problem: Bad News Travels Slowly

Remedies

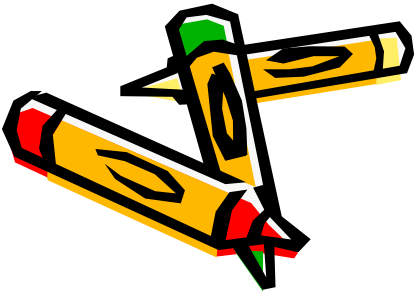
- Defining Infinity

  The first obvious solution is to redefine infinity to a smaller number,such as 16.

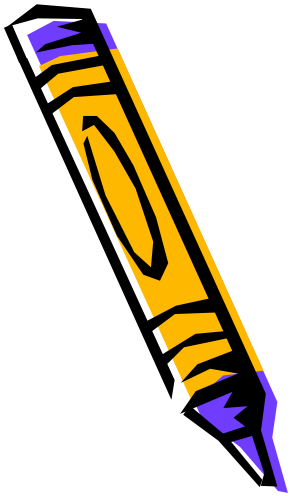
- Split Horizon
  - Do not report route to a destination to the neighbor from which route was learned.
- Poisoned Reverse
  - Report route to a destination to the neighbor from which route was learned, but with infinite distance
  - Breaks erroneous direct loops immediately
  - Does not work on some indirect loops

Two-Node Instability (1)

- Defining Infinity
  - Most implementations define 16 as infinity
- Split Horizon
  - Instead of flooding the table through each interface, each node sends only part of its table through each interface
  - E.g. node B thinks that the optimum route to reach X is via A, it does not need to advertise this piece of information to A



Two-Node Instability (2)



- Split Horizon and Poison Reverse
  - One drawback of Split Horizon
    - Normally, the DV protocol uses a timer and if there is no news about a route, the node deletes the route from its table
    - In the previous e.g., node A cannot guess that this is due to split horizon or because B has not received any news about X recently
  - Poison Reverse
    - Node B can still advertise the value for X, but is the source of information is A, it can replace the distance with infinity as a warning

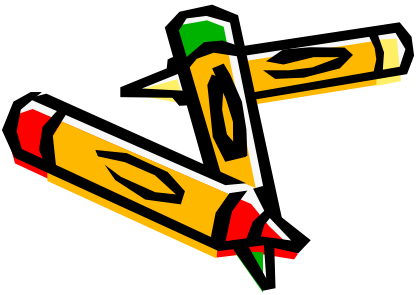
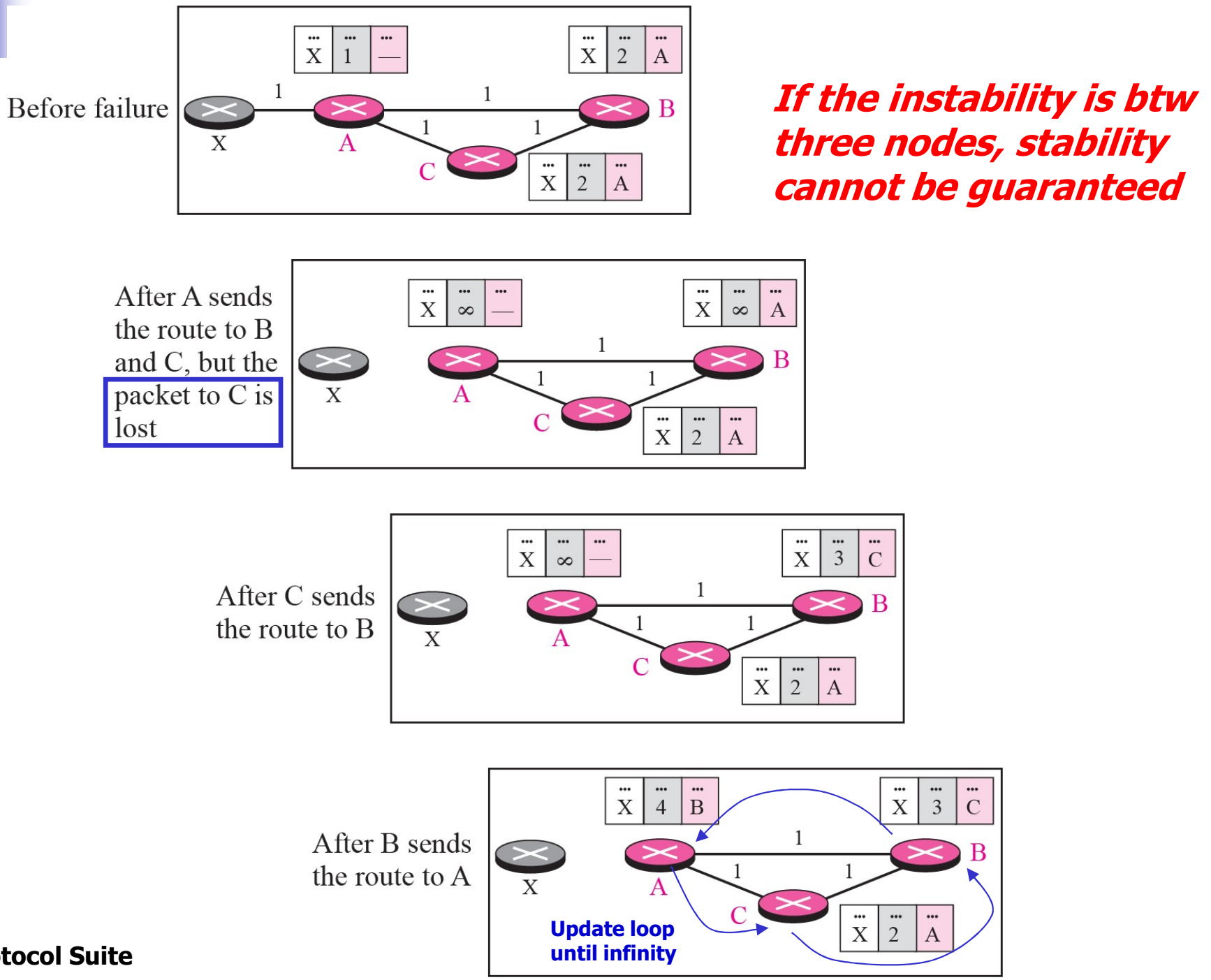


Figure 11.9 *Three-node instability*



If the instability is btw three nodes, stability cannot be guaranteed