# The Network Layer

## Routing in the Internet

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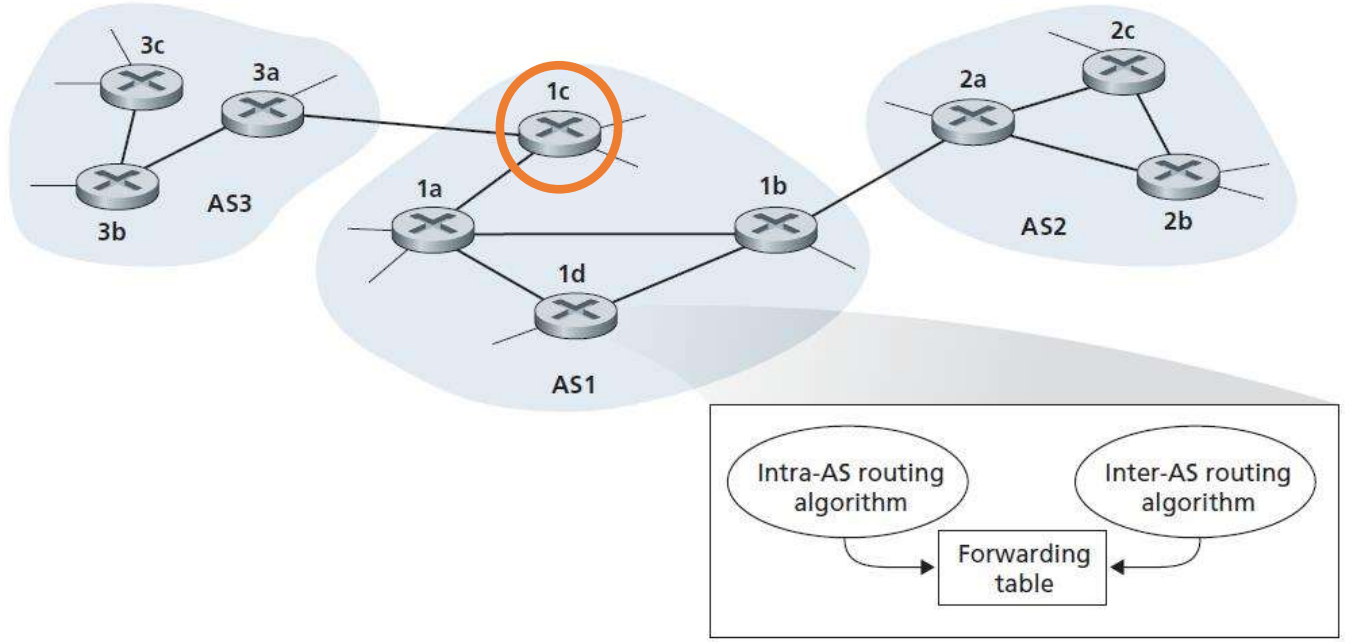
# Hierarchical Routing

- Scale
  - hundreds of millions of routers
- Administrative autonomy: AS

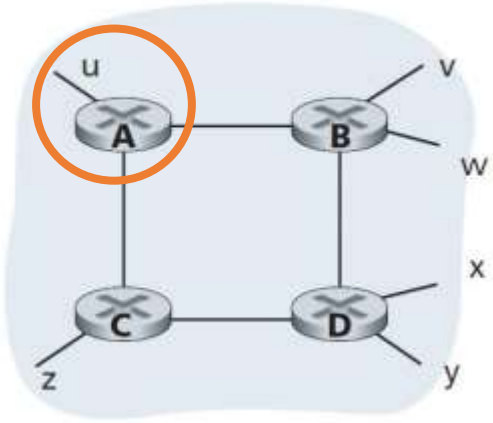


# Intra-AS Routing in the Internet

- An intra-AS routing protocol is used to determine how routing is performed within an autonomous system (AS).
- In the Internet (extensively used)
  - Routing Information Protocol (RIP)
    - distance-vector based
  - Open Shortest Path First (OSPF)
    - link-state based

# Routing Information Protocol (RIP)

- Cost metric: each link has a cost of 1.
- Cost of a path:
  - from source router to a destination subnet;
  - *hop*, which is the number of subnets traversed along the shortest path from source router to destination subnet, including the destination subnet.
- The maximum cost of a path is limited to 15, thus limiting the use of RIP to autonomous systems that are fewer than 15 hops in diameter.




| Destination | Hops |
|---|---|
| u | 1 |
| v | 2 |
| w | 2 |
| x | 3 |
| y | 3 |
| z | 2 |

# Routing Information Protocol (RIP)

- **RIP advertisements/RIP response message**
  - Neighboring routers exchange distance vectors with each other
  - Approximately every 30 seconds
  - the sender’s distance to each of a list of up to 25 destination subnets

# Routing Information Protocol (RIP)

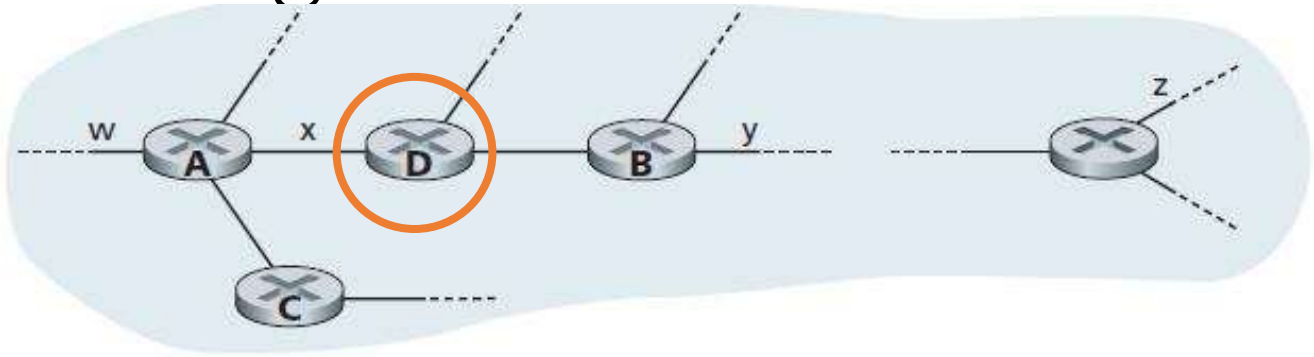



**Figure 4.35** ♦ A portion of an autonomous system

| Destination Subnet | Next Router | Number of Hops to Destination |
|---|---|---|
| w | A | 2 |
| y | B | 2 |
| z | B | 7 |
| x | — | 1 |
| .... | .... | .... |

**Figure 4.36** ♦ Routing table in router *D* before receiving advertisement from router *A*

# Routing Information Protocol (RIP)

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

| Destination Subnet | Next Router | Number of Hops to Destination |
|---|---|---|
| z | C | 4 |
| w | — | 1 |
| x | — | 1 |
| .... | .... | .... |

**Figure 4.37** ♦ Advertisement from router A

C (D, A)= 1

| Destination Subnet | Next Router | Number of Hops to Destination |
|---|---|---|
| w | A | 2 |
| y | B | 2 |
| z | B | 7 |
| x | — | 1 |
| .... | .... | .... |

**Figure 4.36** ♦ Routing table in router *D* before receiving advertisement from router *A*

| Destination Subnet | Next Router | Number of Hops to Destination |
|---|---|---|
| w | A | 2 |
| y | B | 2 |
| z | A | 5 |
| .... | .... | .... |

**Figure 4.38** ♦ Routing table in router *D* after receiving advertisement from router *A*

# Open Shortest Path First (OSPF)

- Individual link costs are configured by the network administrator
  - set all link costs to 1, or
  - set the link weights to be inversely proportional to link capacity in order to discourage traffic from using low-bandwidth links.
- By flooding of link-state information, a router constructs a complete topological map (that is, a graph) of the entire autonomous system.
  - a change in a link's state, or every 30 minutes
- The router then locally runs Dijkstra's shortest-path algorithm to determine a shortest-path tree to all *subnets*, with itself as the root node.

# Inter-AS Routing: BGP

- The **Border Gateway Protocol** version 4 is the *de facto* standard inter-AS routing protocol in today's Internet. It is commonly referred to as BGP4 or simply as **BGP**.
  - Obtain subnet reachability information from neighboring ASs.
  - Propagate the reachability information to all routers internal to the AS.
  - Determine "good" routes to subnets based on the reachability information and on AS policy.
- BGP is extremely complex, not cored here, but you are required to read the chapter in the text book
  - *AS-PATH, NEXT-HOP, Routing Policy*