CS 725/825 & IT 725

Lecture 21

Network Layer

November 20, 2023

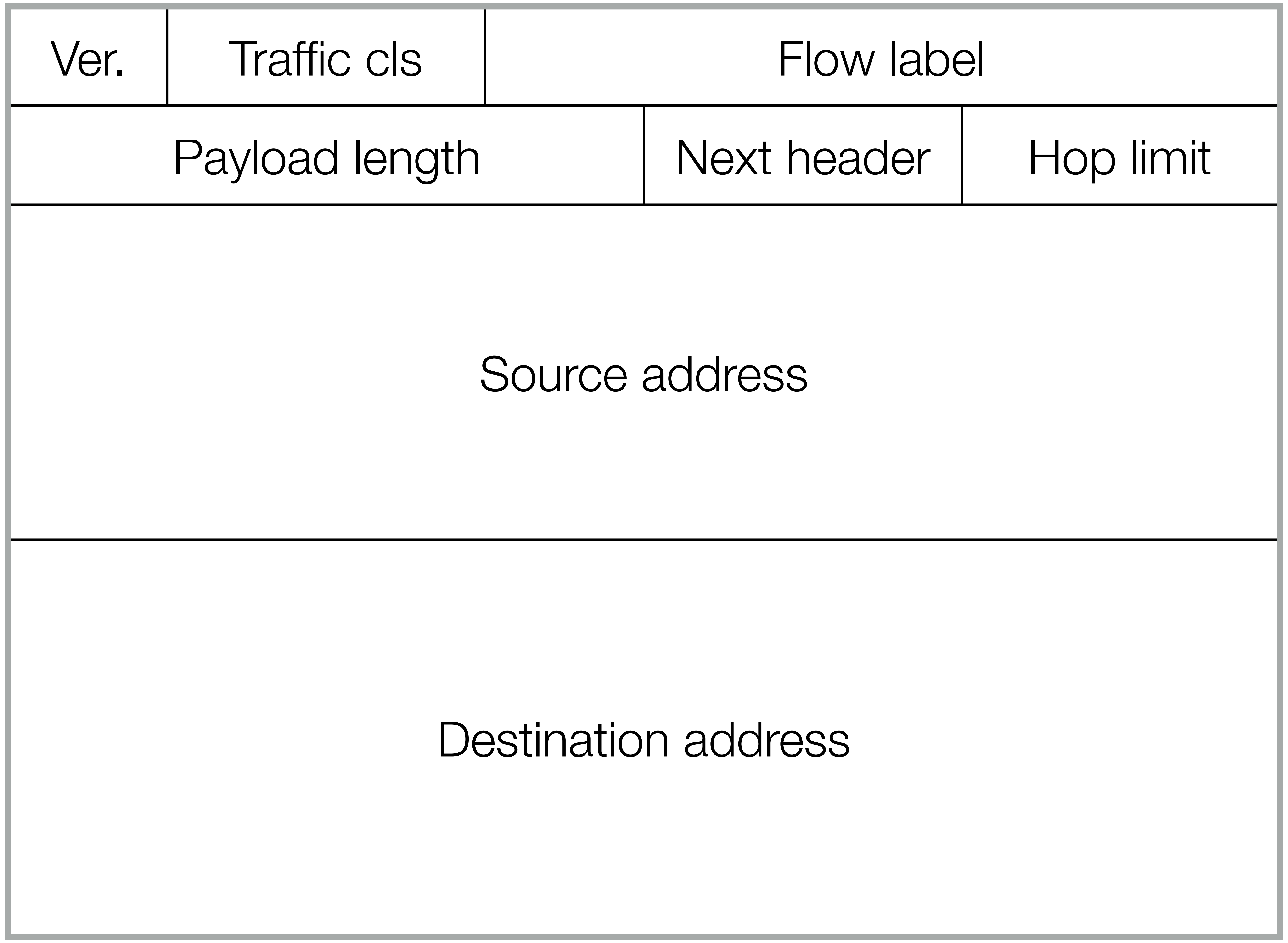
IPv6 - Motivation

- What's wrong with IPv4?
  - not enough addresses
  - to complex to process in routers
  - autoconfiguration
  - security
- Can we avoid switching to IPv6?
  - Network Address Translation (NAT)

IPv6 - Protocol Design

- Keep the good stuff...
  - unreliable datagram service
  - TTL, TOS (for compatibility)
- Eliminate the unnecessary...
  - no fragmentation (only as an option)
  - no header checksums
- Address the issues...
  - longer addresses and more

IPv6 Header



Ver.
Traffic cls
Flow label
Payload length
Next header
Hop limit
Source address
Destination address

IPv6 Address Representation

- An IPv6 address is represented by 8 groups of 16-bit hexadecimal values separated by colons (:)
- Can be abbreviated:
  - omit leading zeroes in a 16-bit value
  - replace one group of consecutive zeroes by a double colon
- Example:
  - 2606:4100:38c0:9::5 vs 2606:4100:38c0:0009:0000:0000:0000:0005

Special Use IPv6 Addresses

- ::/128 - Unspecified address
- ::1/128 - Loopback address
- ::FFFF:0:0/96 - IPv4-mapped address
- FE80::/10 - Link-local unicast
- FF00::/8 - Multicast

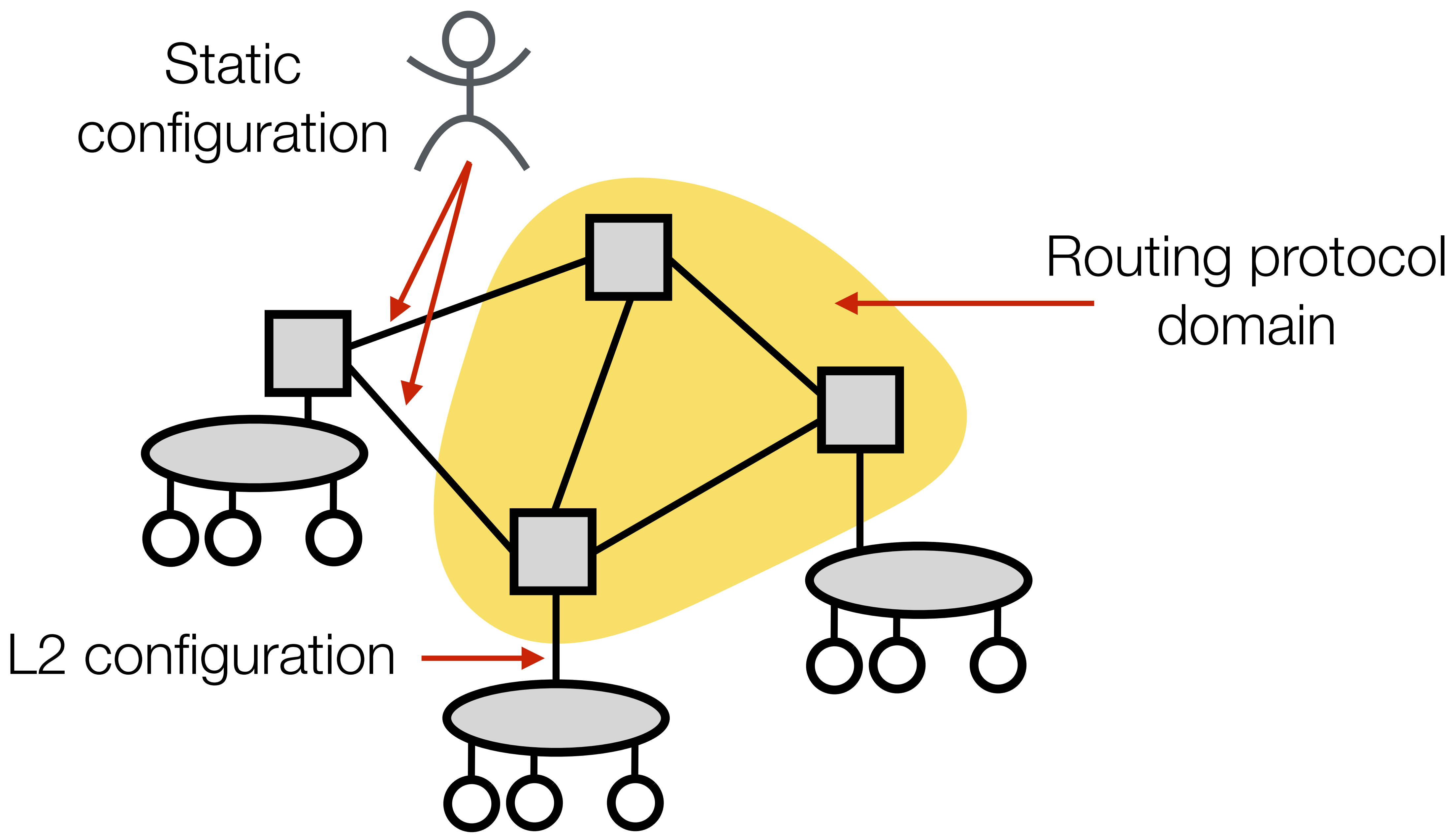
Routing

- Approaches:
  - First find a path from source to destination and then follow it… (Source Routing)
  - Go to the first corner, ask for direction to the next corner that is on the way to the destination*. Repeat until you reach the destination… (Hop-by-hop Forwarding)

* Routing tables give you that information

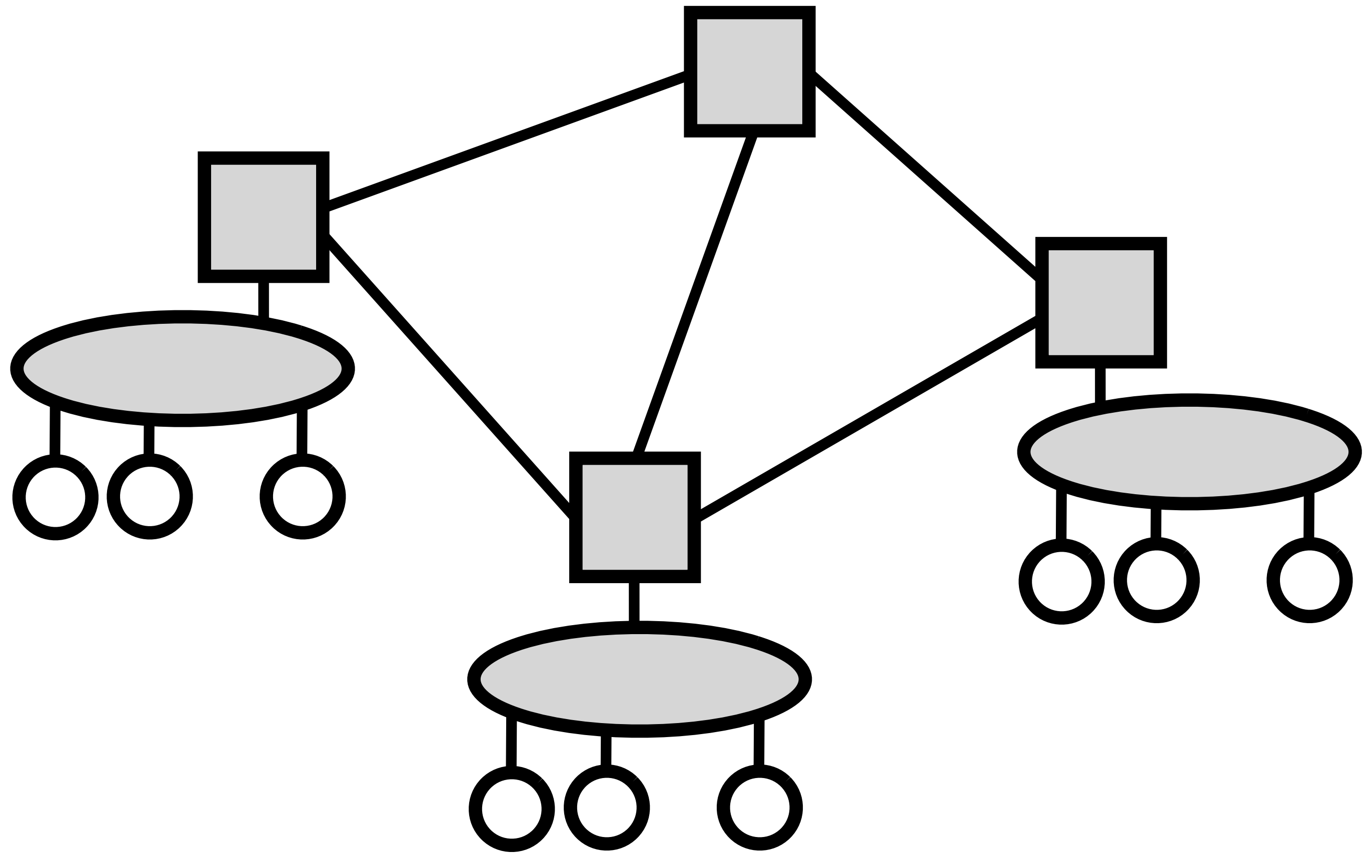
Routing Table Content

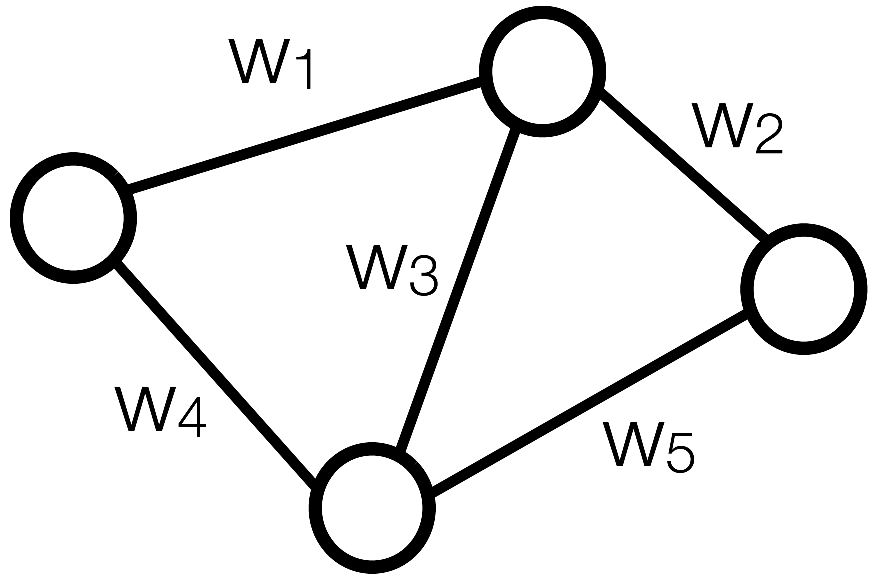
- Automatically populated with entries based in local L2 configuration
- Static entries - added by the network administrator
- Dynamic entries - added by dynamic routing protocols



Routing

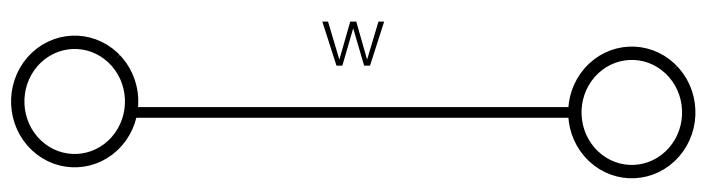
- Finding a good path from source to destination
  - topology discovery
  - route selection
- Network as a graph...
  - links (point to point and L2 subnets) and routers
  - destinations are typically L2 subnets, not individual nodes
  - links may have "weights"



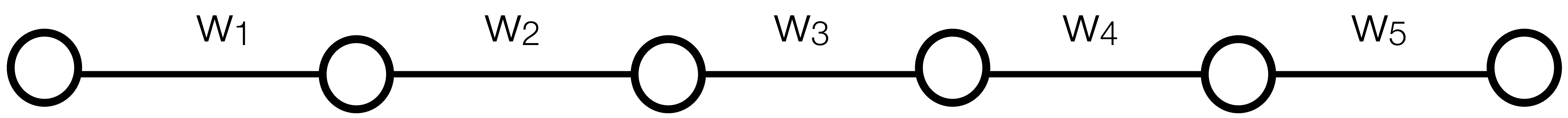


Link weights

- What is a good measure of “weight” of a link?



- Weight of a path?



Link & Path Measures

- Link measures:
  - Throughput / bit rate
  - Latency
  - Loss probability
  - Availability
  - Current load
  - Security
  - Monetary cost

- Path measures:
  - Sum

    Latency

    Monetary cost
  - Min/Max

    Throughput / bit rate
  - Product

    Loss probability

Trivial routing methods

- Hot potato routing (not practical)
  - send to randomly chosen outgoing link…
- Flooding (not practical)
  - send a copy to every outgoing link…
- Limited flooding
  - every packet has a sequence number (together with the source address, this makes a copy of a packet uniquely identifiable)
  - send a copy to every other outgoing link
  - keep track of forwarded packets so that copies are sent only once

Routing Protocols - Categories

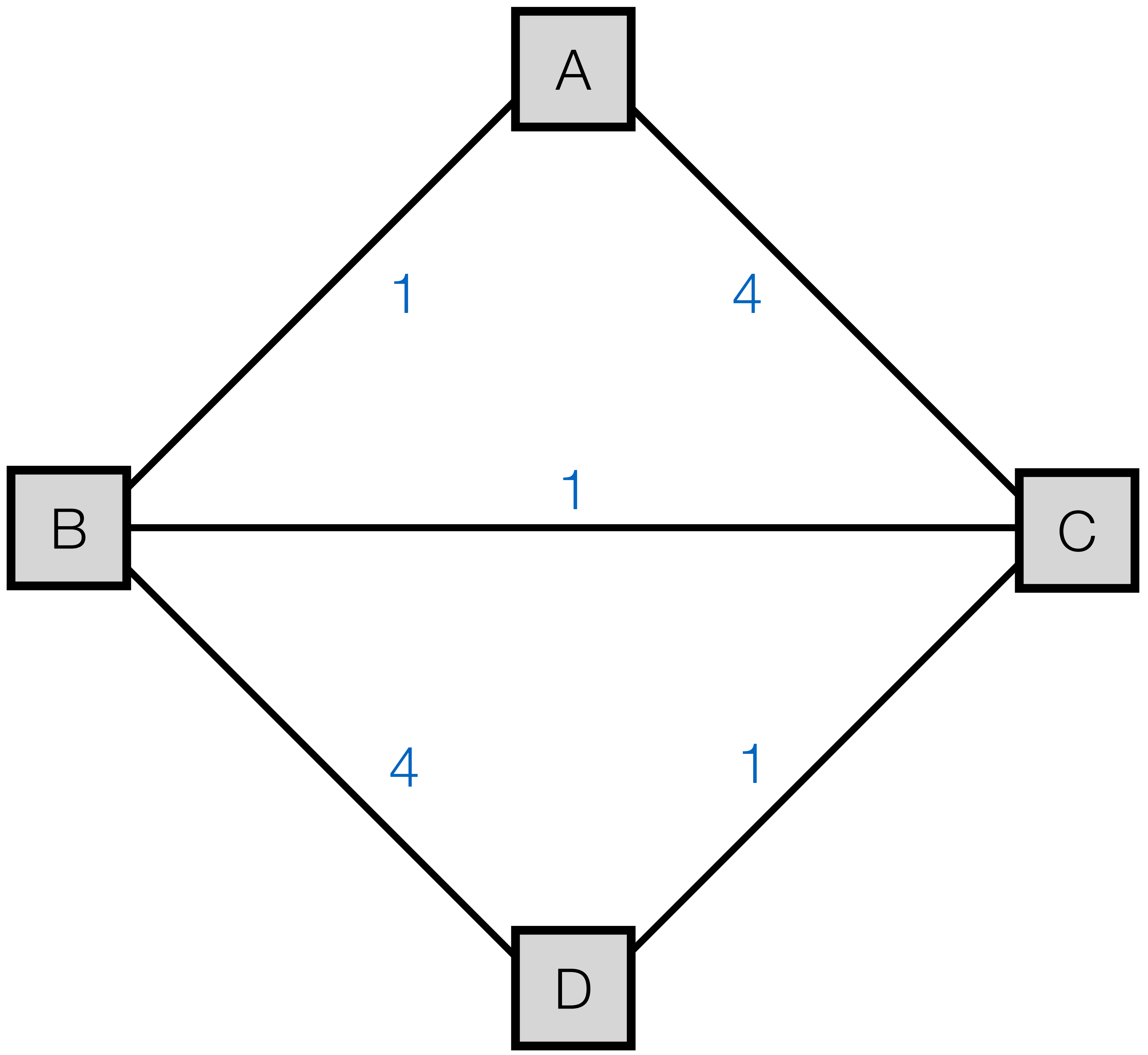
- Link State
  - exact neighbor information flooded to everyone
  - topology of the entire networks is discovered in each node
  - shortest paths calculated and used to populate the routing tables

- Distance Vector
  - estimates of distances to all nodes in the network sent to all neighbors
  - estimates are improved based on information from neighbors
  - the process is repeated and routing tables are populated based on the estimates

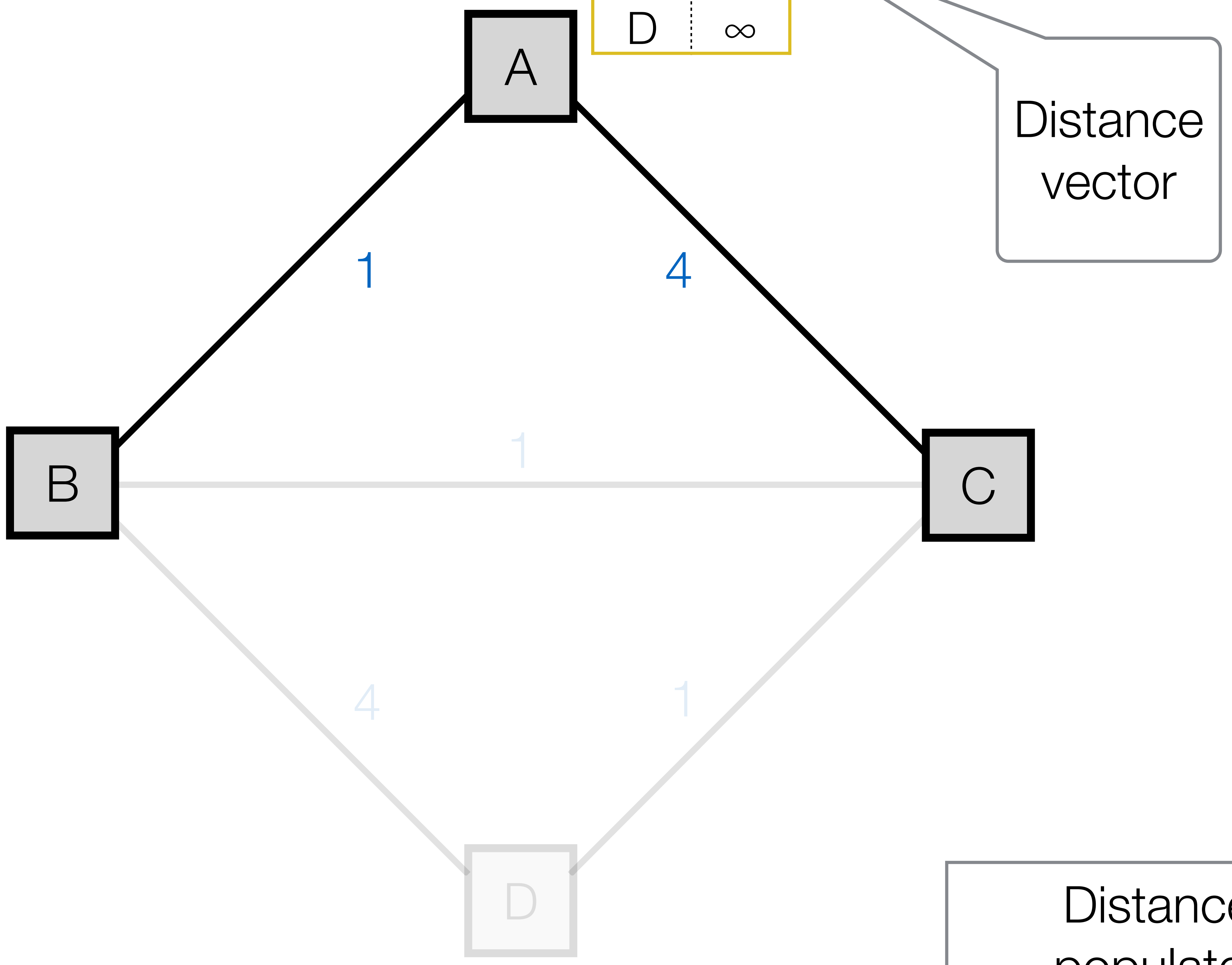
Distance Vector (recap)

- Estimates of distances to all nodes in the network (Distance Vector) is sent to all neighbors
- Estimates are improved based on information from neighbors
- The process is repeated and routing tables are populated based on the estimates

Distance Vector routing



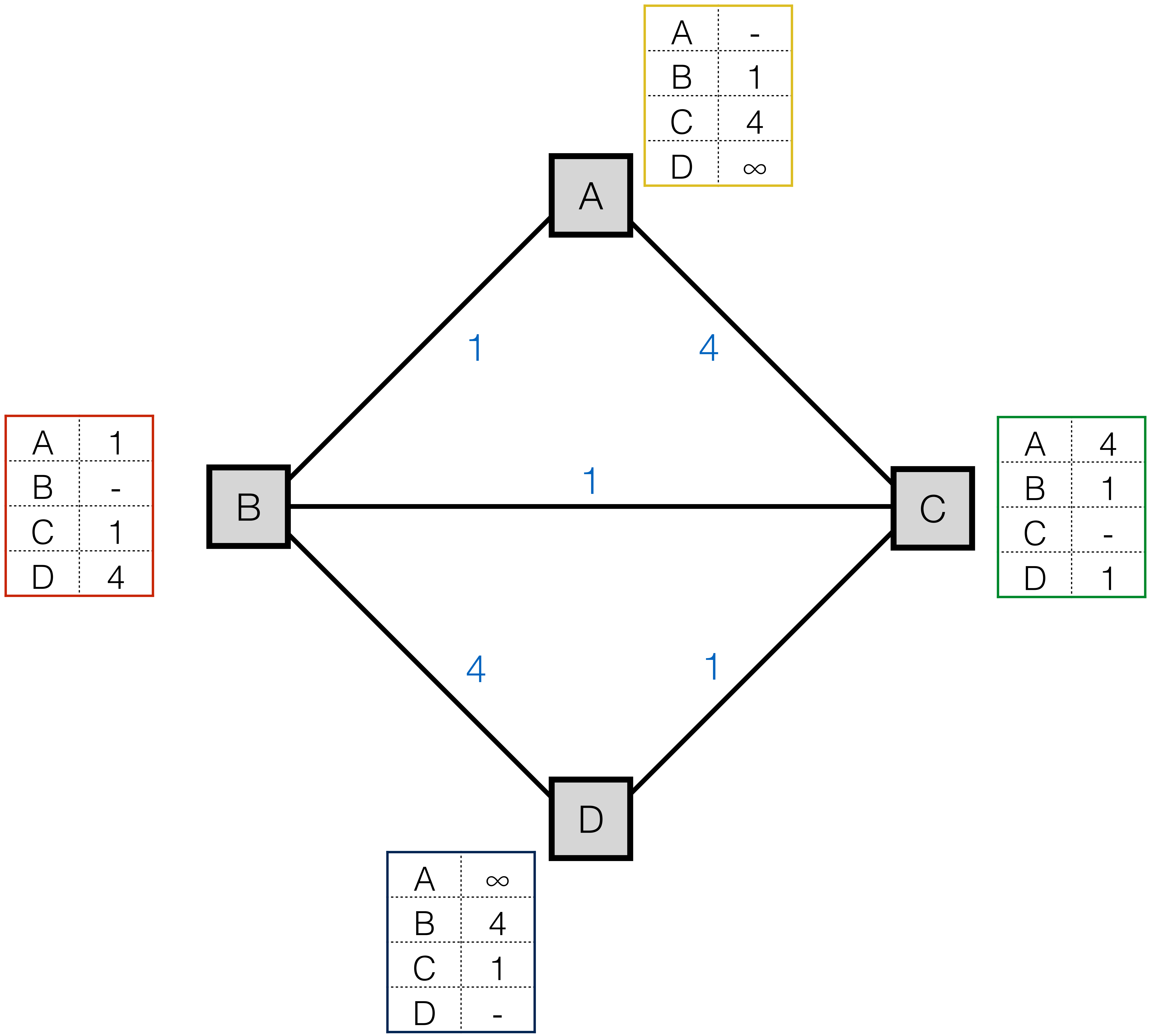
Distance Vector routing



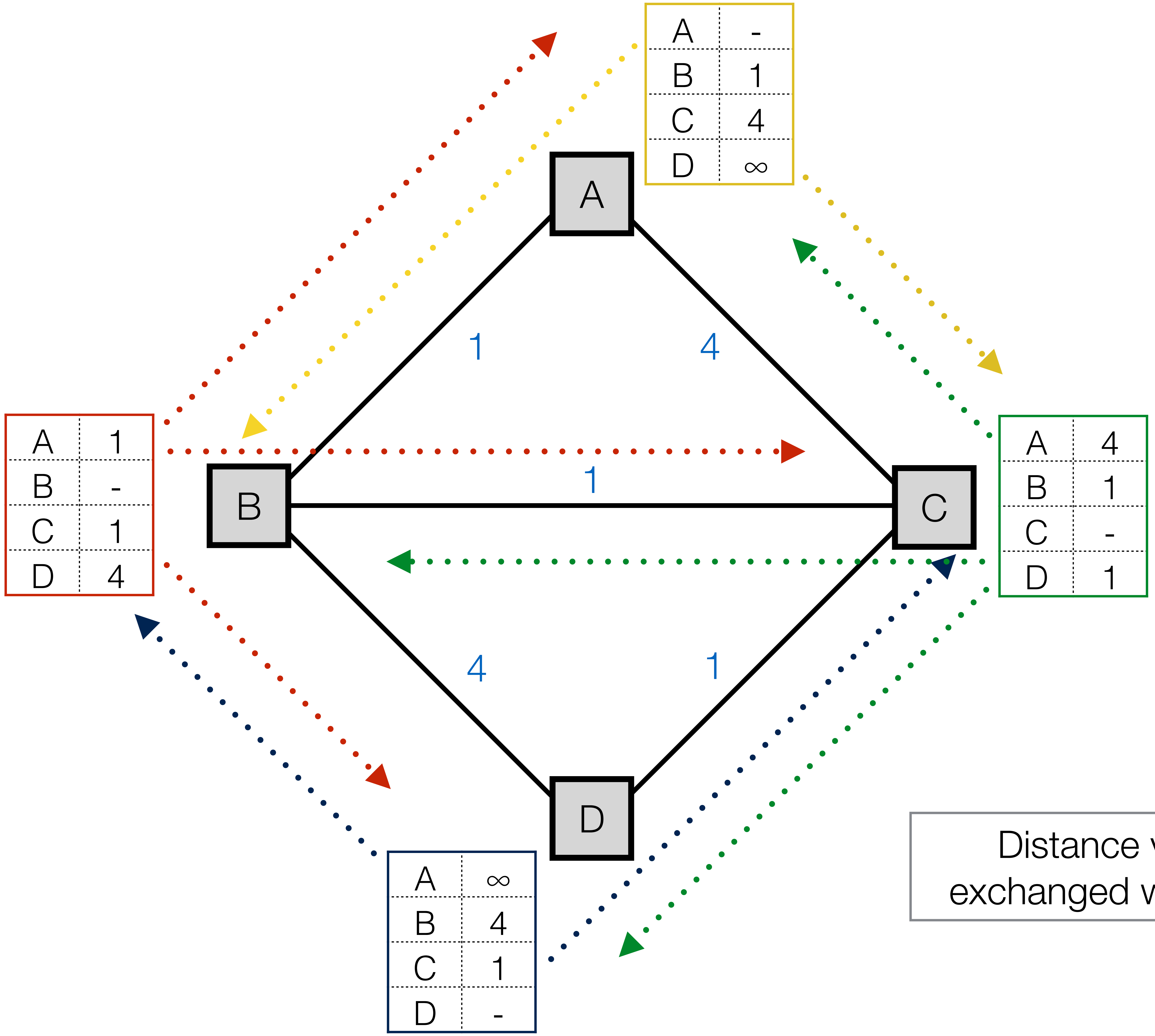
A	-
B	1
C	4
D	∞

Distance vectors are populated using local interface information

Distance Vector routing



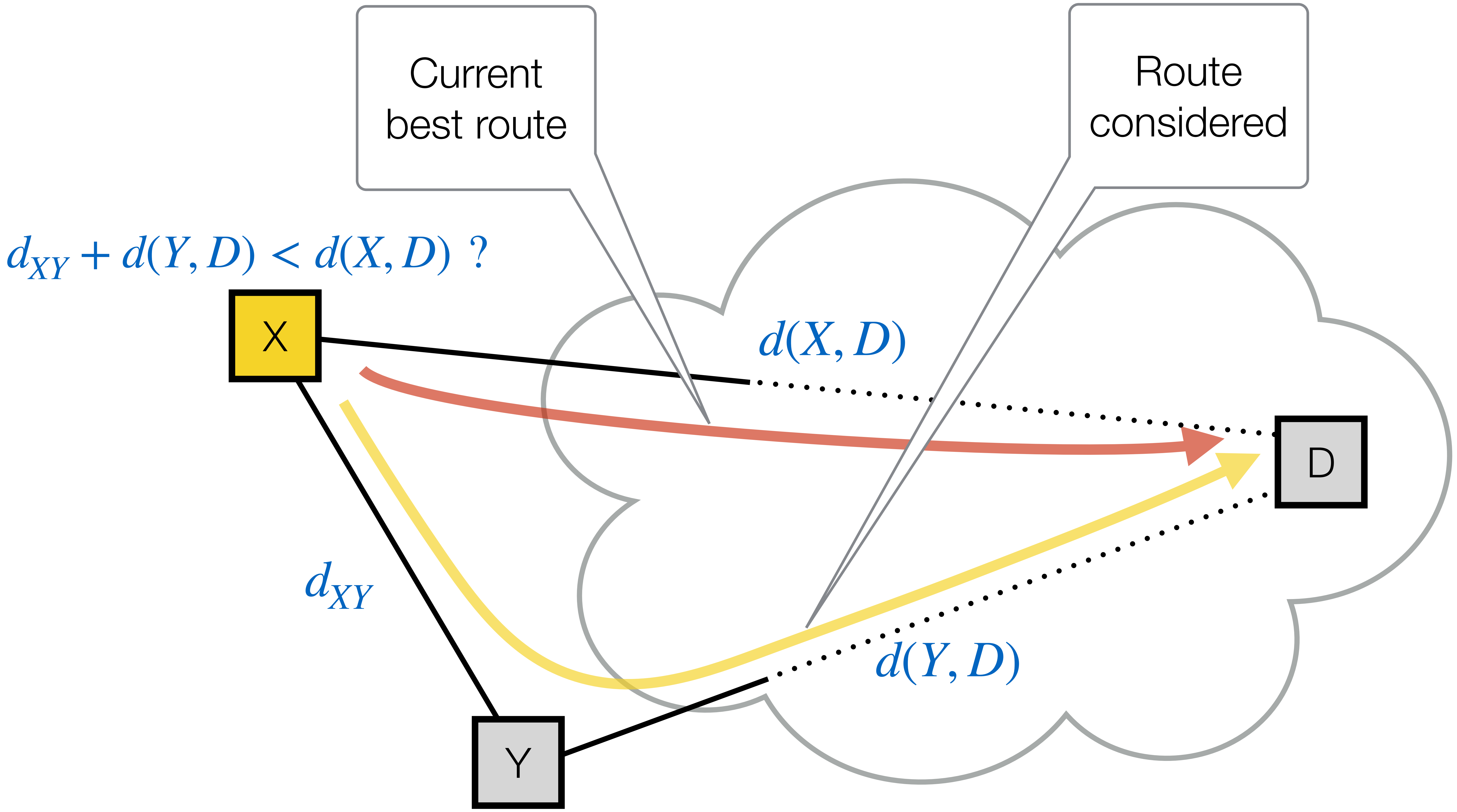
Distance Vector routing



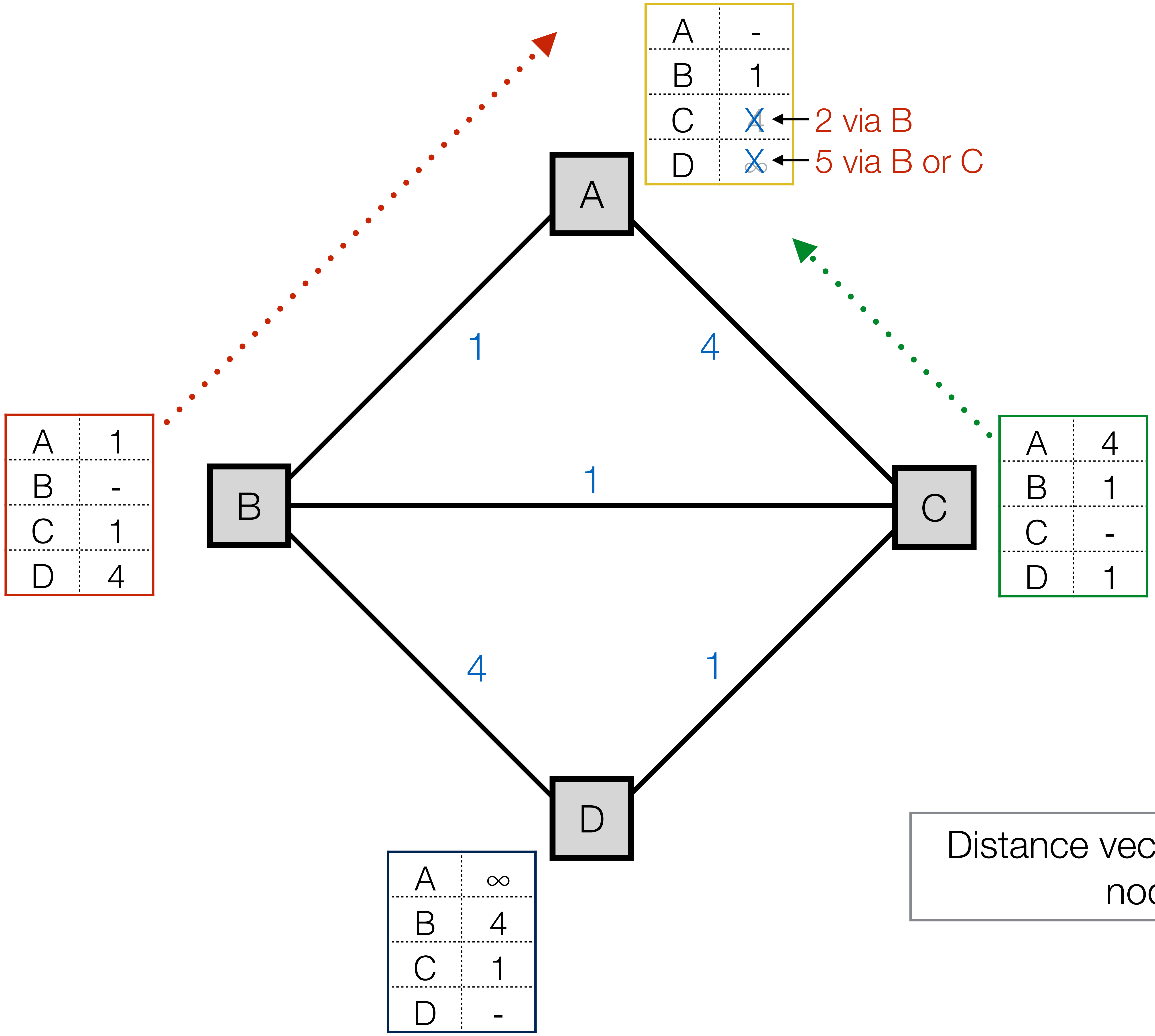
Distance vectors are exchanged with neighbors

Distance Vector update

- Is routing to D through X's neighbor Y (with distance $d_{XY} + d(Y, D)$) better than the current best route from X (with distance $d(X, D)$)?

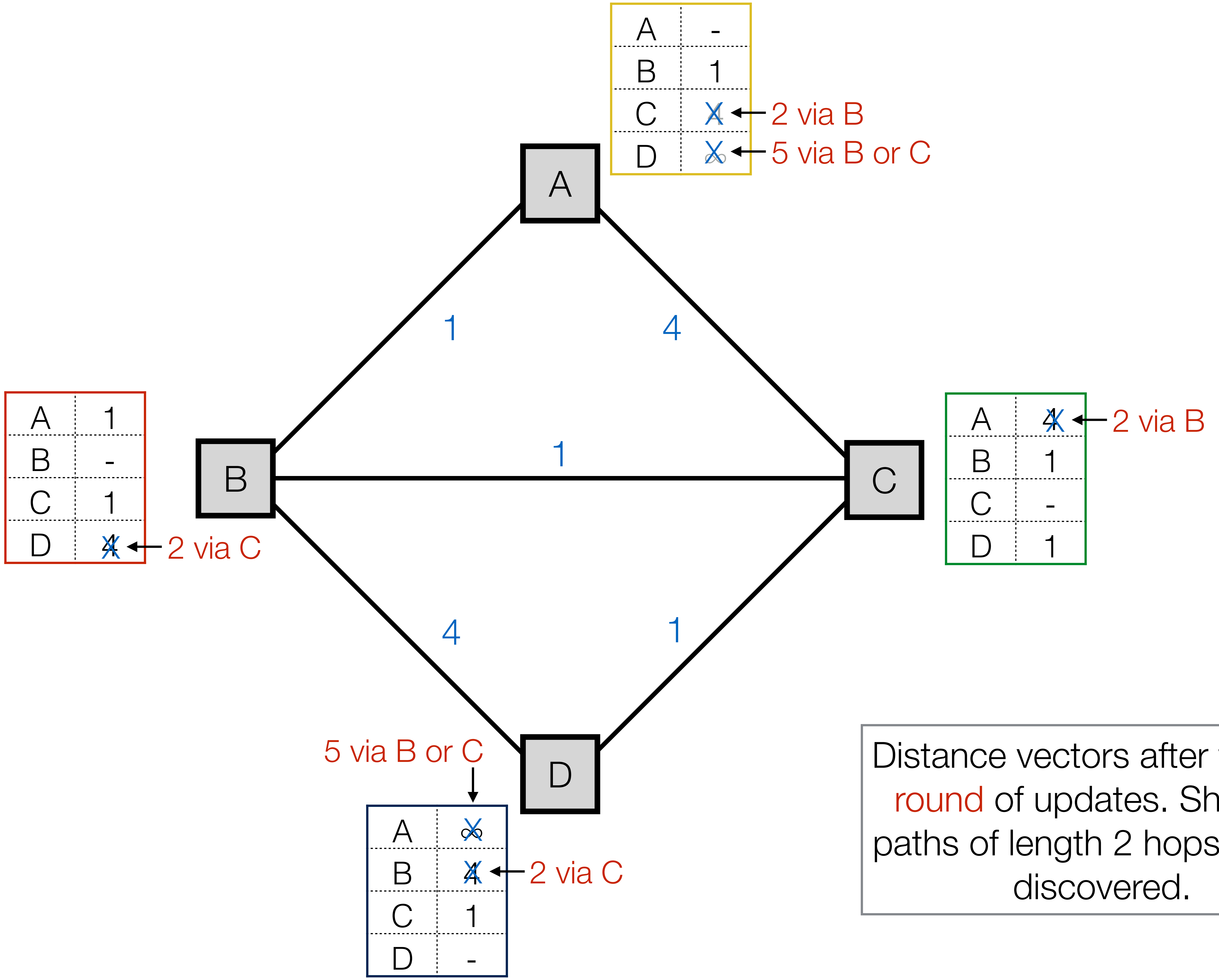


Distance Vector routing



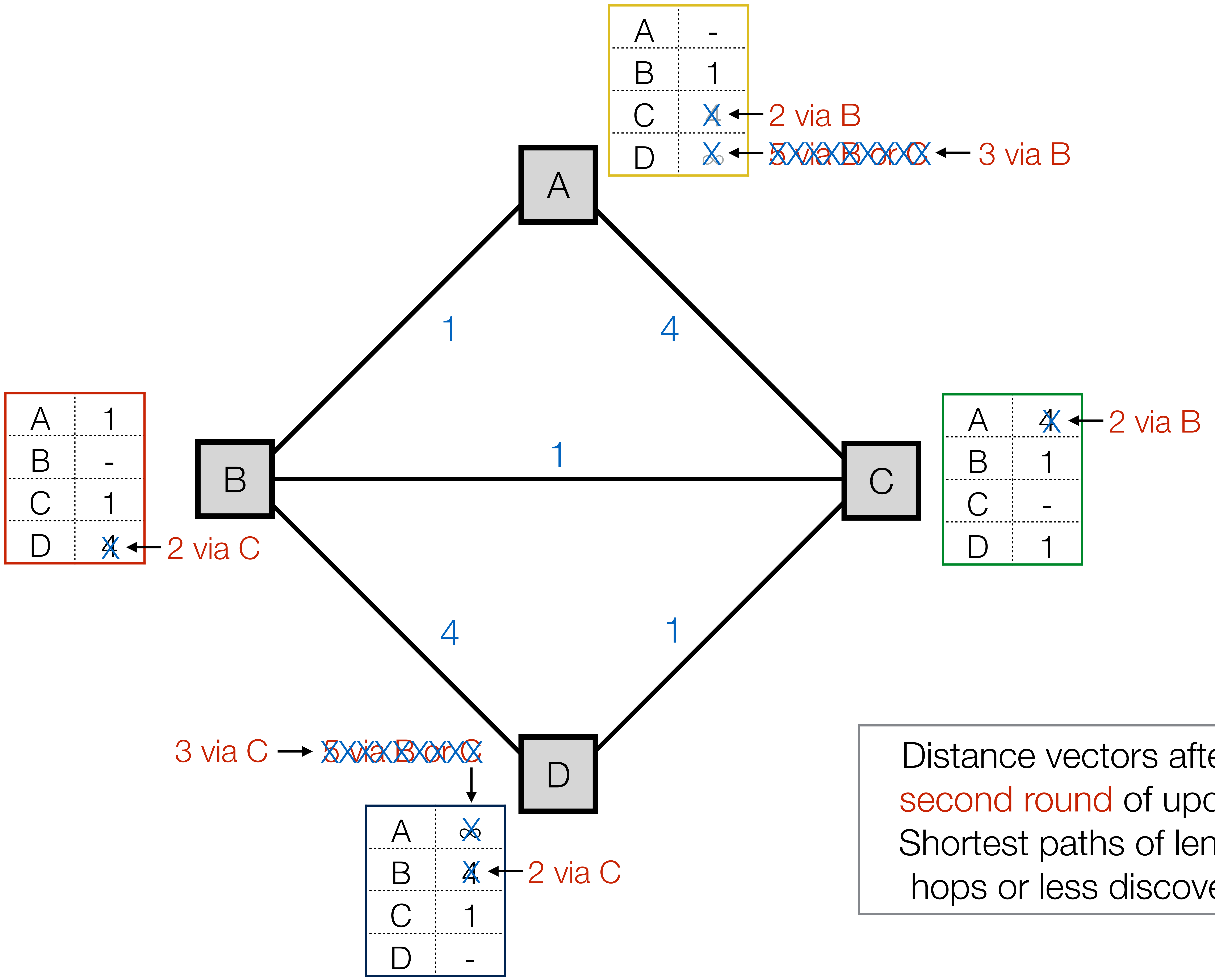
Distance vectors update in node A

Distance Vector routing



Distance vectors after the first round of updates. Shortest paths of length 2 hops or less discovered.

Distance Vector routing



Distance vectors after the second round of updates. Shortest paths of length 3 hops or less discovered.

Distance Vector routing