CS 725/825 & IT 725

Lecture 20

Network Layer

November 17, 2025

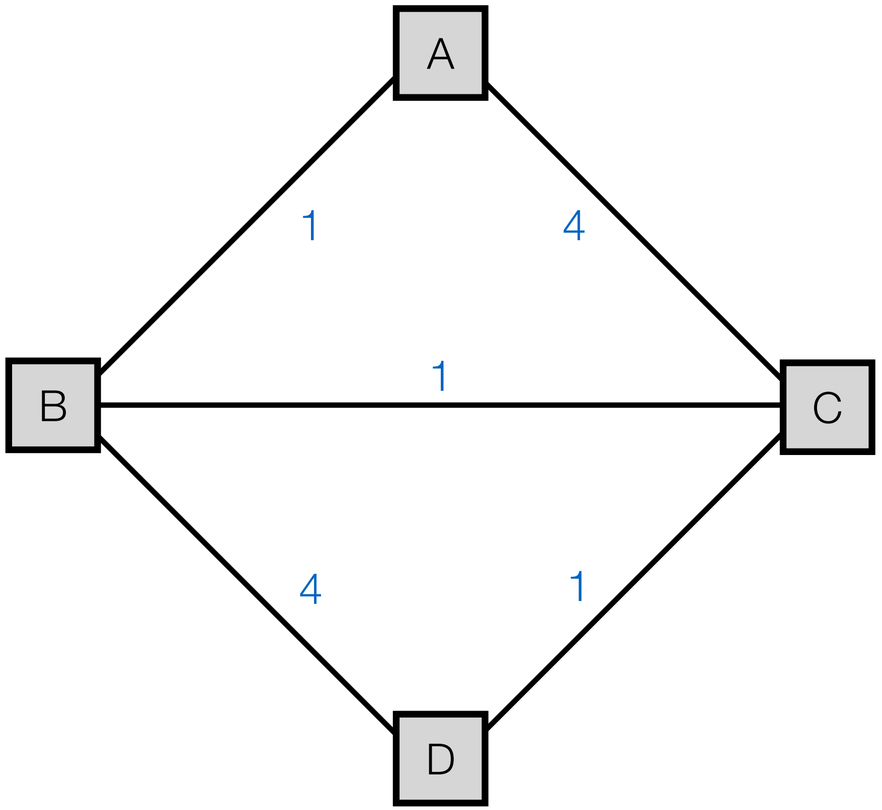
Routing Protocols - Categories

- 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

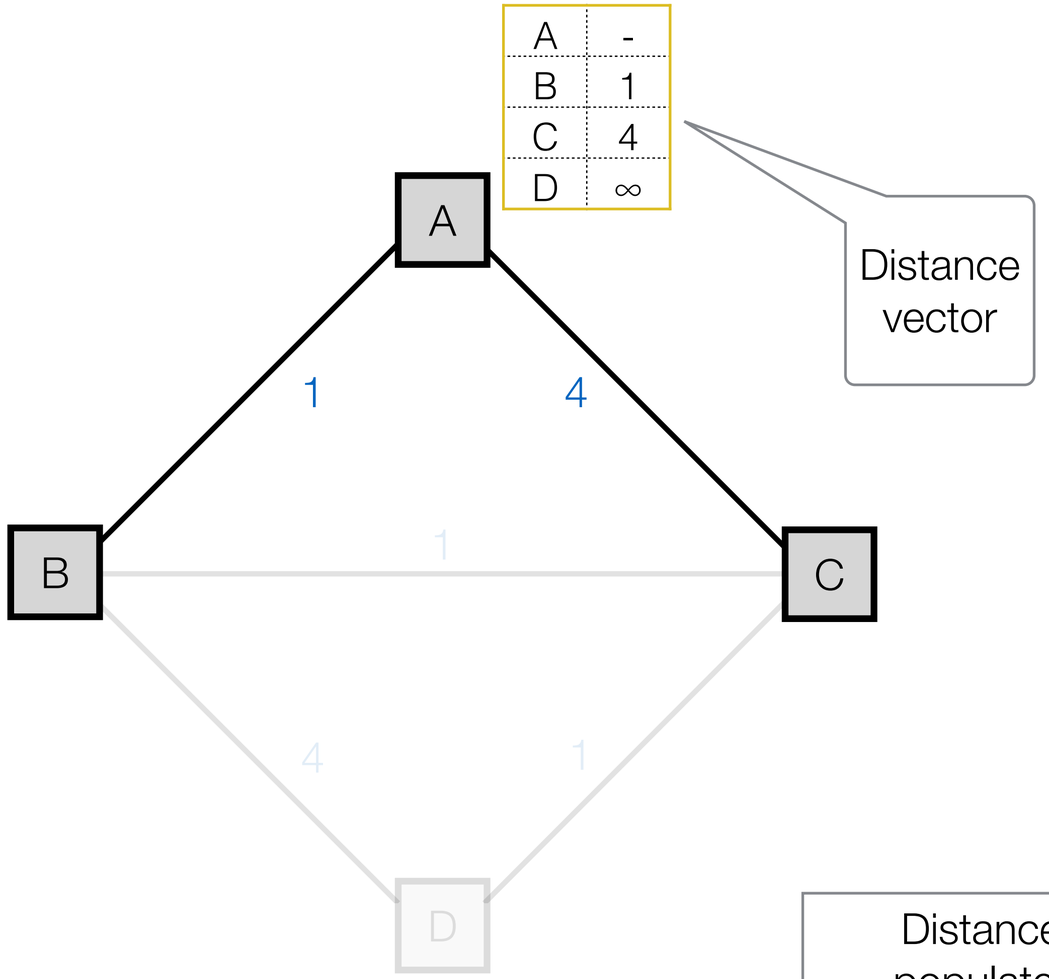
Distance Vector (recap)

- 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

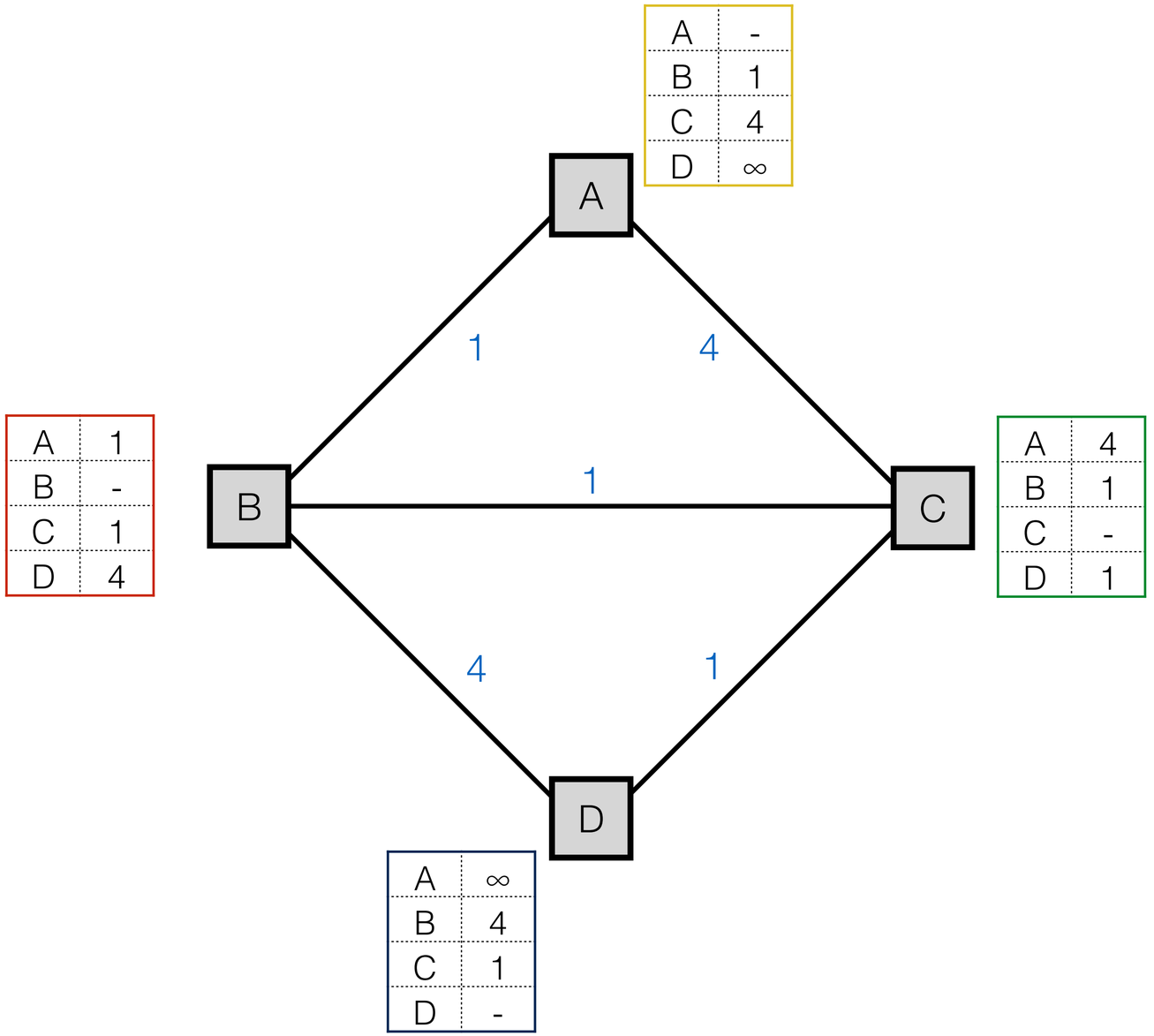


Distance Vector routing

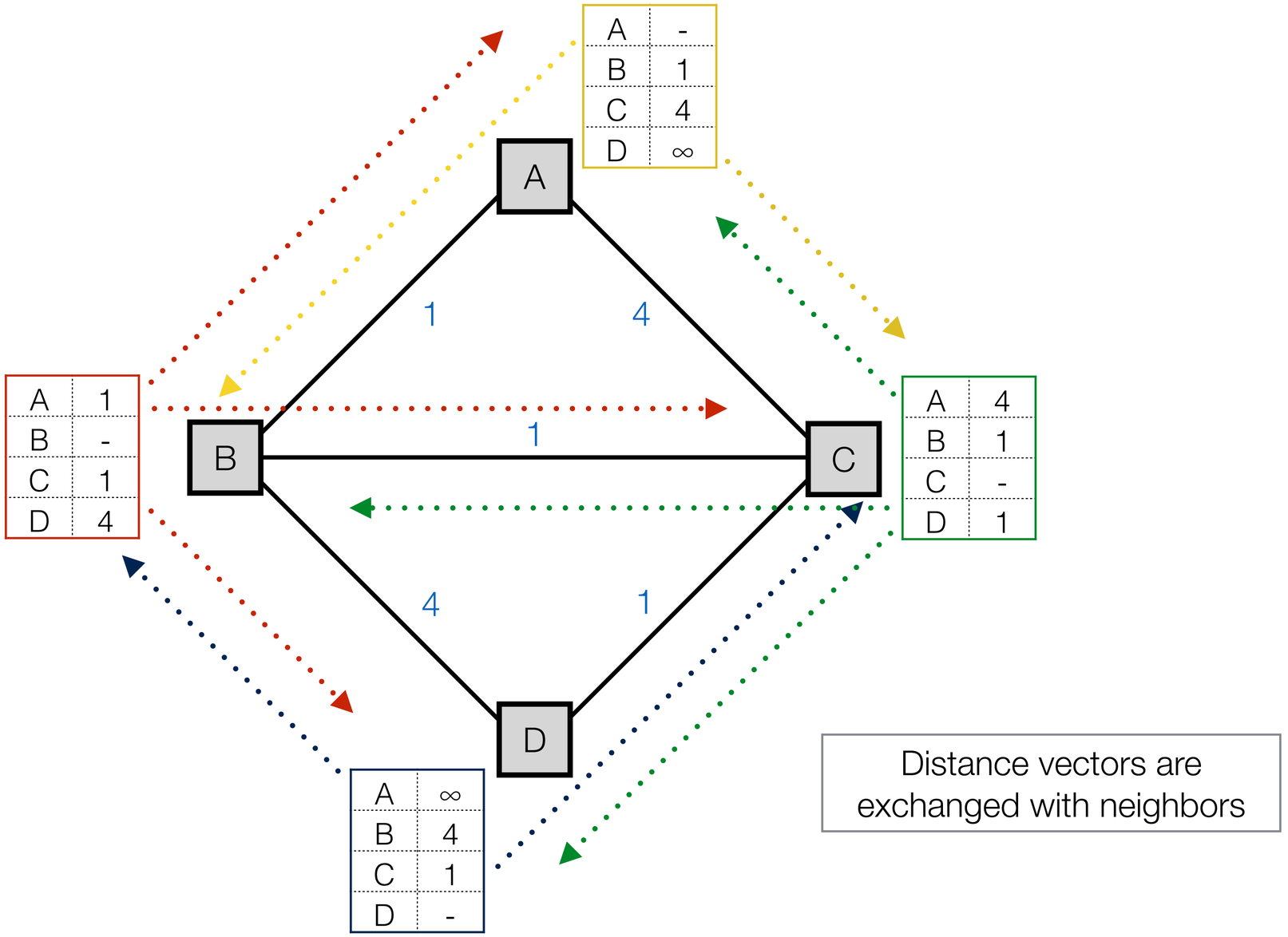


Distance vectors are populated using local interface information

Distance Vector routing

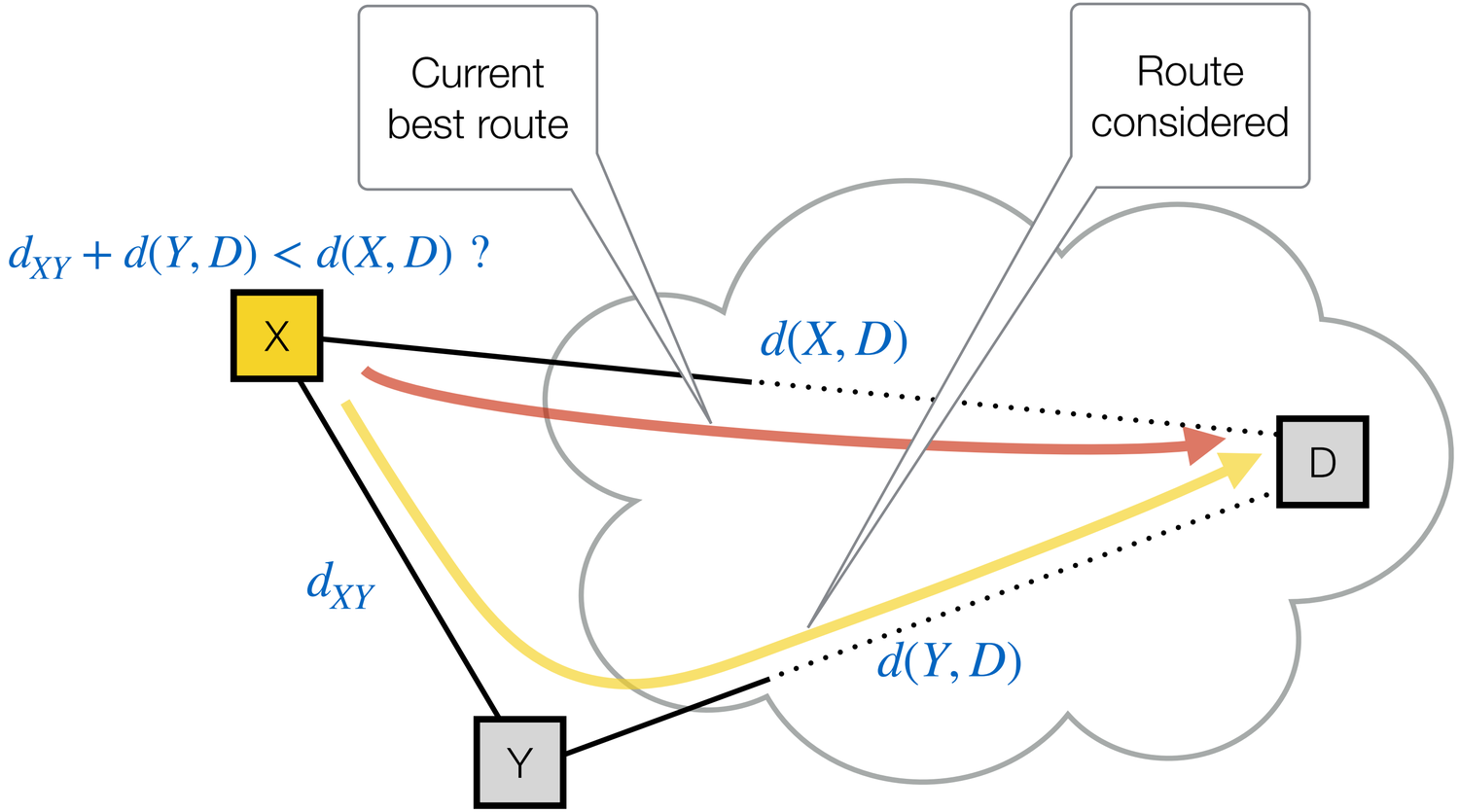


Distance Vector routing

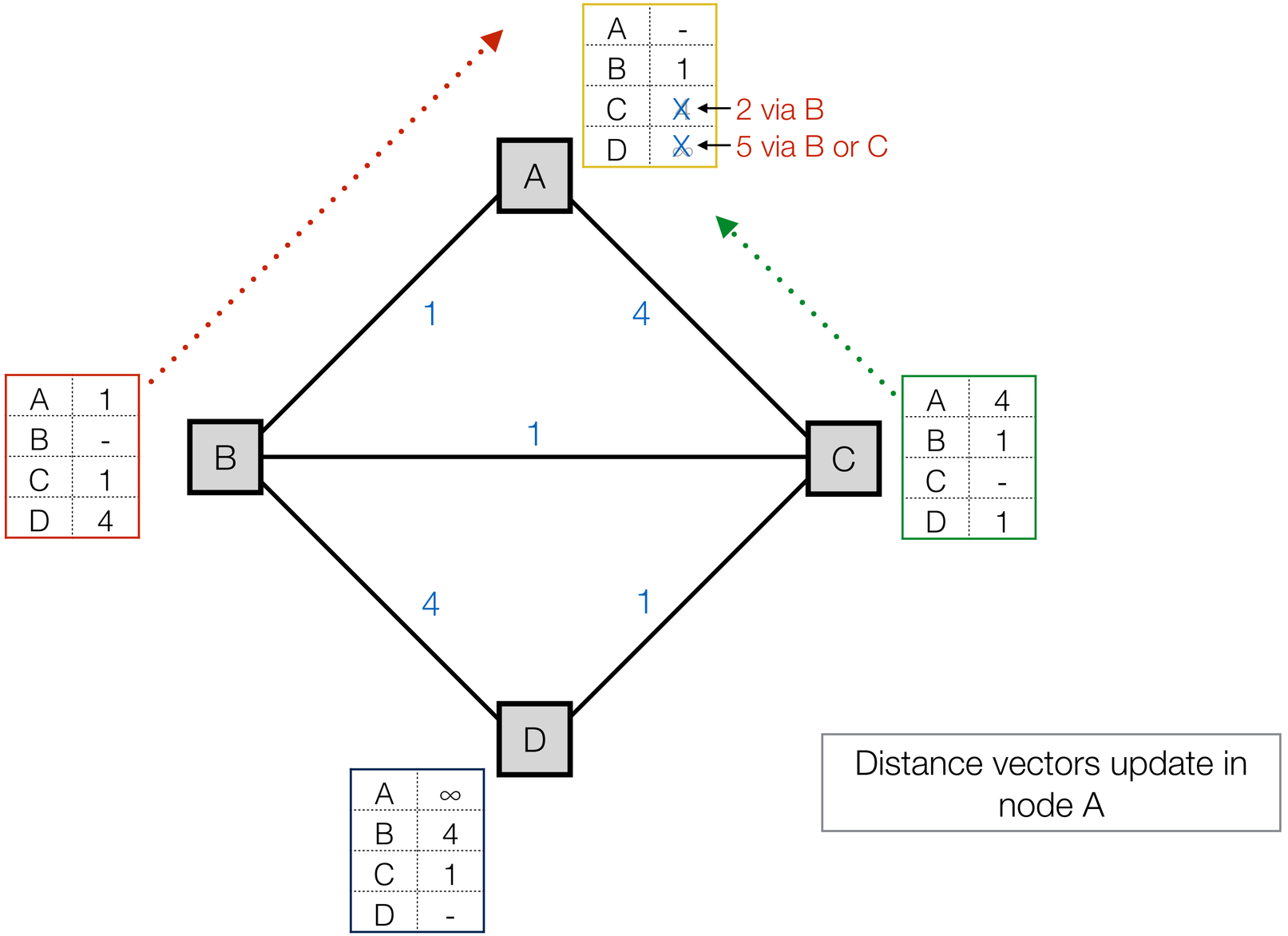


Distance Vector update

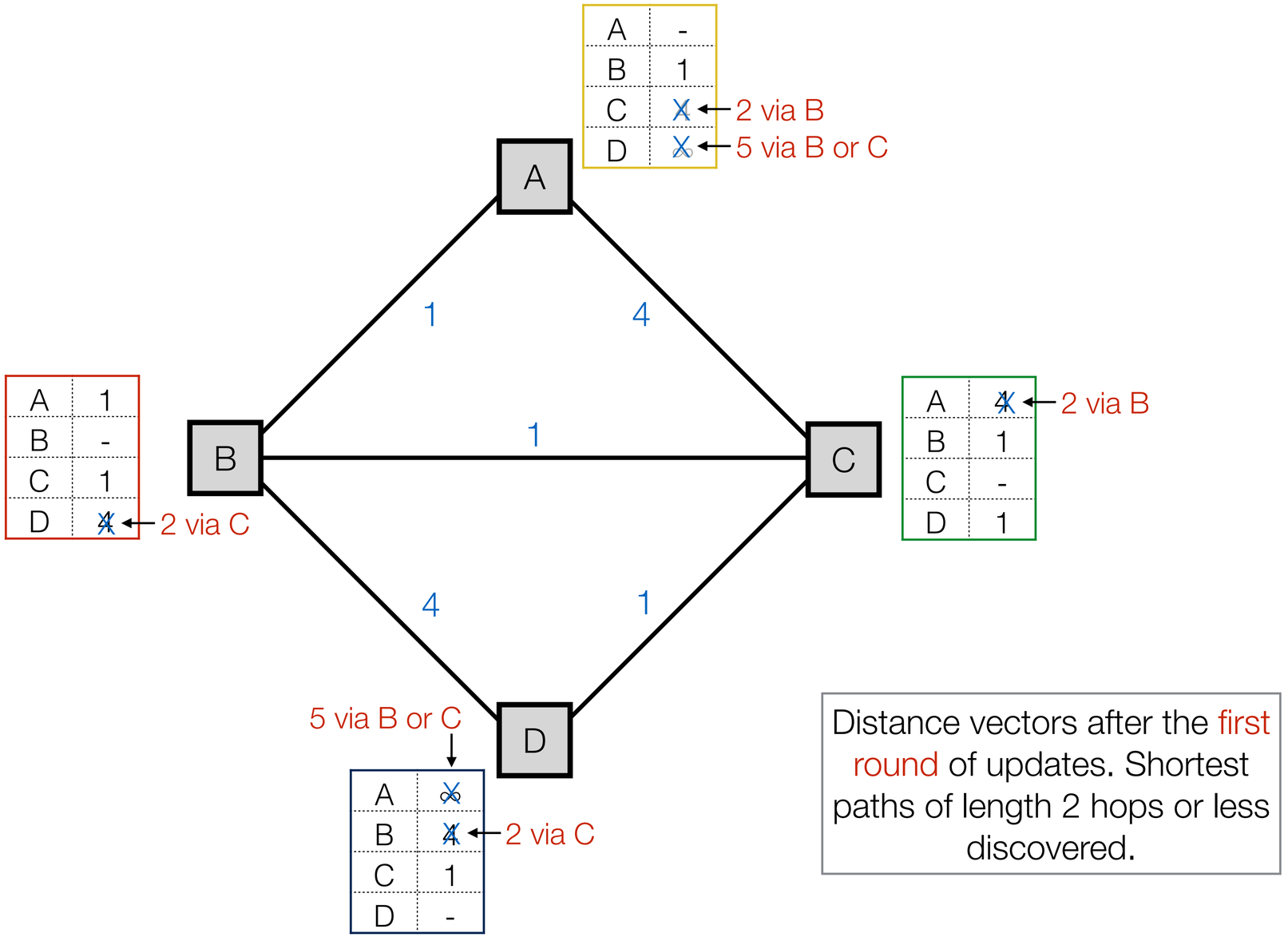
- Is routing to D through X's neighbor Y (with distance $d_{XY} + d(Y, D)$) better than the current best route from X (with distance $d(X, D)$)?



Distance Vector routing

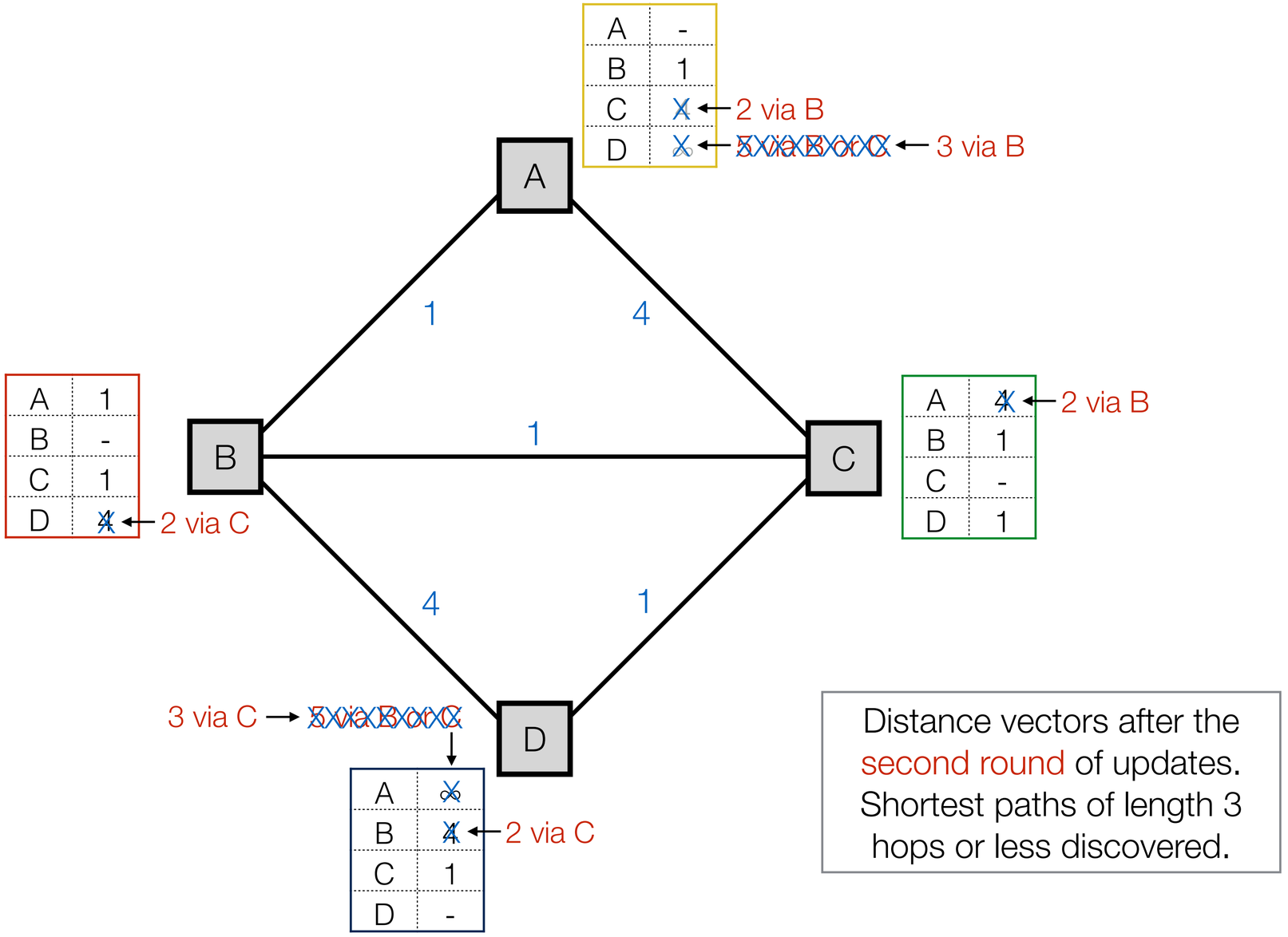


Distance Vector routing



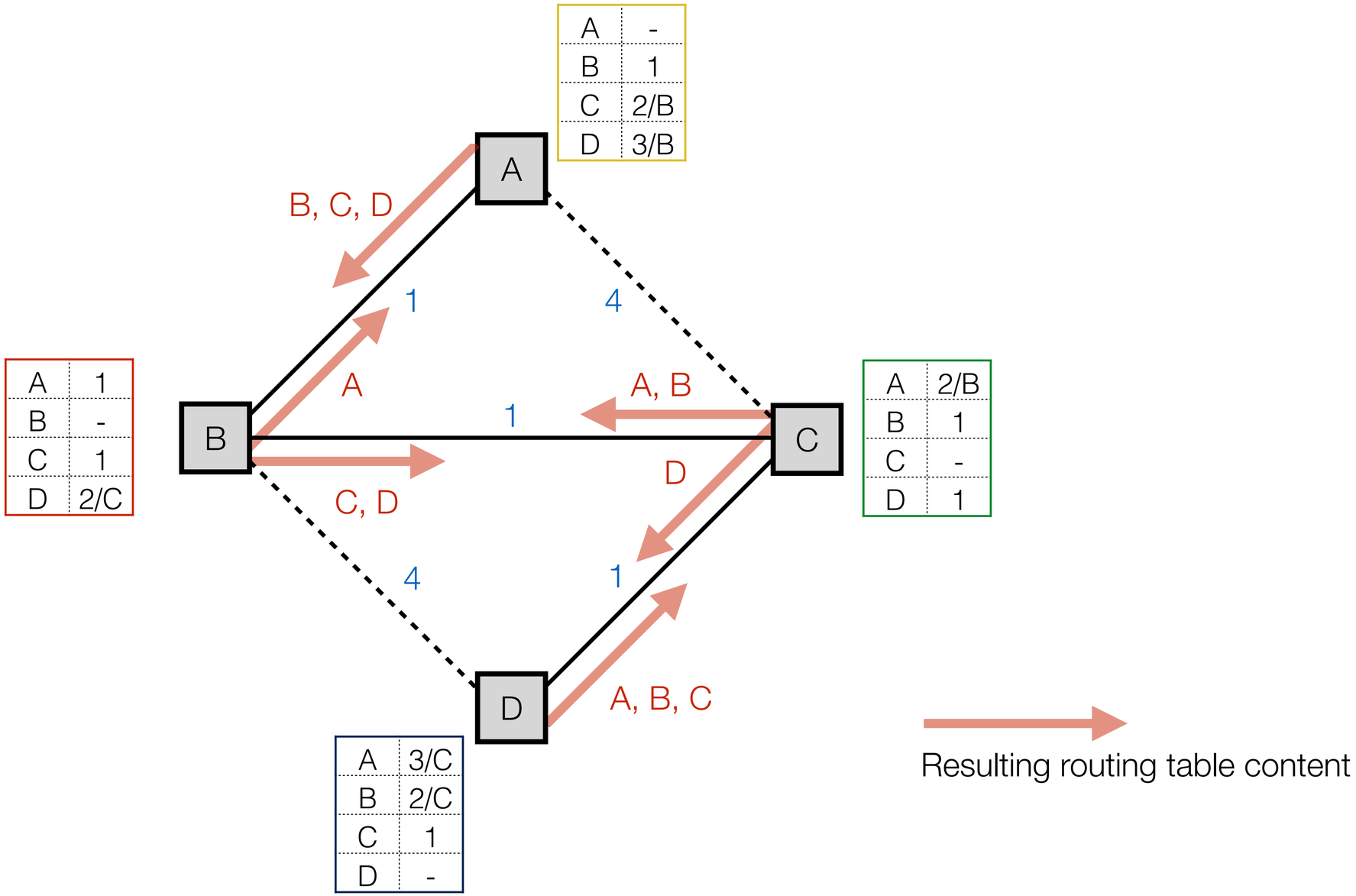
Distance vectors after the first round of updates. Shortest paths of length 2 hops or less discovered.

Distance Vector routing



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

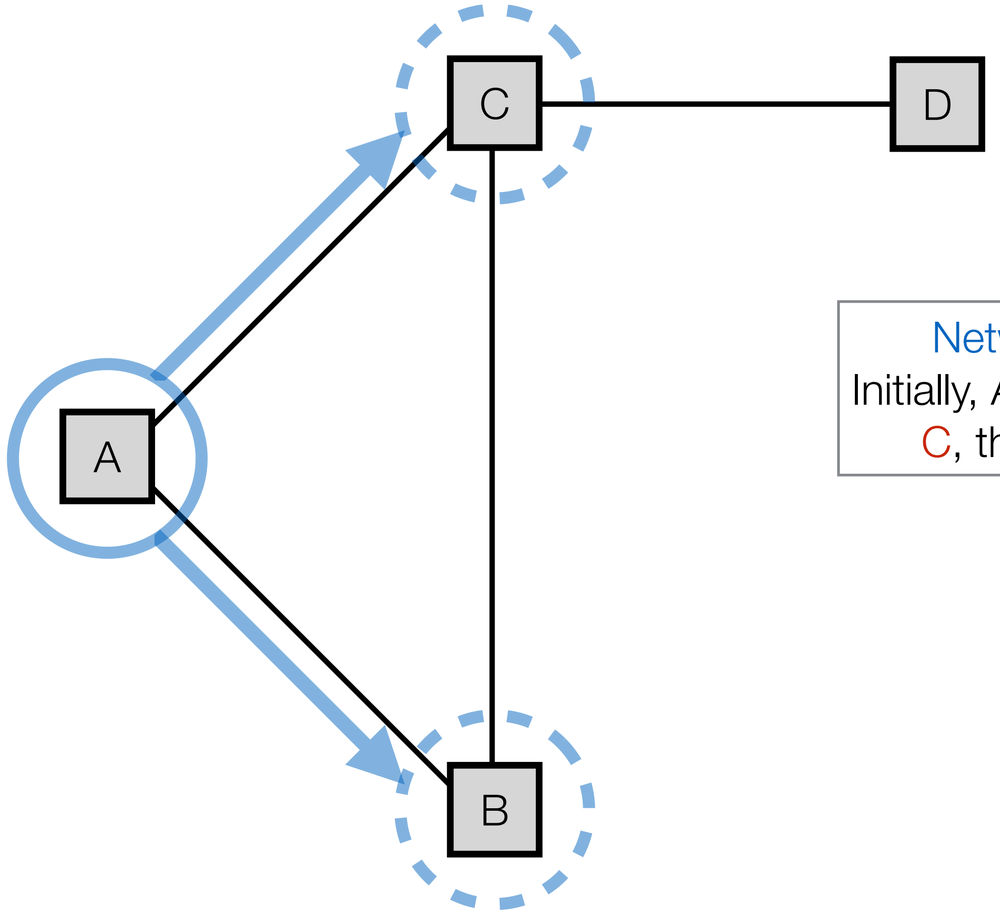
Distance Vector routing



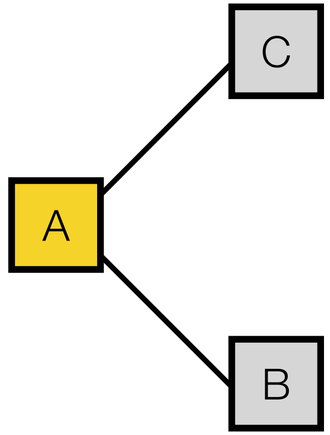
Link State (recap)

- Exact neighbor information flooded to every node on the network
- Topology of the entire networks is discovered in each node
- Shortest paths calculated and used to populate the routing tables

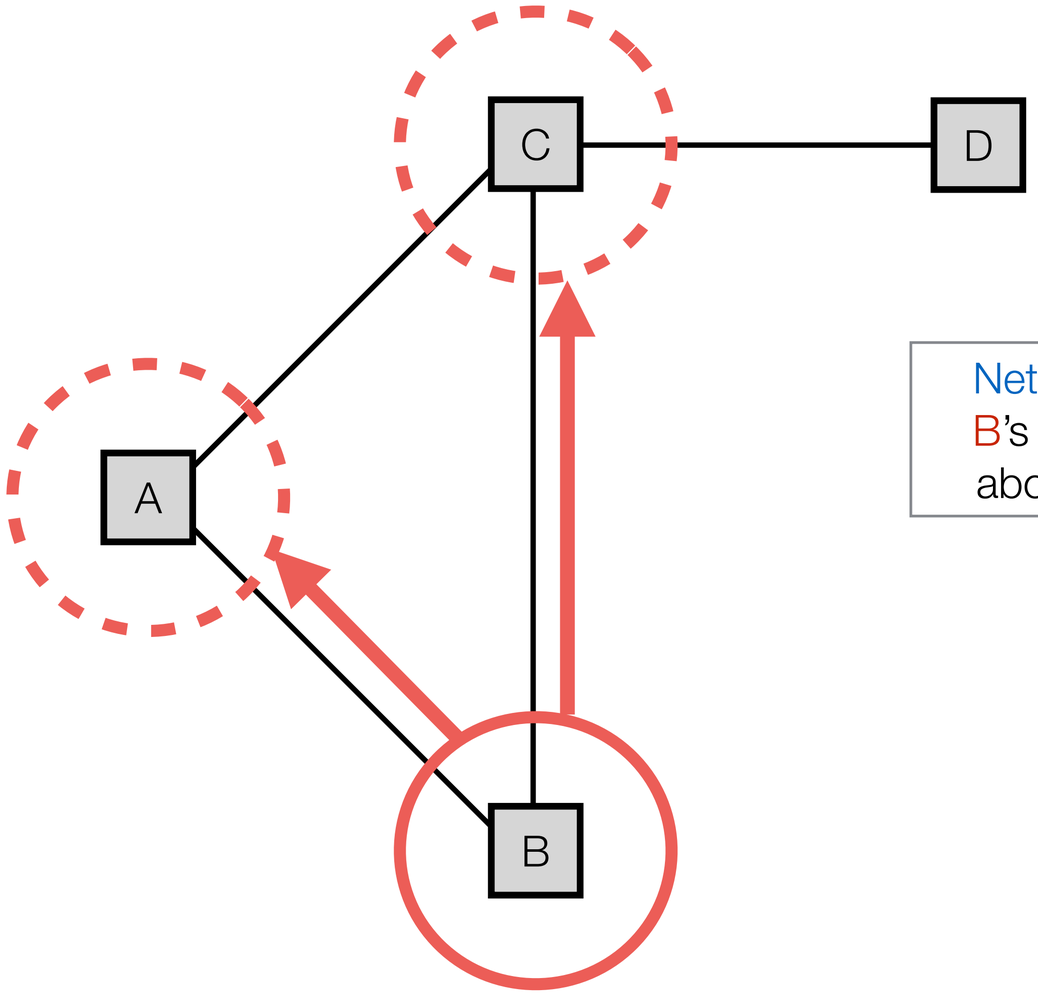
Link State routing



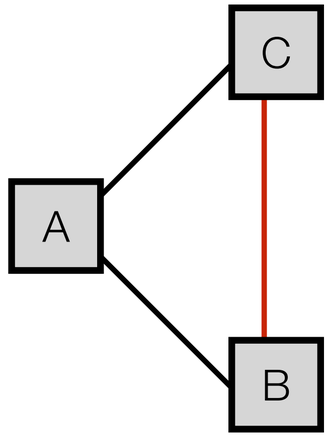
Network topology as seen by A:
Initially, A knows it is connected to B and C, this info is flooded to all nodes



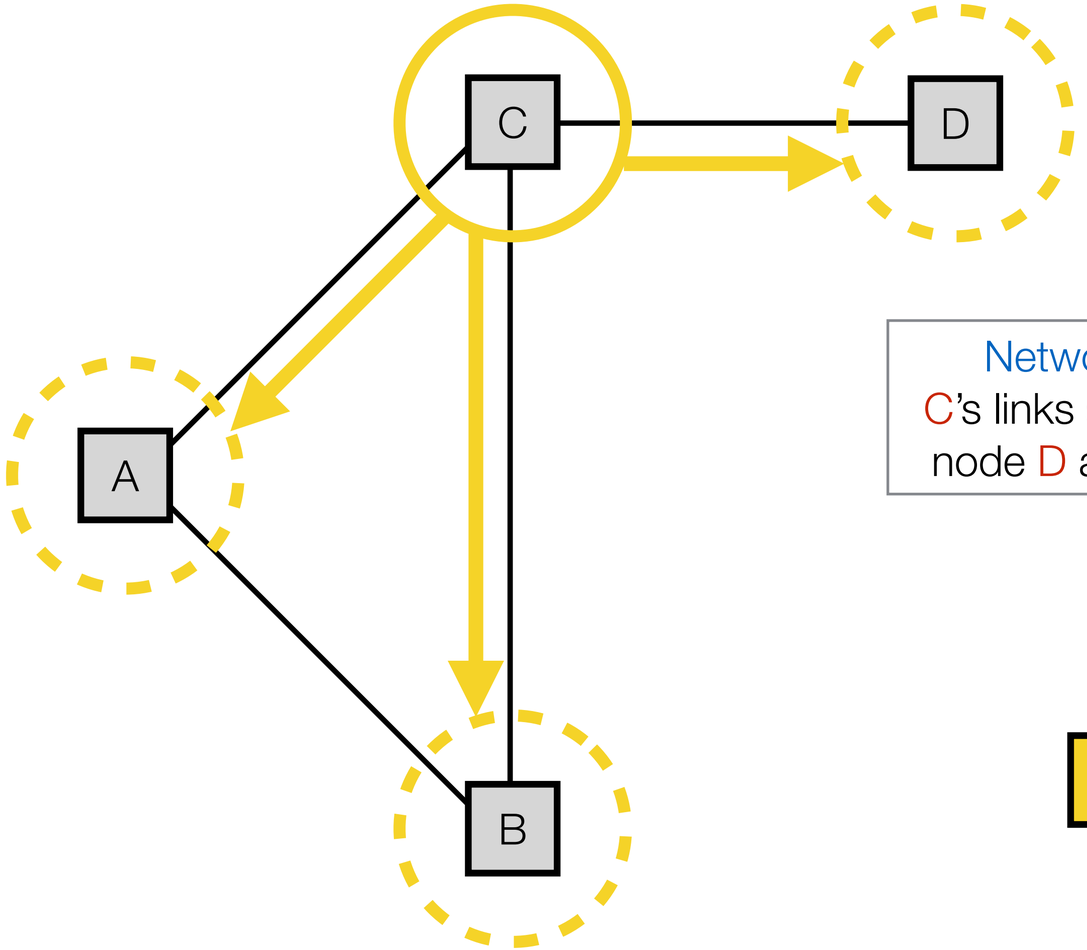
Link State routing



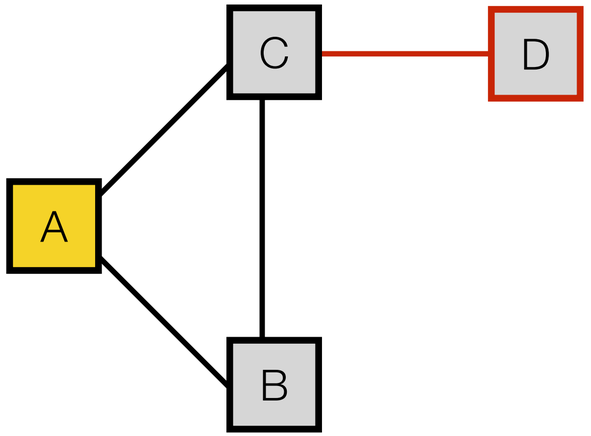
Network topology as seen by A:
B's links state received, A learns about the link between B and C



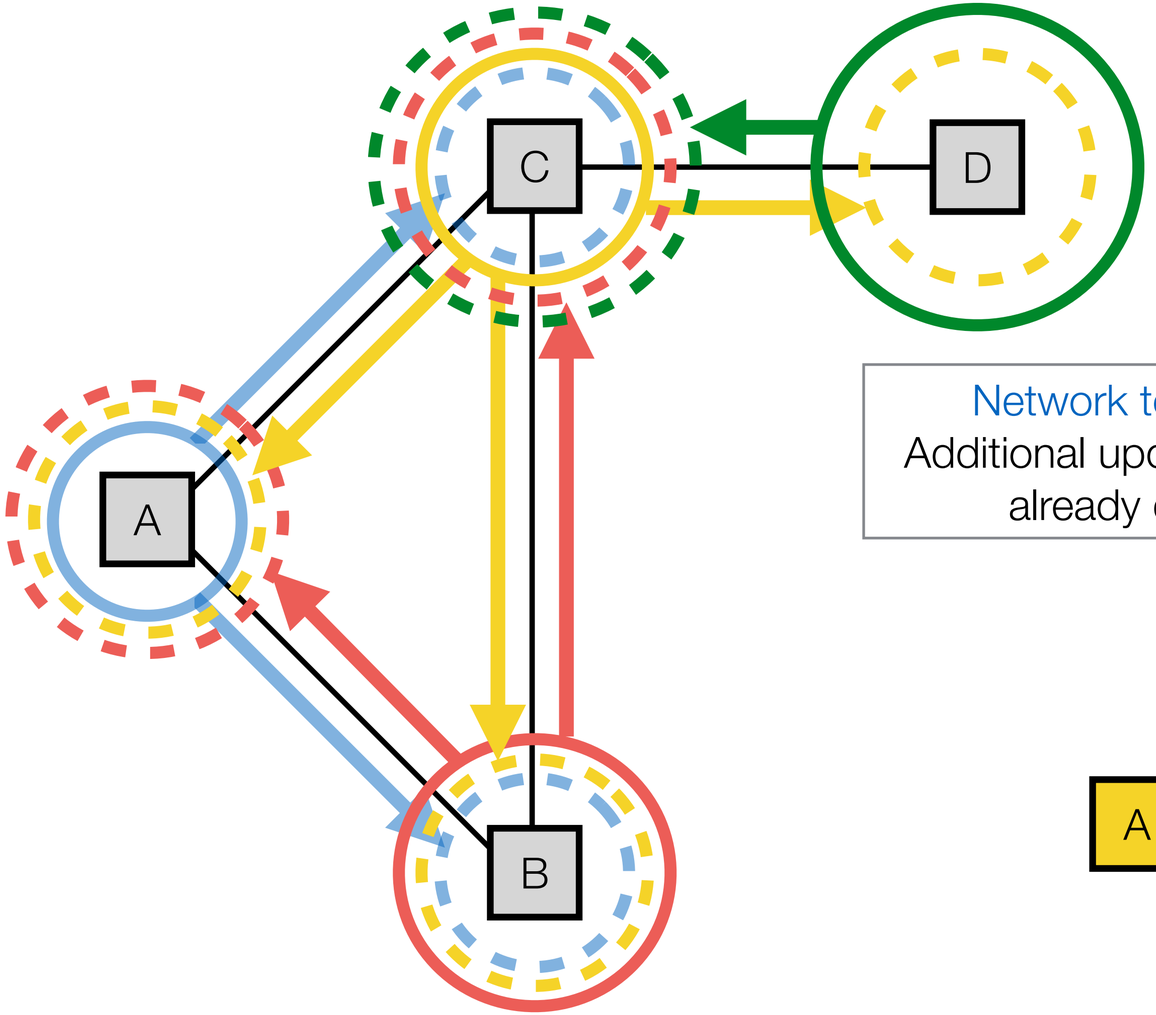
Link State routing



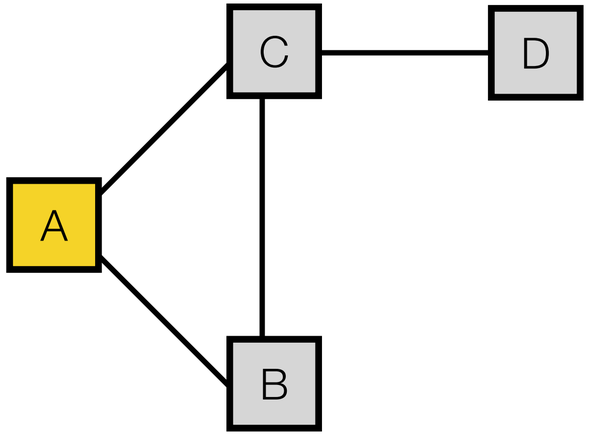
Network topology as seen by A:
C's links state received, A learns about node D and the link between C and D



Link State routing



Network topology as seen by A:
Additional updates received, confirming already discovered topology



Scalability of Routing Protocols

- Internet is large...
- Need to introduce hierarchy
  - ... into something that naturally does not have one
  - divide and conquer, abandoning hope for optimality
  - based on ownership - Autonomous System (AS)
- Different routing problems:
  - Intra AS routing - interior gateway routing (IGP)
  - Inter AS routing - exterior gateway routing (EGP)

Examples of Routing Protocols

	Distance Vector	**Link State**
IGP	RIP	OSPF
EGP	BGP-4*	

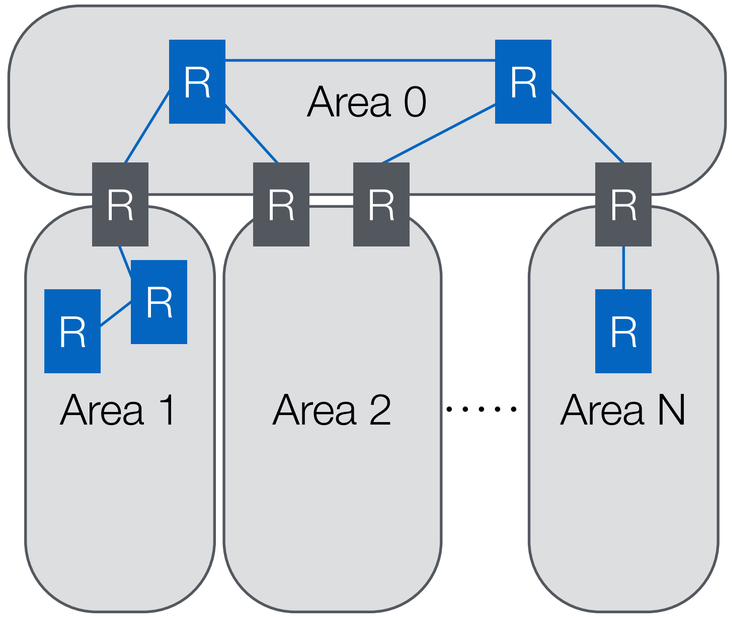
* BGP-4 extends the concept of *Distance Vector* routing to include the path information and is typically referred to as a ***Path Vector*** routing protocol

RIP

- Routing Information Protocol
  - a distance vector routing protocol
  - hops used as a measure of distance
  - 30 second update interval
- Version history
  - RIPv1 - 1988
  - RIPv2 - 1993 (includes CIDR, authentication)
  - RIPng - 1997 (IPv6 support)

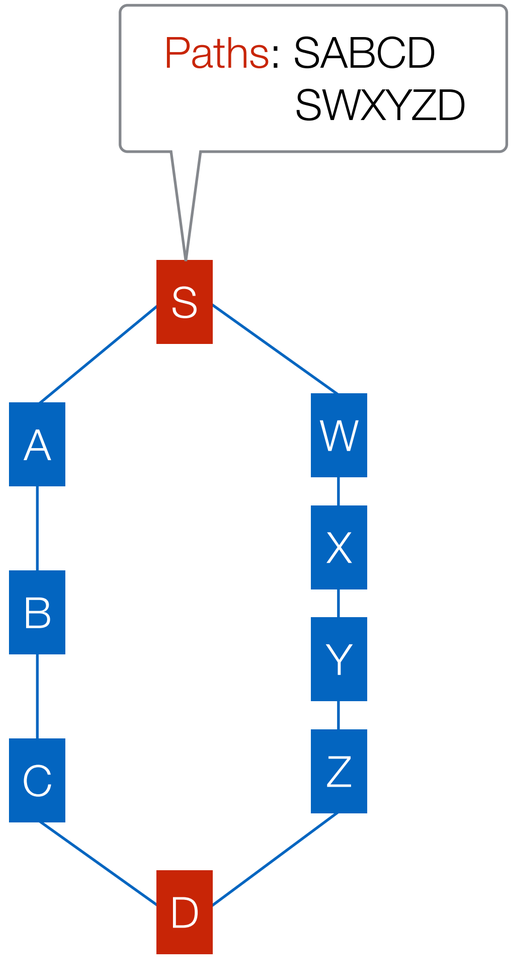
OSPF

- Open Shortest Path First
  - link state routing protocol
  - two-level hierarchy
  - user-defined link weights
- Version history:
  - OSPF (1989)
  - OSPFv2 (1998)
  - OSPFv3 (2008, IPv6)



BGP-4

- Border Gateway Protocol
  - exterior gateway routing protocol
  - *path* vector routing
  - allows policy based routing
  - AS as a routing hop
- Version history
  - Version 4 (1995)
  - Latest “version” of version 4 (2006)



QoS Measures

- Throughput
  - bits, bytes, packets per second
- Latency
  - one way or round trip
- Latency variation (jitter)
  - average, max, etc.
- Probability of successful delivery
  - packet loss rate
  - bit error rate

Quality of Service in IP

- Type of Service (TOS) field in IPv4, Traffic Class in IPv6
  - 8 bits
  - priority (3 bits)
  - bits to request high throughput, low latency, low loss, and low monetary cost
  - set by traffic generating applications
- For most parts, this attempt has failed:
  - no cost for requesting higher category of service
  - no broad agreement on how to handle the different categories

Differentiated Services

- Domain-based solution
- Relative guarantees
- Few classes of service
- Framework rather than a complete and prescriptive solution
- Reuses TOS field (called DSCP - Differentiated Services Code Point)

Differentiated Services