# Lecture 13: Distance-vector Routing

CSE 123: Computer Networks

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HW 3 due now

UCSDCSE

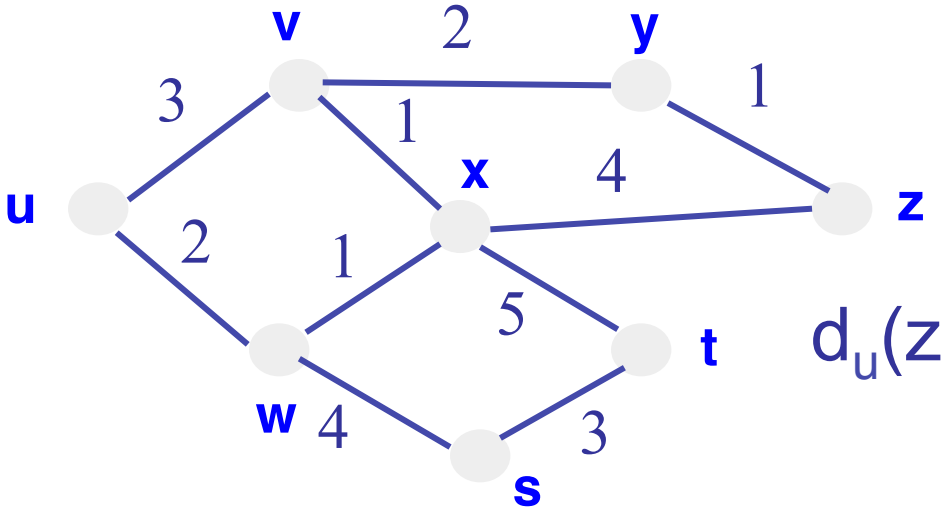
# Lecture 13 Overview

- Distance vector
  - Assume each router knows its own address and cost to reach each of its directly connected neighbors
- Bellman-Ford algorithm
  - Distributed route computation using only neighbor's info
- Mitigating loops
  - Split horizon and posion reverse

# Bellman-Ford Algorithm



- Define distances at each node *X*
  - $d_x(y)$ = cost of least-cost *path* from *X* to *Y*
- Update distances based on neighbors
  - $d_x(y) = \min \{c(x,v) + d_v(y)\}$ over all neighbors *V*




$$d_u(z) = \min\{c(u,v) + d_v(z), c(u,w) + d_w(z)\}$$

# Distance Vector Algorithm

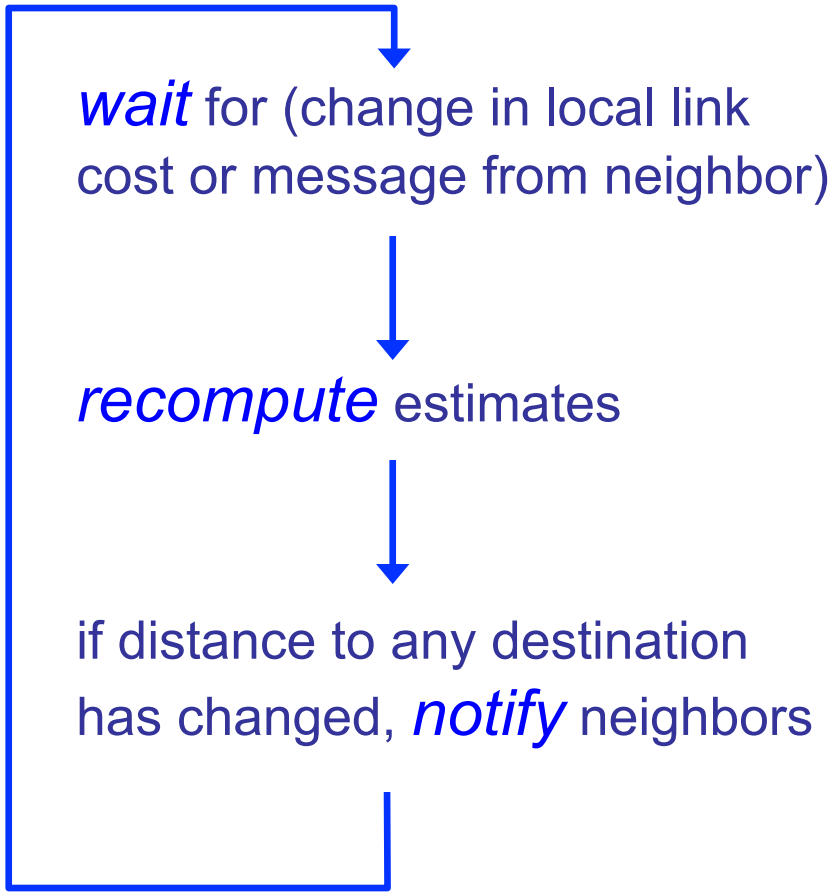
Iterative, asynchronous: each local iteration caused by:

- Local link cost change
- Distance vector update message from neighbor

Distributed:

- Each node notifies neighbors *only* when its DV changes
- Neighbors then notify their neighbors if necessary

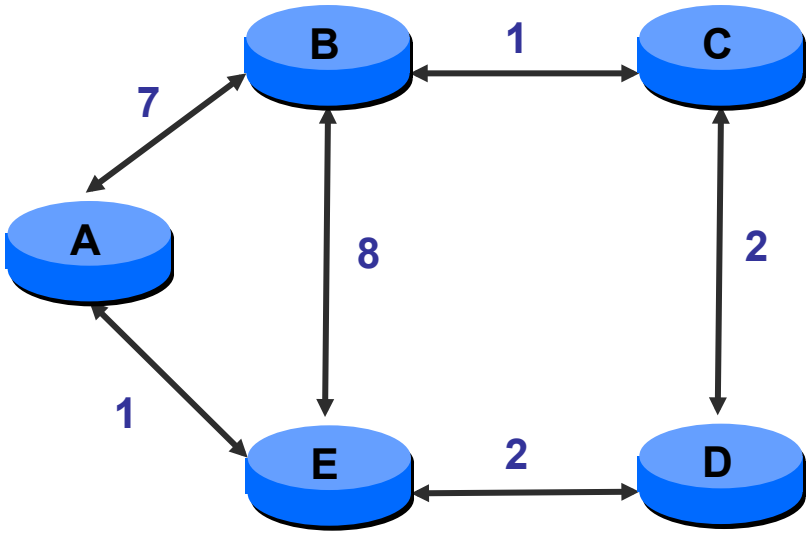
Each node:



# Step-by-Step

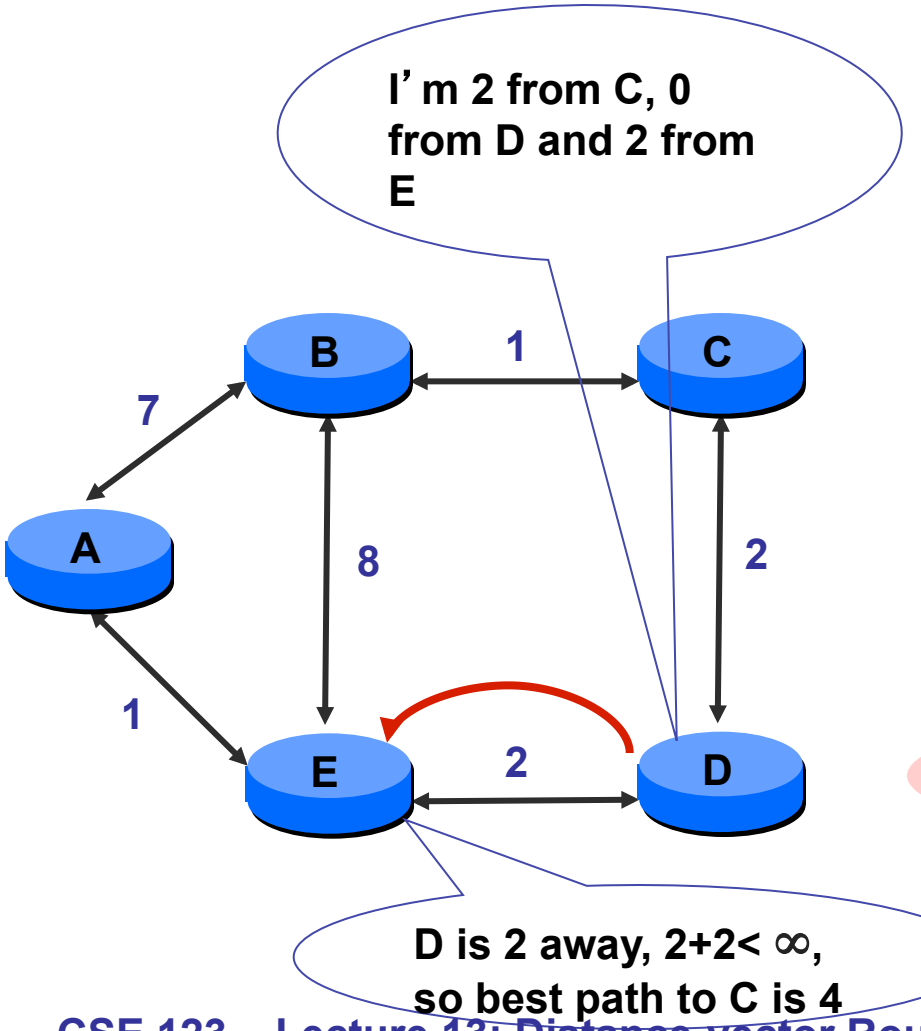
- $c(x,v)$ = cost for direct link from $x$ to $v$
  - Node x maintains costs of direct links $c(x,v)$
- $D_x(y)$ = estimate of least cost from $x$ to $y$
  - Node $x$ maintains distance vector $\boldsymbol{D}_x = [D_x(y): y \in N]$
- Node $x$ maintains its neighbors' distance vectors
  - For each neighbor $v$, $x$ maintains $\boldsymbol{D}_v = [D_v(y): y \in N]$
- Each node $v$ periodically sends $D_v$ to its neighbors
  - And neighbors update their own distance vectors
  - $D_x(y) \leftarrow min_v\{c(x,v) + D_v(y)\}$ for each node $y \in N$

# Example: Initial State



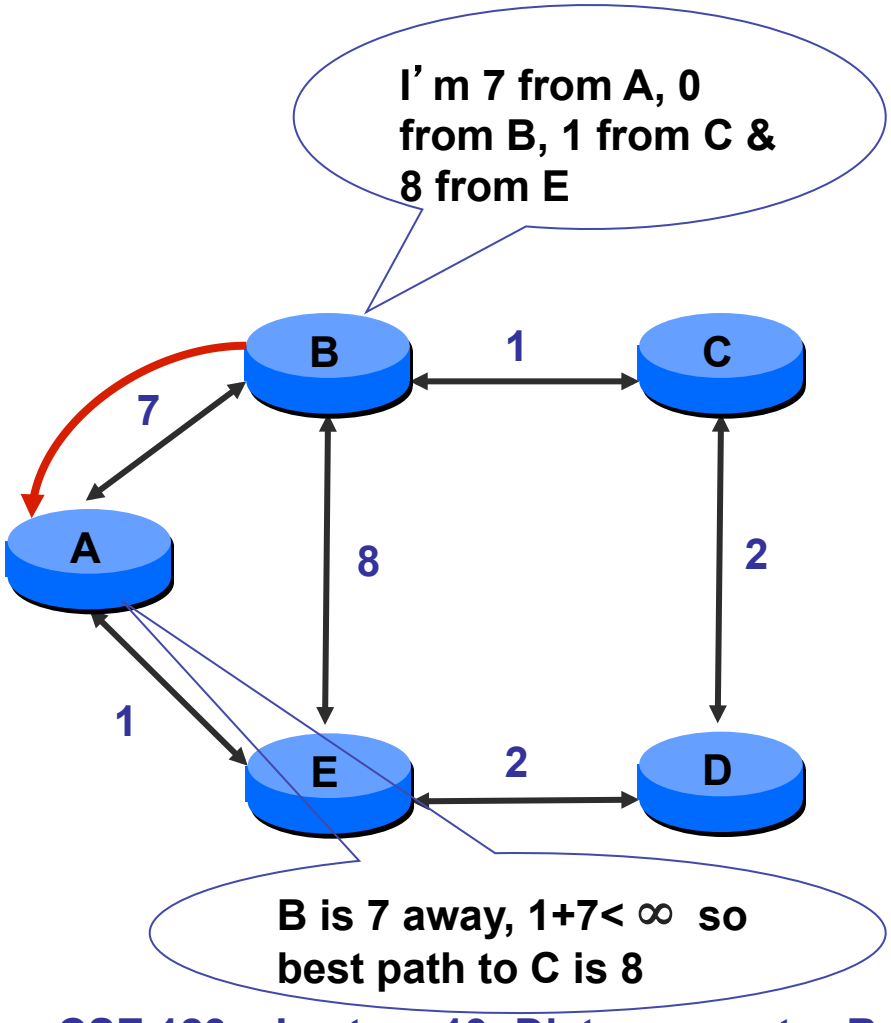

| Info at node | Distance to Node | | | | |
|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** |
| **A** | 0 | 7 | ∞ | ∞ | 1 |
| **B** | 7 | 0 | 1 | ∞ | 8 |
| **C** | ∞ | 1 | 0 | 2 | ∞ |
| **D** | ∞ | ∞ | 2 | 0 | 2 |
| **E** | 1 | 8 | ∞ | 2 | 0 |

# *D* sends vector to *E*



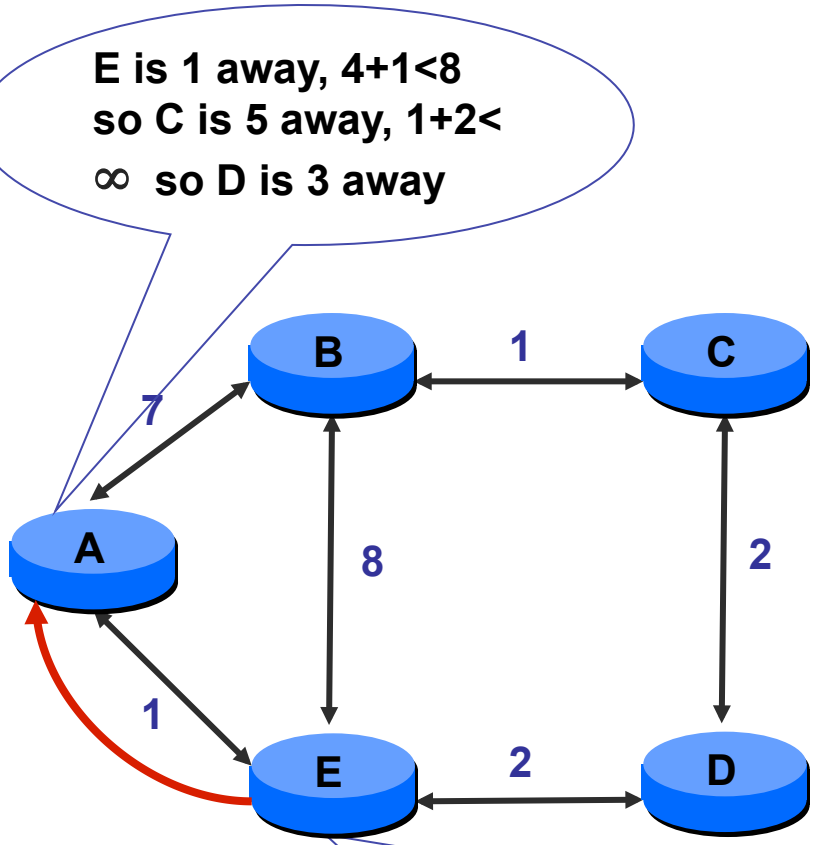

| Info at node | Distance to Node A | B | C | D | E |
|---|---|---|---|---|---|
| **A** | 0 | 7 | ∞ | ∞ | 1 |
| **B** | 7 | 0 | 1 | ∞ | 8 |
| **C** | ∞ | 1 | 0 | 2 | ∞ |
| **D** | ∞ | ∞ | 2 | 0 | 2 |
| **E** | 1 | 8 | **4** | 2 | 0 |

# *B* sends vector to *A*



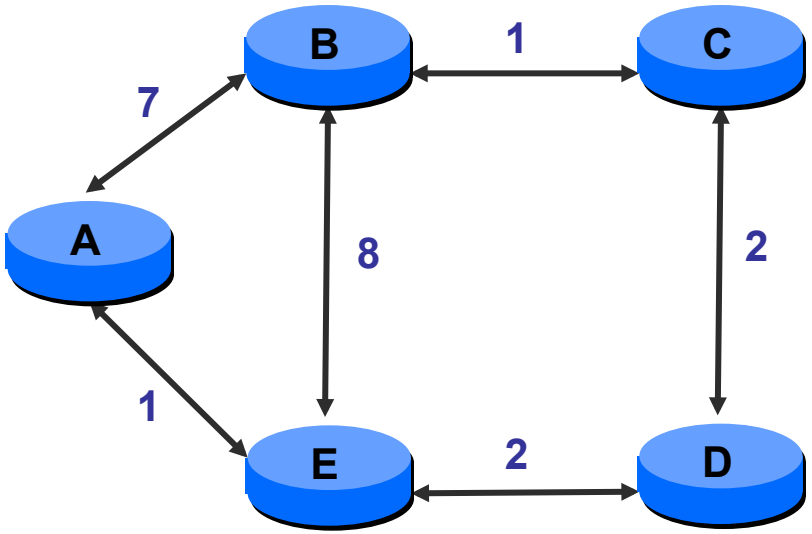

| Info at node | Distance to Node A | B | C | D | E |
|---|---|---|---|---|---|
| **A** | 0 | 7 | **8** | ∞ | 1 |
| **B** | 7 | 0 | 1 | ∞ | 8 |
| **C** | ∞ | 1 | 0 | 2 | ∞ |
| **D** | ∞ | ∞ | 2 | 0 | 2 |
| **E** | 1 | 8 | 4 | 2 | 0 |

# *E* sends vector to *A*



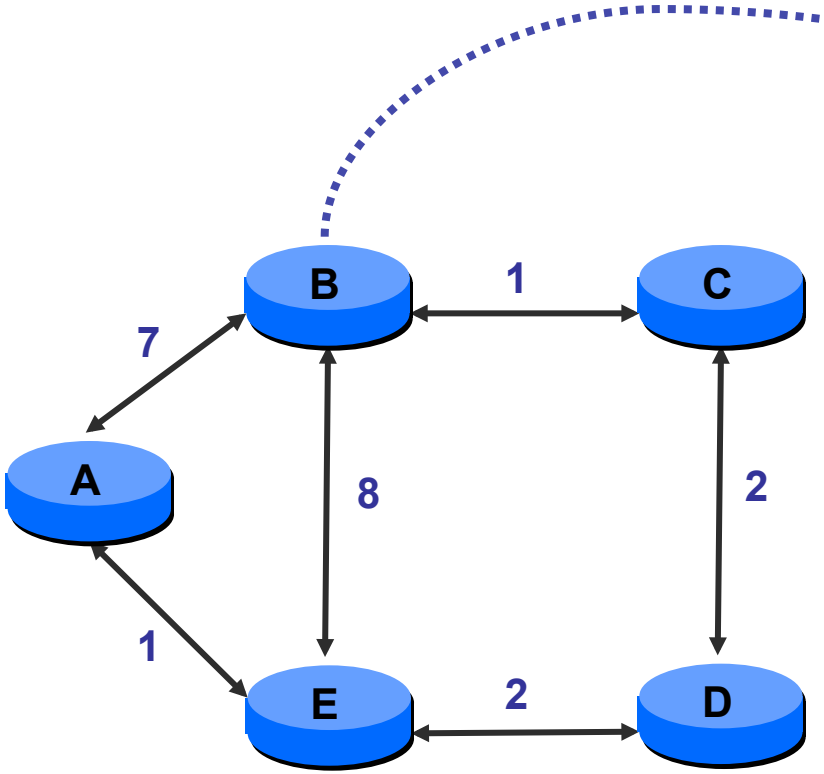

| Info at node | Distance to Node A | B | C | D | E |
|---|---|---|---|---|---|
| **A** | 0 | 7 | **5** | **3** | 1 |
| **B** | 7 | 0 | 1 | ∞ | 8 |
| **C** | ∞ | 1 | 0 | 2 | ∞ |
| **D** | ∞ | ∞ | 2 | 0 | 2 |
| **E** | 1 | 8 | 4 | 2 | 0 |

# …until Convergence




| Info at node | Distance to Node | | | | |
|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** |
| **A** | 0 | 6 | 5 | 3 | 1 |
| **B** | 6 | 0 | 1 | 3 | 5 |
| **C** | 5 | 1 | 0 | 2 | 4 |
| **D** | 3 | 3 | 2 | 0 | 2 |
| **E** | 1 | 5 | 4 | 2 | 0 |

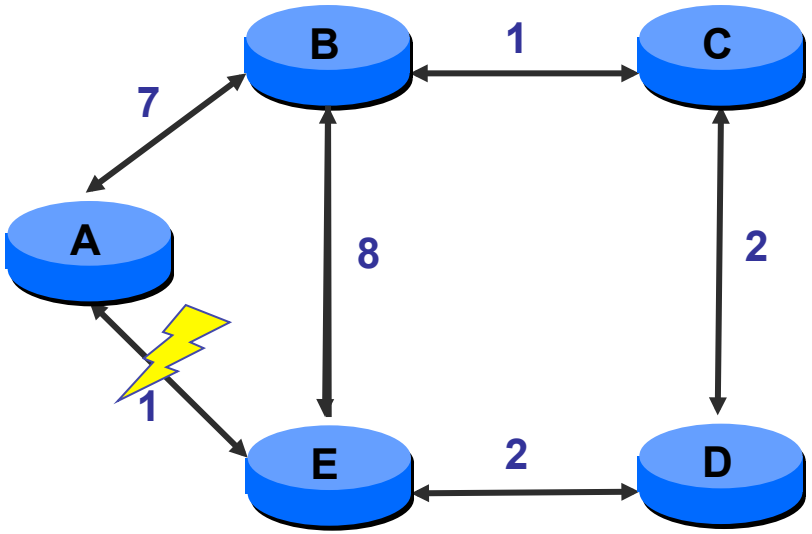
# Node *B*'s distance vectors




| Dest | Next hop A | E | C |
|---|---|---|---|
| **A** | 7 | 9 | **6** |
| **C** | 12 | 12 | **1** |
| **D** | 10 | 10 | **3** |
| **E** | 8 | 8 | **5** |

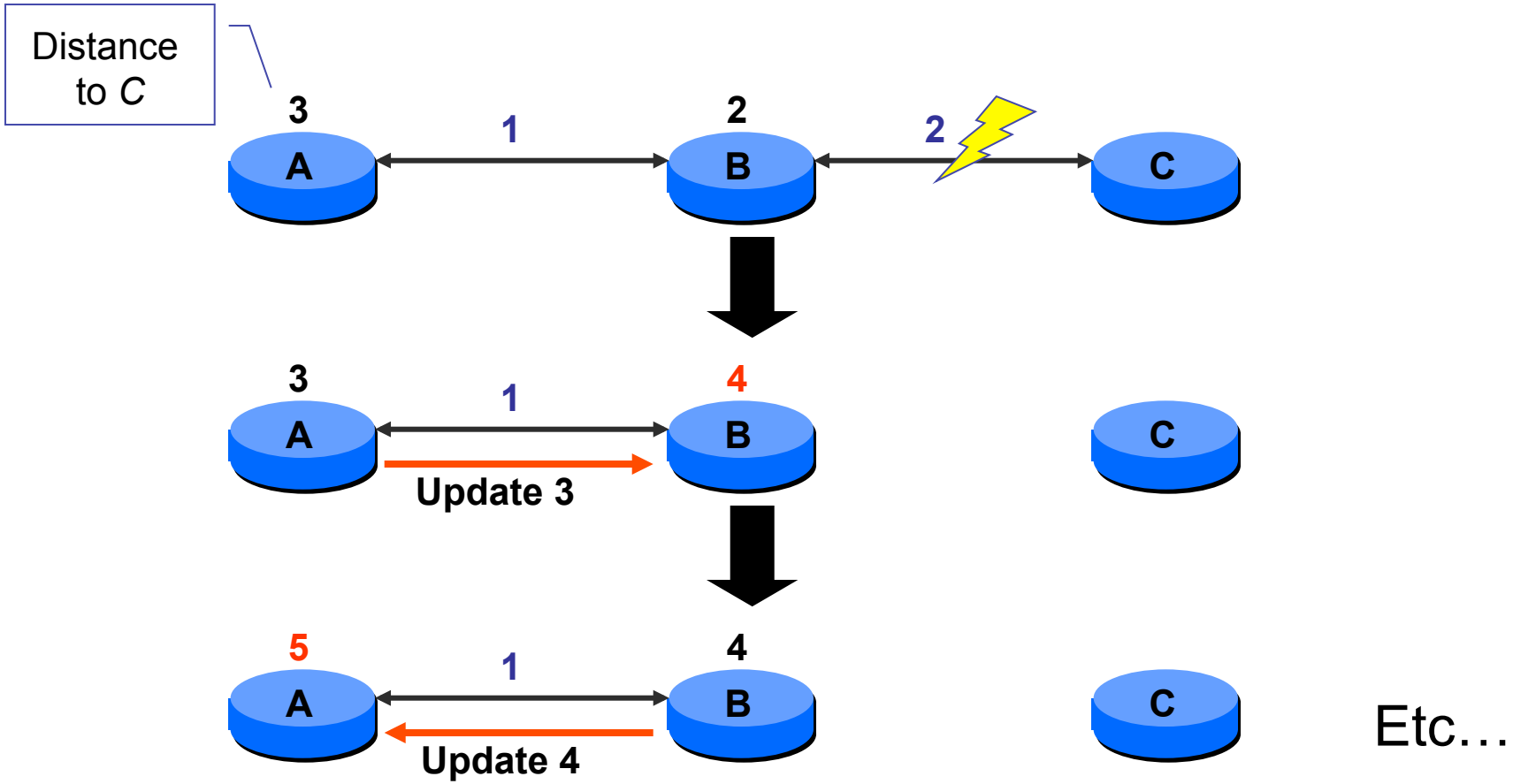
# Handling Link Failure

- A marks distance to E as ∞ , and tells B
- E marks distance to A as ∞ , and tells B and D
- B and D recompute routes and tell C, E and E
- etc… until converge




| Info at node | Distance to Node A | B | C | D | E |
|---|---|---|---|---|---|
| **A** | 0 | 7 | 8 | 10 | 12 |
| **B** | 7 | 0 | 1 | 3 | 5 |
| **C** | 8 | 1 | 0 | 2 | 4 |
| **D** | 10 | 3 | 2 | 0 | 2 |
| **E** | 12 | 5 | 4 | 2 | 0 |

# Counting to Infinity



# Why so High?

- Updates don't contain enough information
- Can't totally order bad news above good news
- *B* accepts *A*'s path to *C* that is *implicitly* through *B*!
- Aside: this also causes delays in convergence even when it doesn't count to infinity

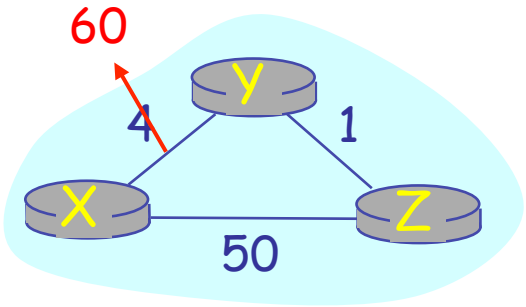
# Mitigation Strategies

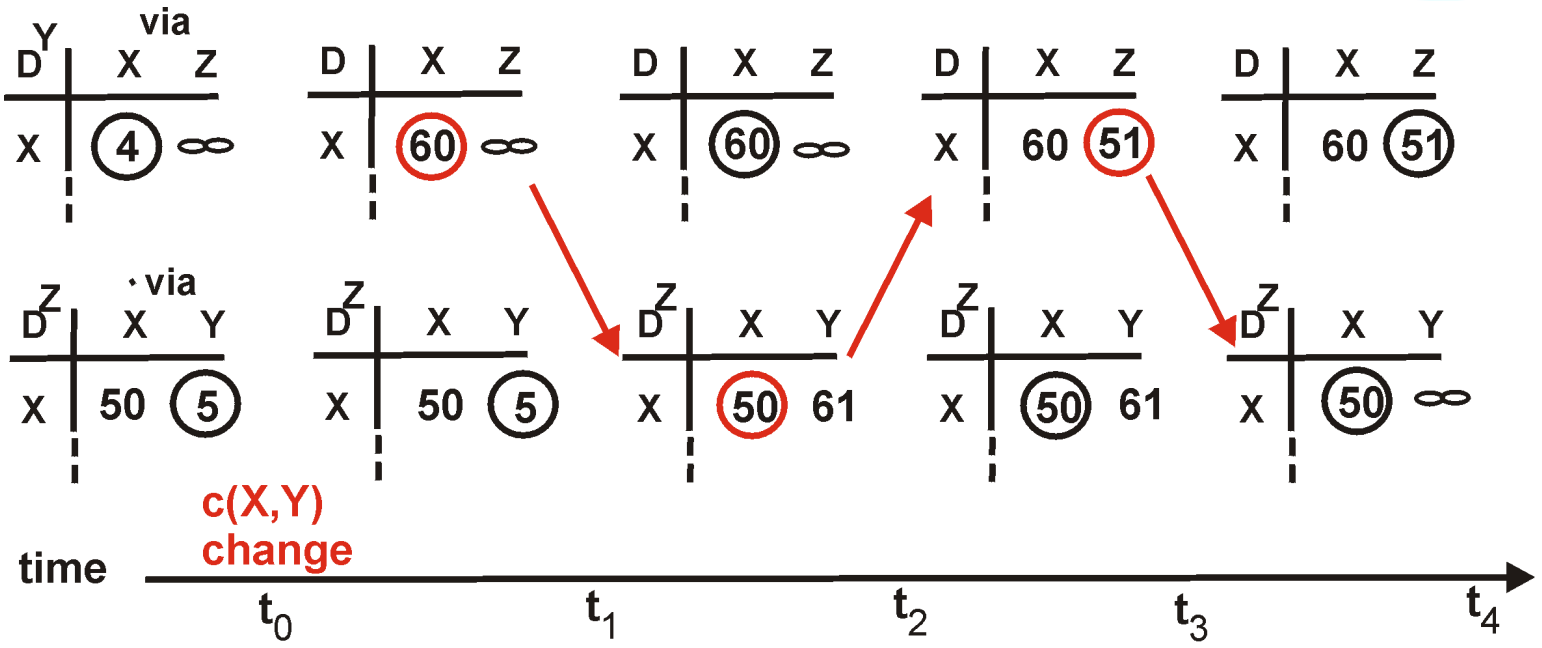
- Hold downs
  - As metric increases, delay propagating information
  - Limitation: Delays convergence
- Loop avoidance
  - Full path information in route advertisement
  - Explicit queries for loops (e.g. DUAL)
- Split horizon
  - Never advertise a destination through its next hop
    - » *A* doesn't advertise *C* to *B*
  - Poison reverse: Send negative information when advertising a destination through its next hop
    - » *A* advertises *C* to *B* with a metric of ∞
    - » Limitation: Only works for "loop"s of size 2

# Poison Reverse Example

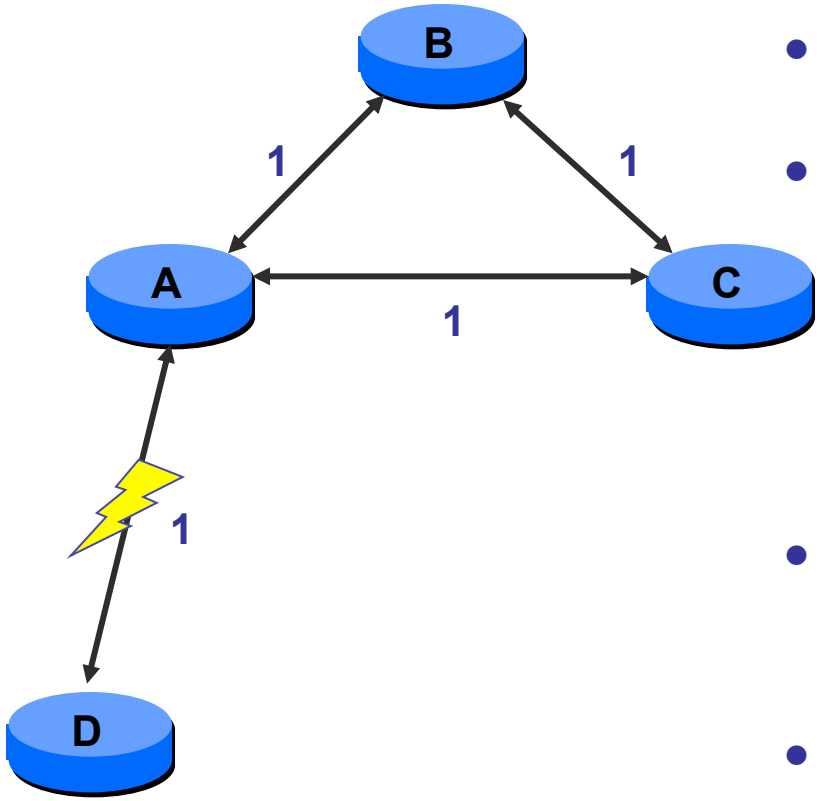
If *Z* routes through *Y* to get to *X*:

- *Z* tells *Y* its (*Z*'s) distance to *X* is infinite (so *Y* won't route to *X* via *Z*)



# Split Horizon Limitations




- A tells B & C that D is unreachable
- *B* computes new route through C
  - Tells *C* that *D* is unreachable (poison reverse)
  - Tells *A* it has path of cost 3 (split horizon doesn't apply)
- *A* computes new route through *B*
  - *A* tells *C* that *D* is now reachable
- Etc…

# Routing Information Protocol

- DV protocol with hop count as metric
  - Infinity value is 16 hops; limits network size
  - Includes split horizon with poison reverse
- Routers send vectors every 30 seconds
  - With triggered updates for link failures
  - Time-out in 180 seconds to detect failures
- RIPv1 specified in RFC1058
  - www.ietf.org/rfc/rfc1058.txt
- RIPv2 (adds authentication etc.) in RFC1388
  - www.ietf.org/rfc/rfc1388.txt

# Link-state *vs.* Distance-vector

Message complexity

- LS: with *n* nodes, *E* links, O(nE) messages sent
- DV: exchange between neighbors only

Speed of Convergence

- LS: relatively fast
- DV: convergence time varies
  - May be routing loops
  - Count-to-infinity problem

Robustness: what happens if router malfunctions?

LS:

- Node can advertise incorrect *link* cost
- Each node computes only its *own* table

DV:

- Node can advertise incorrect *path* cost
- Each node's table used by others (error propagates)

# Routing so far…

- Shortest-path routing
  - Metric-based, using link weights
  - Routers share a common view of path "goodness"
- As such, commonly used *inside* an organization
  - RIP and OSPF are mostly used as *intra*domain protocols
- But the Internet is a "network of networks"
  - How to stitch the many networks together?
  - When networks may not have common goals
  - … and may not want to share information

# For next time…

- Read Ch. 4.3.3-4 in P&D
- Keep moving on Project 2