# *Chapter 20*

# *Unicast Routing*

# General Idea

**In unicast routing, a packet is routed,**

- **hop by hop, from its source to its destination by the help of forwarding tables**

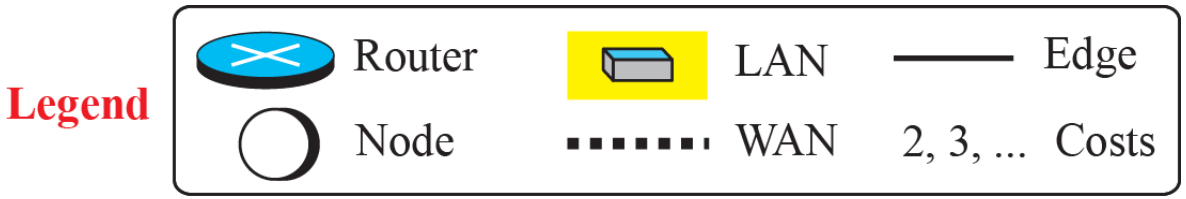
- **only the routers that glue together the networks in the Internet need forwarding tables.**

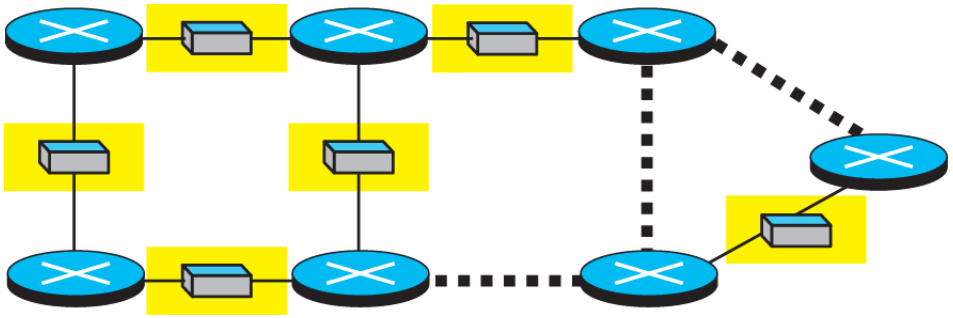
# Least-Cost Routing

- **The best route from the source router to the destination router is to find the least cost between the two**

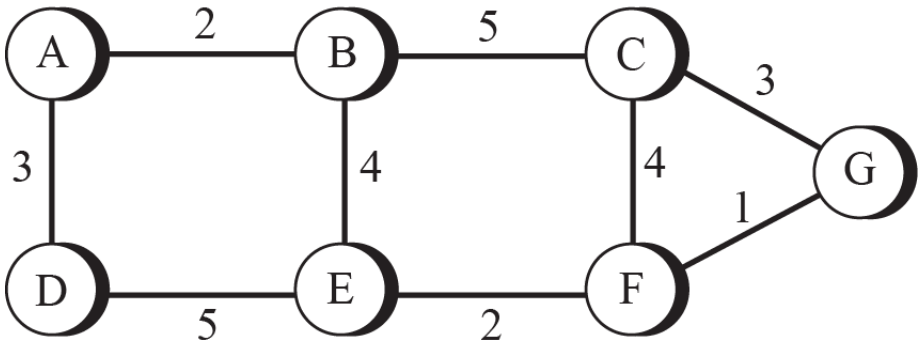
- **In other words, the source router chooses a route to the destination router in such a way that the total cost for the route is the least cost among all possible routes**

## An internet and its graphical representation



a. An internet




b. The weighted graph

# Distance-Vector Routing

- a router continuously tells all of its neighbors what it knows about the whole internet (although the knowledge can be incomplete)

# Link-State Routing

- **the cost associated with an edge defines the state of the link**

- **Links with lower costs are preferred to links with higher costs**

- **if the cost of a link is infinity, it means that the link does not exist or has been broken.**

# UNICAST ROUTING PROTOCOLS

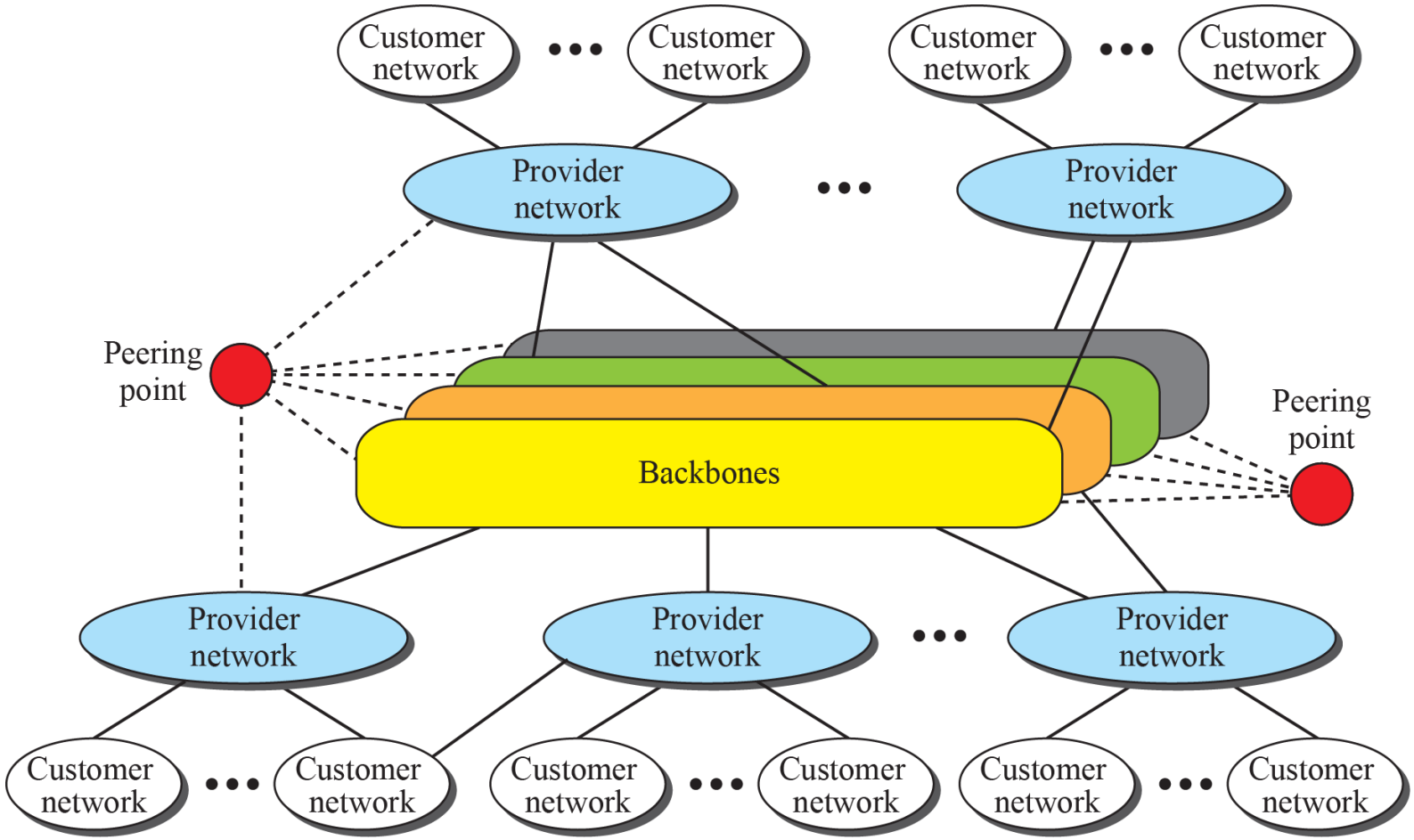
**three common protocols used in the Internet:**

- **Routing Information Protocol (RIP), based on the distance-vector algorithm**

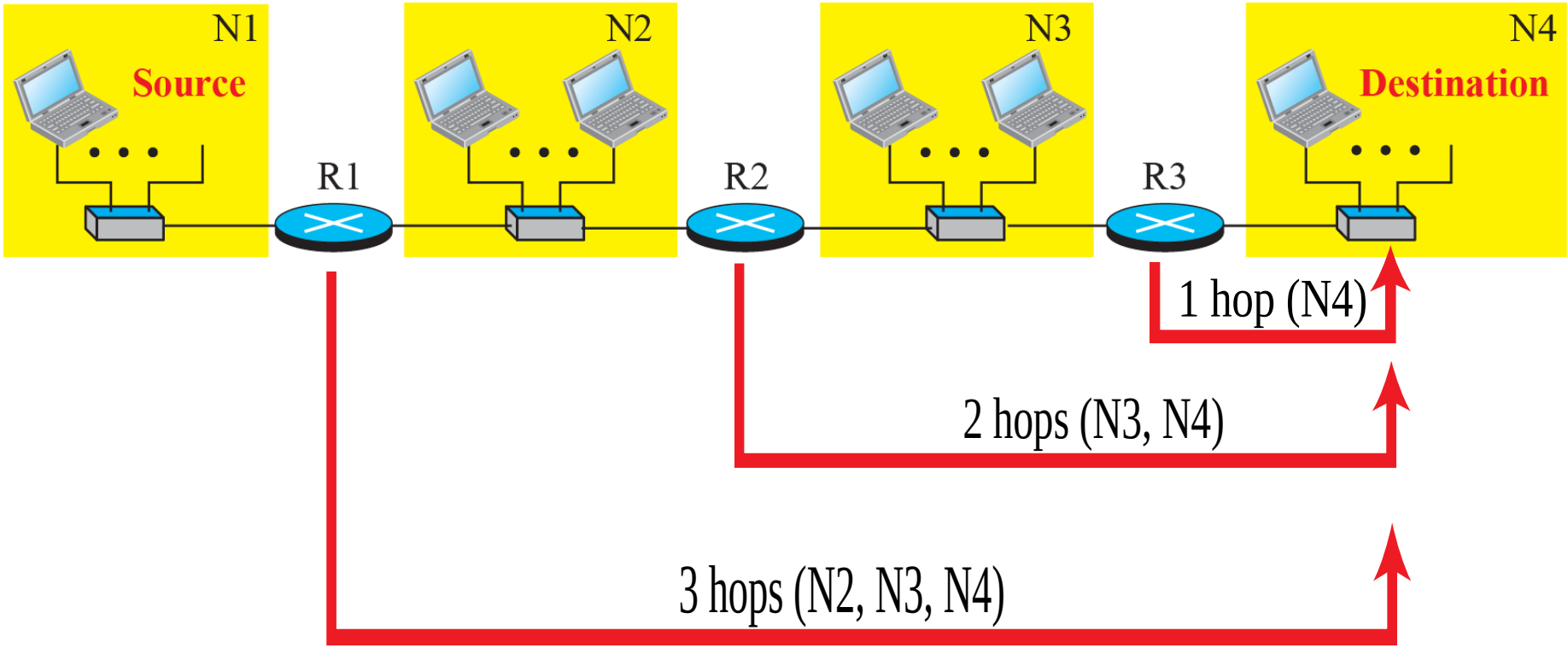
- **Open Shortest Path First (OSPF), based on the link-state algorithm**

- **Border Gateway Protocol (BGP), based on the path-vector algorithm**

## *Internet structure*



## *Hop counts in RIP*



# Forwarding tables

Forwarding table for R1

| Destination network | Next router | Cost in hops |
|---|---|---|
| N1 | —— | 1 |
| N2 | —— | 1 |
| N3 | R2 | 2 |
| N4 | R2 | 3 |

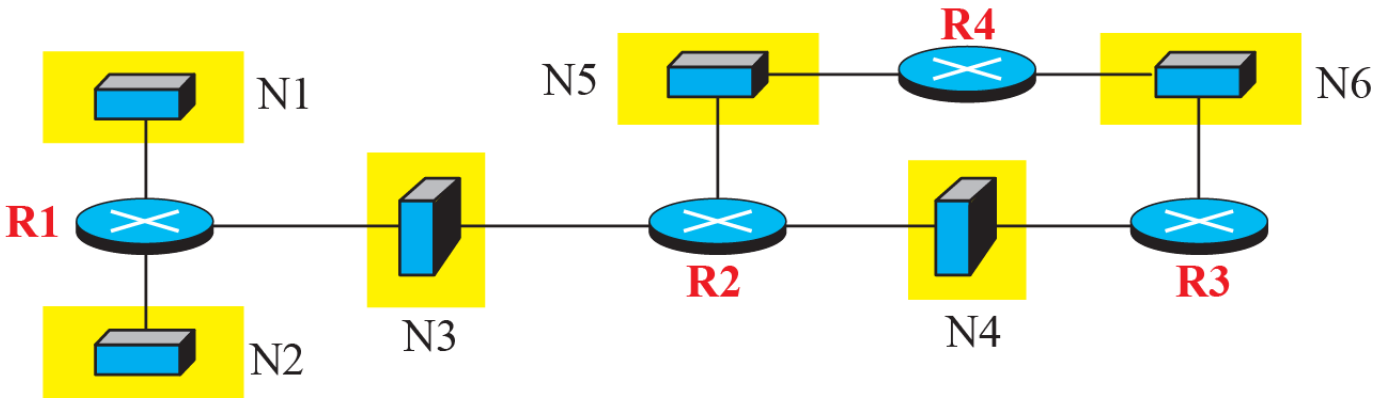
Forwarding table for R2

| Destination network | Next router | Cost in hops |
|---|---|---|
| N1 | R1 | 2 |
| N2 | —— | 1 |
| N3 | —— | 1 |
| N4 | R3 | 2 |

Forwarding table for R3

| Destination network | Next router | Cost in hops |
|---|---|---|
| N1 | R2 | 3 |
| N2 | R2 | 2 |
| N3 | —— | 1 |
| N4 | —— | 1 |

# Example of an autonomous system using RIP (Part I)




**Legend**

Des.: Destination network
N. R.: Next router
Cost: Cost in hops

**R1**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | ——— | 1 |
| N2 | ——— | 1 |
| N3 | ——— | 1 |

**R2**

| Des. | N. R. | Cost |
|---|---|---|
| N3 | ——— | 1 |
| N4 | ——— | 1 |
| N5 | ——— | 1 |

**R3**

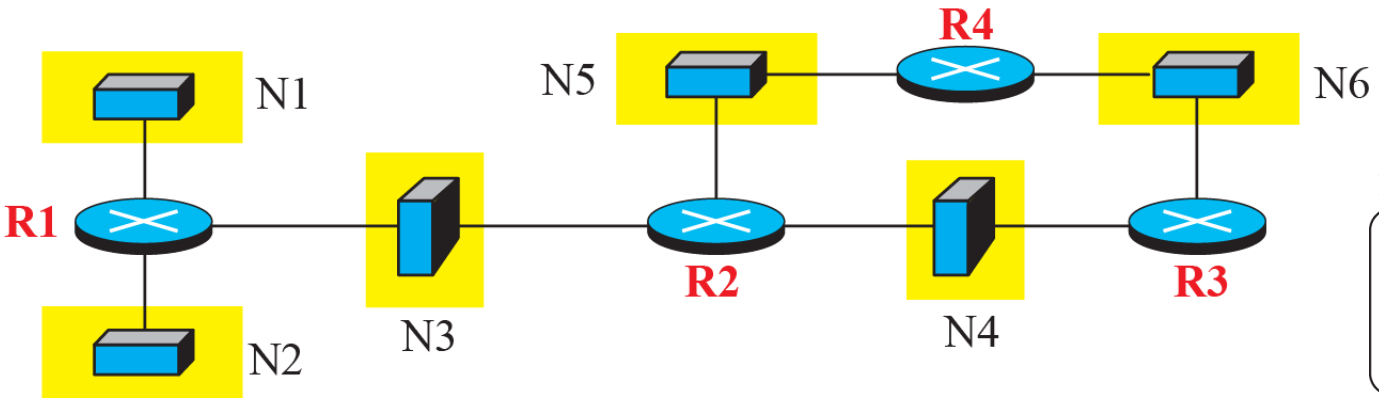
| Des. | N. R. | Cost |
|---|---|---|
| N4 | ——— | 1 |
| N6 | ——— | 1 |

**R4**

| Des. | N. R. | Cost |
|---|---|---|
| N5 | ——— | 1 |
| N6 | ——— | 1 |

Forwarding tables after all routers booted

# Example of an autonomous system using RIP (Part II)




**Legend**

Des.: Destination network
N. R.: Next router
Cost: Cost in hops
: New route
: Old route

**New R1**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | —— | 1 |
| N2 | —— | 1 |
| N3 | —— | 1 |
| N4 | R2 | 2 |
| N5 | R2 | 2 |

**Old R1**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | —— | 1 |
| N2 | —— | 1 |
| N3 | —— | 1 |

**R2 Seen by R1**

| Des. | N. R. | Cost |
|---|---|---|
| N3 | R2 | 2 |
| N4 | R2 | 2 |
| N5 | R2 | 2 |

**New R3**

| Des. | N. R. | Cost |
|---|---|---|
| N3 | R2 | 2 |
| N4 | —— | 1 |
| N5 | R2 | 2 |
| N6 | —— | 1 |

**Old R3**

| Des. | N. R. | Cost |
|---|---|---|
| N4 | —— | 1 |
| N6 | —— | 1 |

**R2 Seen by R3**

| Des. | N. R. | Cost |
|---|---|---|
| N3 | R2 | 2 |
| N4 | R2 | 2 |
| N5 | R2 | 2 |

**New R4**

| Des. | N. R. | Cost |
|---|---|---|
| N3 | R2 | 2 |
| N4 | R2 | 2 |
| N5 | —— | 1 |
| N6 | —— | 1 |

**Old R4**

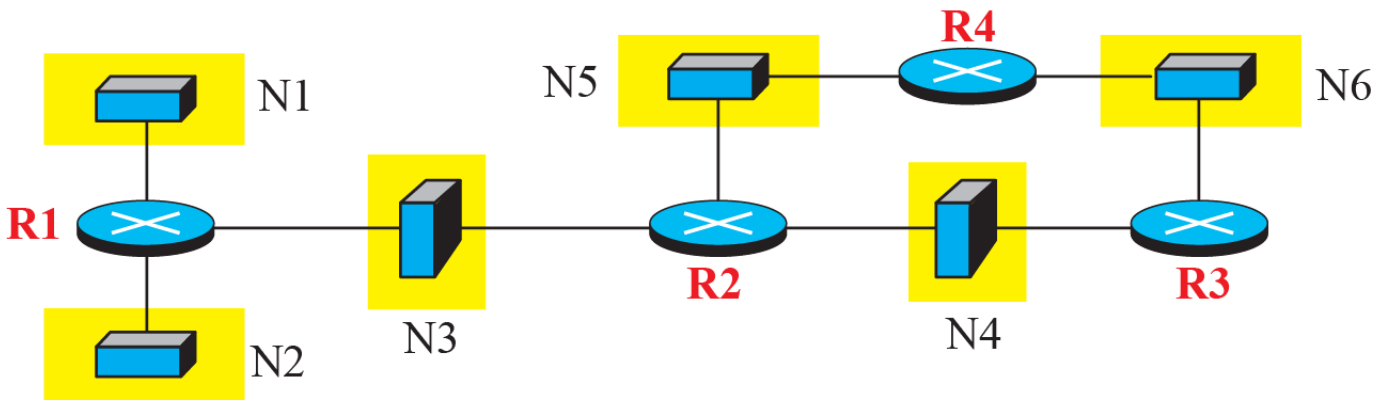
| Des. | N. R. | Cost |
|---|---|---|
| N5 | —— | 1 |
| N6 | —— | 1 |

**R2 Seen by R4**

| Des. | N. R. | Cost |
|---|---|---|
| N3 | R2 | 2 |
| N4 | R2 | 2 |
| N5 | R2 | 2 |

Changes in the forwarding tables of R1, R3, and R4 after they receive a copy of R2's table

# Example of an autonomous system using RIP (Part III)




**Legend**

Des.: Destination network
N. R.: Next router
Cost: Cost in hops

Forwarding tables for all routers after they have been stablized

**Final R1**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | ——— | 1 |
| N2 | ——— | 1 |
| N3 | ——— | 1 |
| N4 | R2 | 2 |
| N5 | R2 | 2 |
| N6 | R2 | 3 |

**Final R2**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | R1 | 2 |
| N2 | R1 | 2 |
| N3 | ——— | 1 |
| N4 | ——— | 1 |
| N5 | ——— | 1 |
| N6 | R3 | 2 |

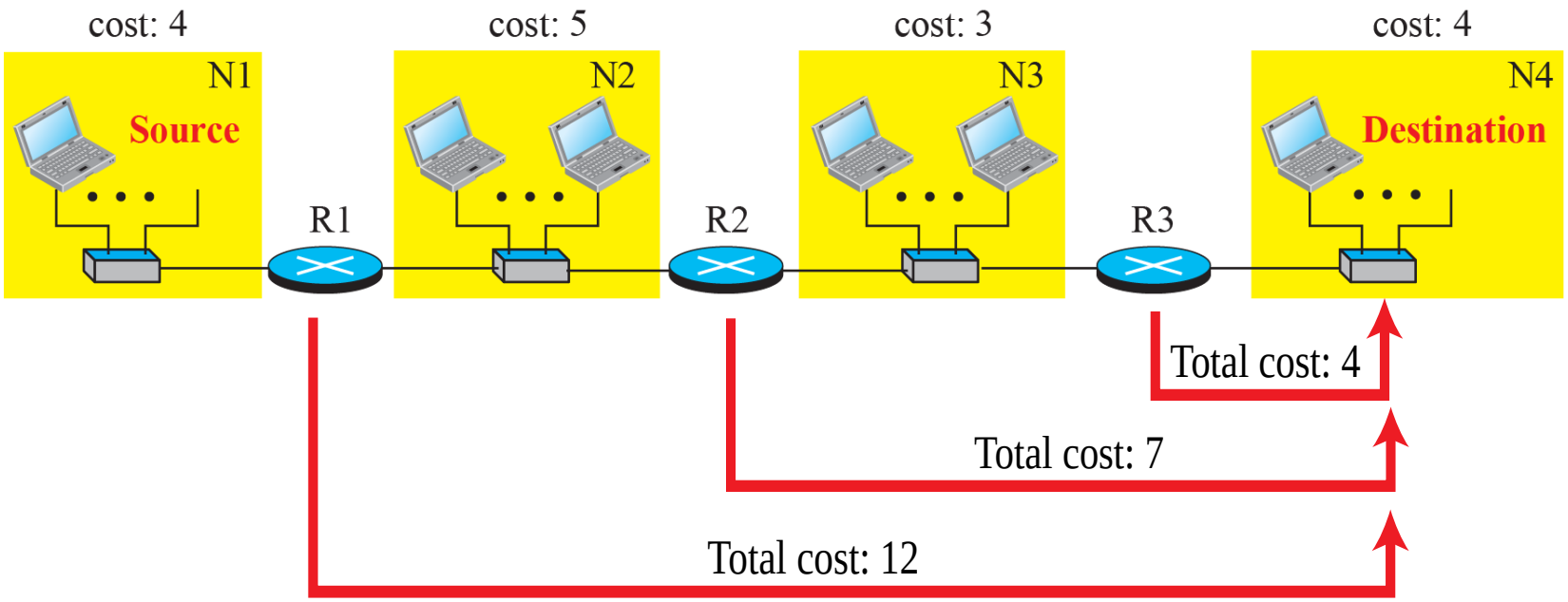
**Final R3**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | R2 | 3 |
| N2 | R2 | 3 |
| N3 | R2 | 2 |
| N4 | ——— | 1 |
| N5 | R2 | 2 |
| N6 | ——— | 1 |

**Final R4**

| Des. | N. R. | Cost |
|---|---|---|
| N1 | R2 | 3 |
| N2 | R2 | 3 |
| N3 | R2 | 2 |
| N4 | R2 | 2 |
| N5 | ——— | 1 |
| N6 | ——— | 1 |

## *Metric in OSPF*



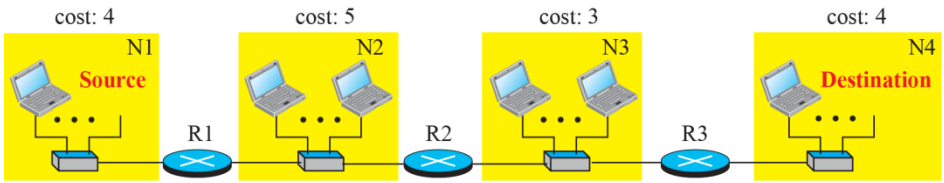
# *Forwarding tables in OSPF*

Forwarding table for R1

| Destination network | Next router | Cost |
|---|---|---|
| N1 | —— | |
| N2 | —— | |
| N3 | R2 | |
| N4 | R2 | 12 |

Forwarding table for R3

| Destination network | Next router | Cost |
|---|---|---|
| N1 | R2 | 12 |
| N2 | R2 | 8 |
| N3 | —— | 3 |
| N4 | —— | 4 |

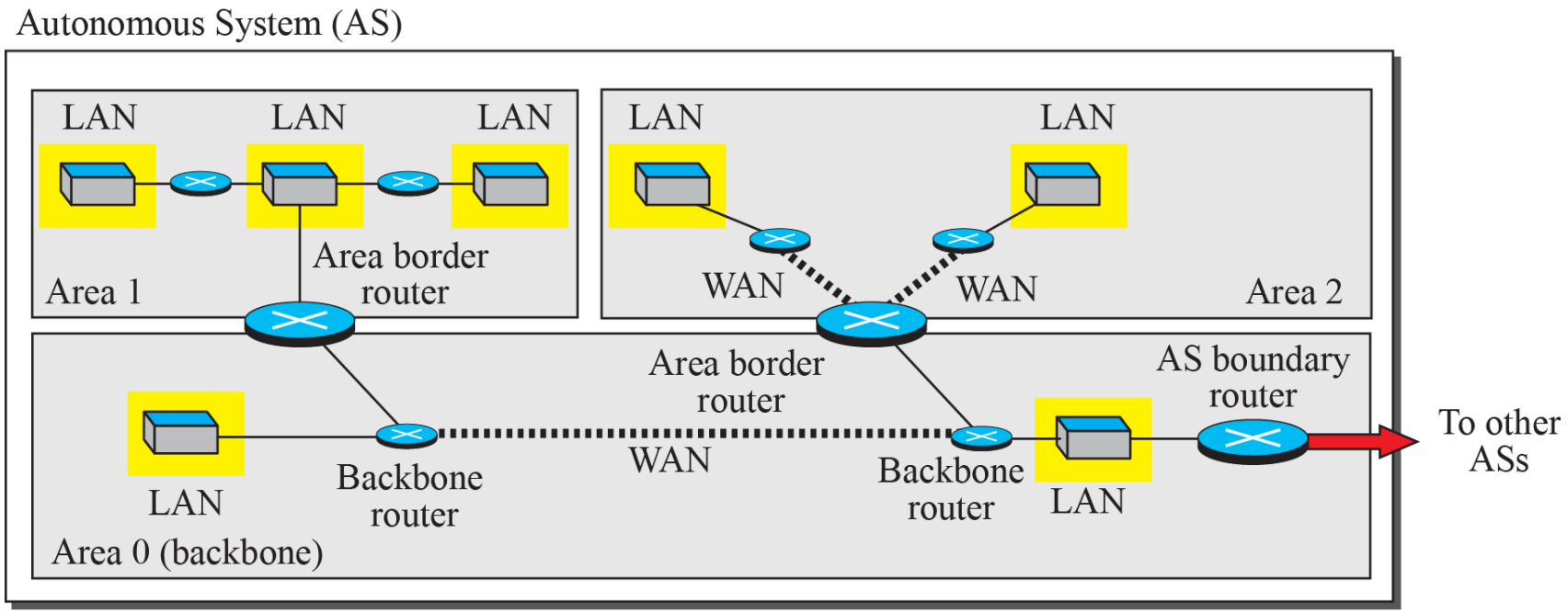



The internet from previous figure

Forwarding table for R2

| Destination network | Next router | Cost |
|---|---|---|
| N1 | R1 | 9 |
| N2 | —— | 5 |
| N3 | —— | 3 |
| N4 | R3 | 7 |

## *Areas in an autonomous system*



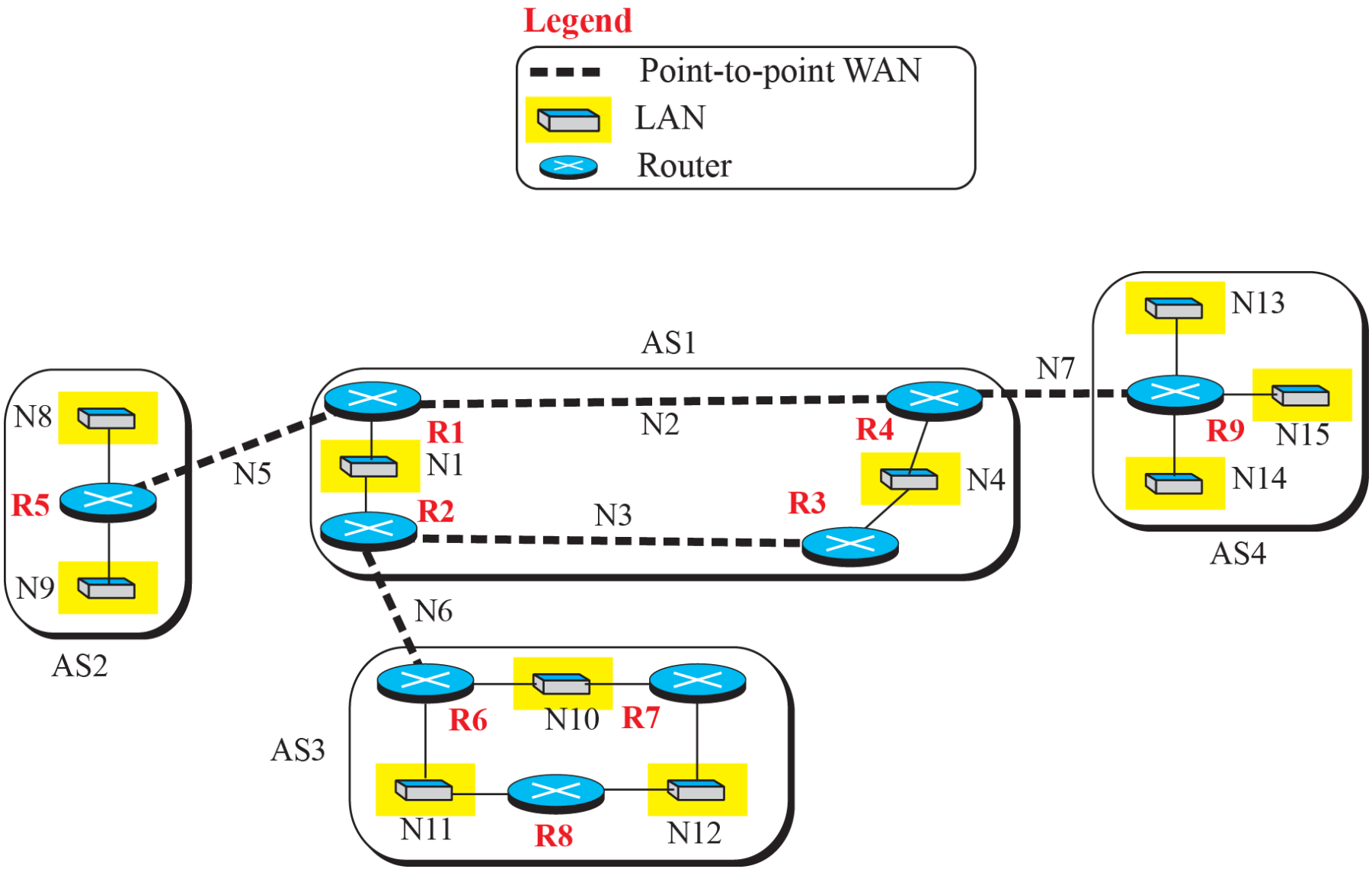
# Border Gateway Protocol

- **the only interdomain routing protocol used in the Internet today**

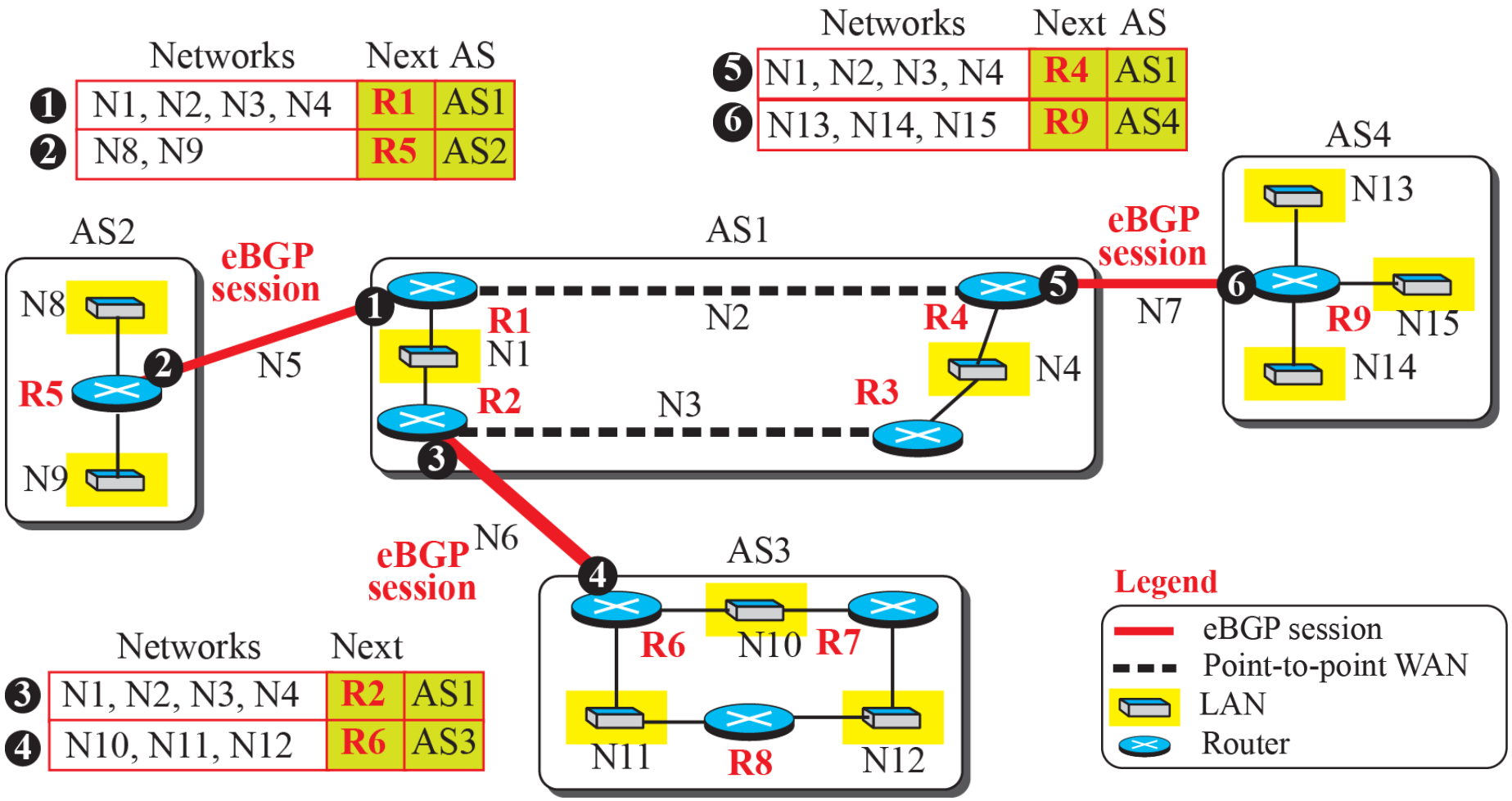
- **is based on the path-vector algorithm**

- **is tailored to provide information about the reachability of networks in the Internet.**

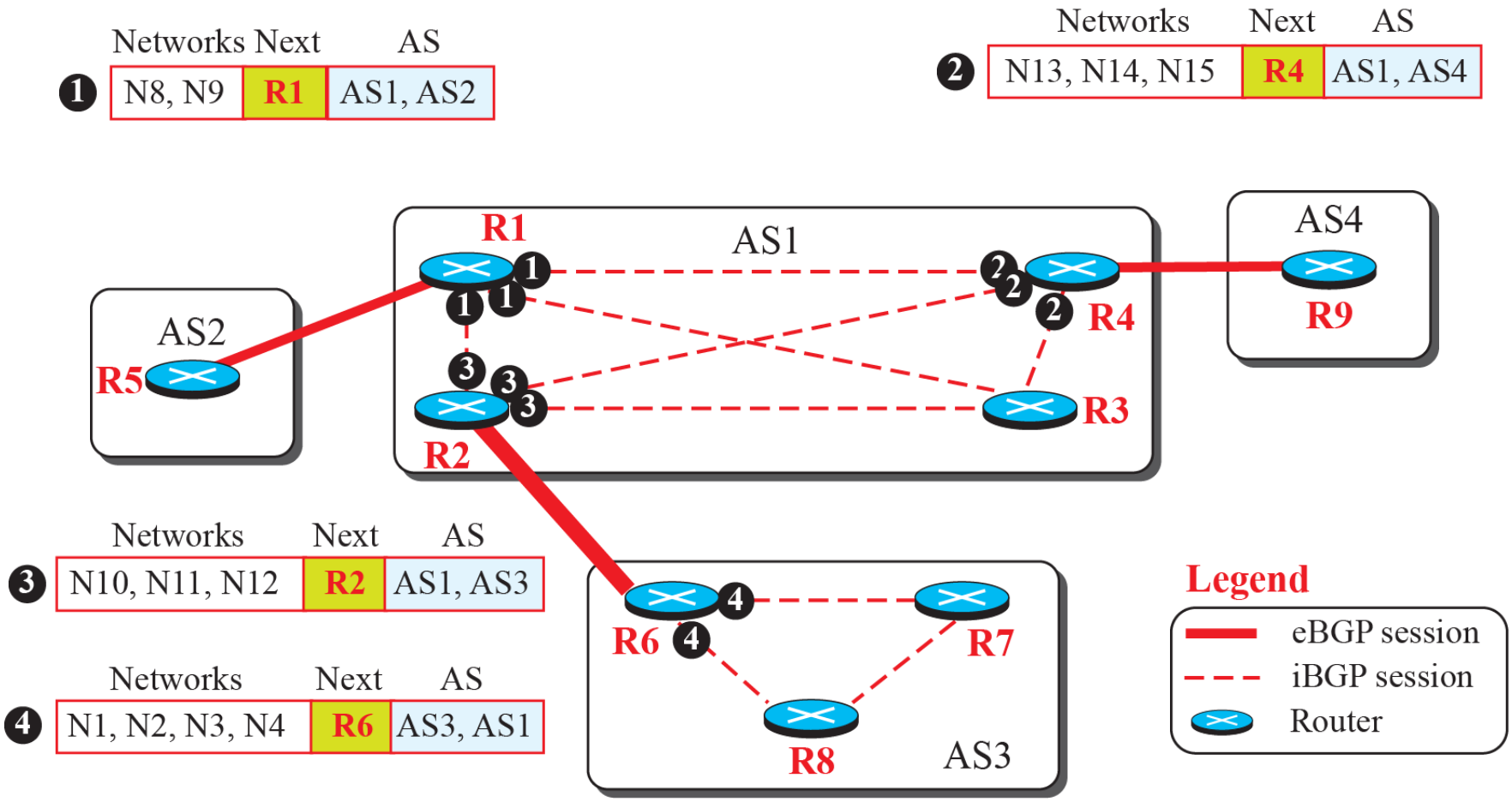
## *A sample internet with four ASs*



## *eBGP operation*



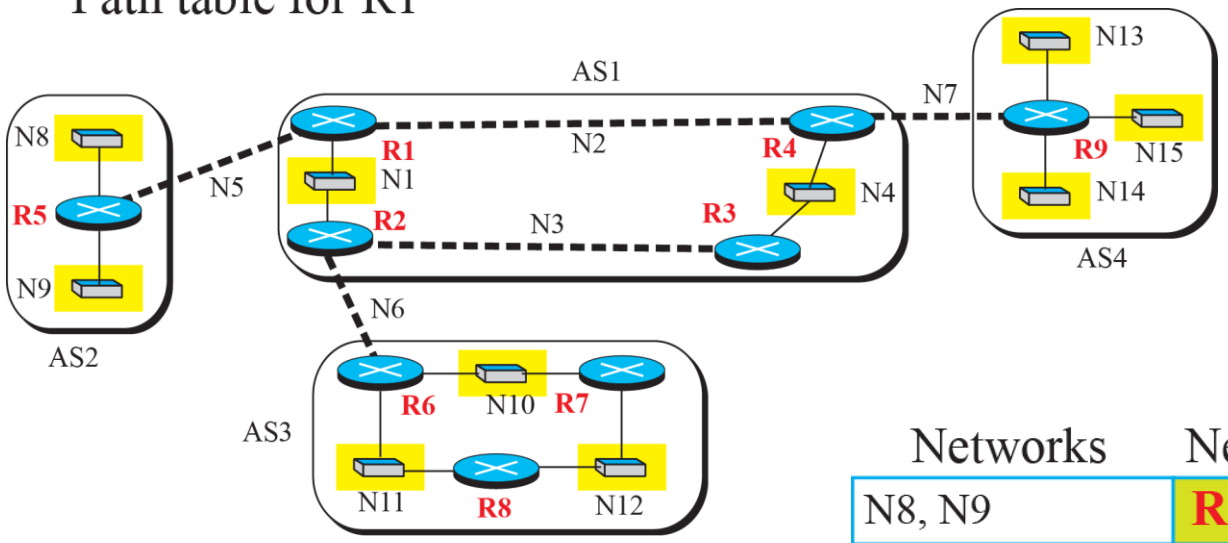
# Combination of eBGP and iBGP sessions in our internet



# *Finalized BGP path tables (Part I)*

| Networks | Next | Path |
|---|---|---|
| N8, N9 | R5 | AS1, AS2 |
| N10, N11, N12 | R2 | AS1, AS3 |
| N13, N14, N15 | R4 | AS1, AS4 |

Path table for R1




| Networks | Next | Path |
|---|---|---|
| N8, N9 | R1 | AS1, AS2 |
| N10, N11, N12 | R6 | AS1, AS3 |
| N13, N14, N15 | R1 | AS1, AS4 |

Path table for R2

| Networks | Next | Path |
|---|---|---|
| N8, N9 | R2 | AS1, AS2 |
| N10, N11, N12 | R2 | AS1, AS3 |
| N13, N14, N15 | R4 | AS1, AS4 |

Path table for R3

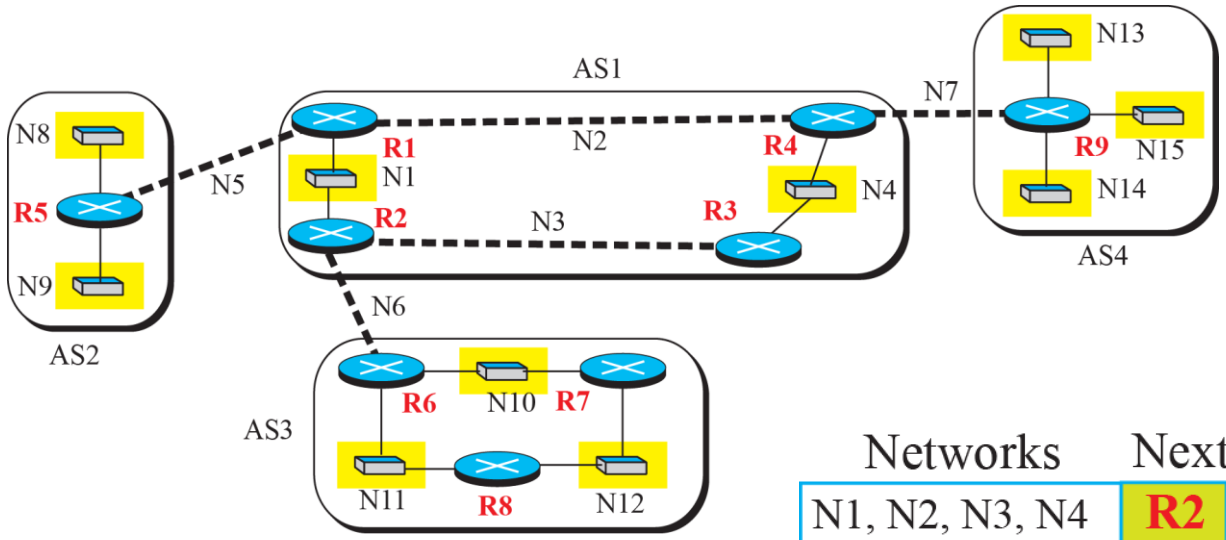
# *Finalized BGP path tables (Part II)*

| Networks | Next | Path |
|---|---|---|
| N1, N2, N3, N4 | R1 | AS2, AS1 |
| N10, N11, N12 | R1 | AS2, AS1, AS3 |
| N13, N14, N15 | R1 | AS2, AS1, AS4 |

Path table for R5

| Networks | Next | Path |
|---|---|---|
| N8, N9 | R1 | AS1, AS2 |
| N10, N11, N12 | R1 | AS1, AS3 |
| N13, N14, N15 | R9 | AS1, AS4 |

Path table for R4




| Networks | Next | Path |
|---|---|---|
| N1, N2, N3, N4 | R2 | AS3, AS1 |
| N8, N9 | R2 | AS3, AS1, AS2 |
| N13, N14, N15 | R2 | AS3, AS1, AS4 |

Path table for R6