Routing Algorithms

CS 571

Fall 2006

Distributed Routing Algorithms

- Assumptions
  - Network is modeled as a connected, undirected graph
  - Nodes represent <u>both</u> destinations and relays

    (No distinction between routers and hosts)
  - Each node has a unique ID (natural number)
  - Edges are communication channels (bidirectional)
    - Edges may also have an associated "length" or "cost"
      - d[i,j] = length of edge between i and j (∞ if no edge exists)
    - Each node knows the lengths of its incident edges
    - Each node knows the identity of nodes it is connected to
  - Nodes may not communicate except via channels

Problem Statement

- At convergence, for every node i and j:
  - $D_i[j]$ is the length of the shortest path from i to j
  - $h_i[j]$ is the next hop on the shortest path from i to j
- Algorithm converges if channels are not broken

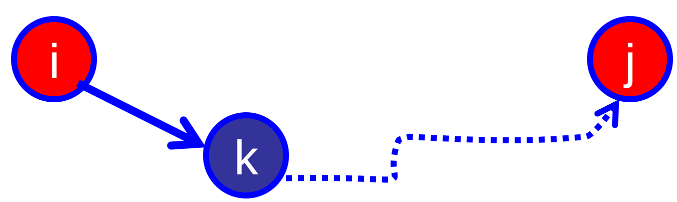
Bellman-Ford Algorithm

- Based on R. Bellman's well-known principle of optimality, which in this context, says:

  If the first step on the shortest path from i to j is k

  then the rest is the shortest path from k to j

  (Suppose not, i.e. there is some shorter path from k to j. Then a shorter path from i to i to j exists, namely that first step followed by that path!.)



Distributed Bellman-Ford Algorithm

- Initialize: For each i and j: $D_i[j] := d[i,j]$
- At each i, iterate forever:

  $\forall j$: $D_i[j] = \min_k d[i,k] + D_k[j]$

  or:

  for each j:

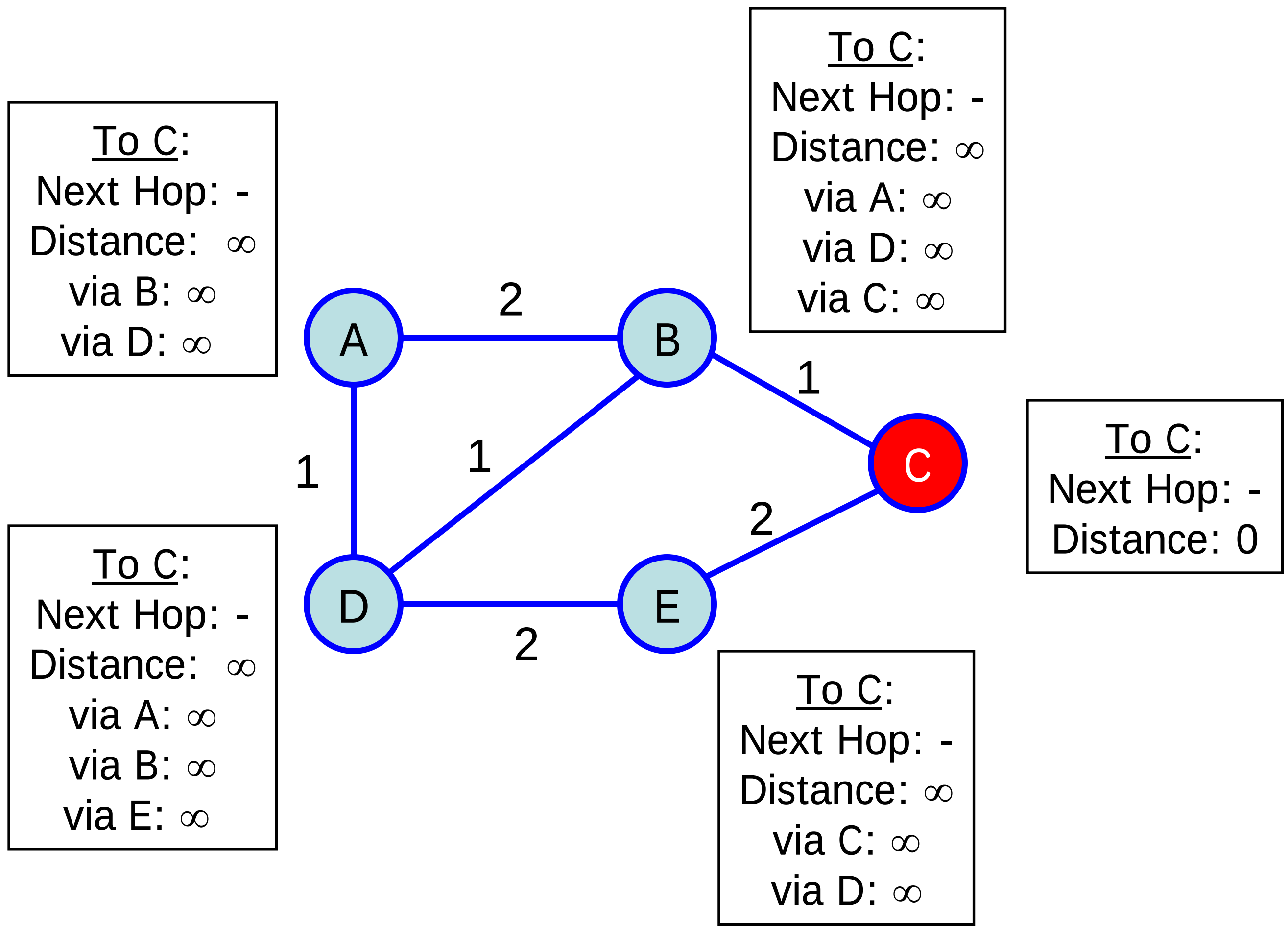
  for each neighbor k:

  if $(d[i,k] + D_k[j] < D_i[j])$

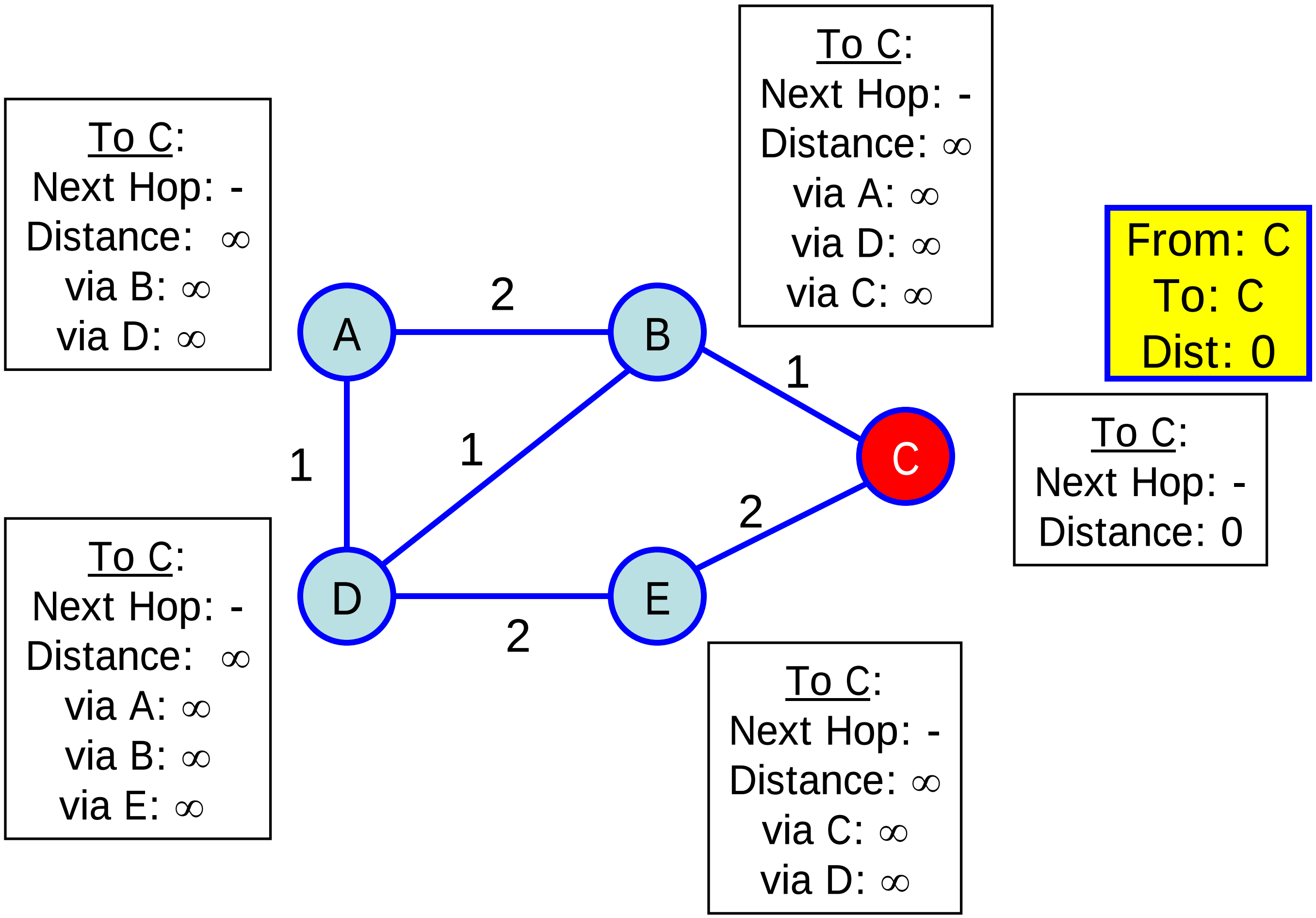
  { $h_i[j] := k$; $D_i[j] := d[i,k] + D_k[j]$ }

- Nodes exchange their Di[j] tables periodically
  - Vector of distances $\Rightarrow$ "Distance Vector" Algorithm

Simplified Bellman-Ford Example



Simplified Bellman-Ford Example



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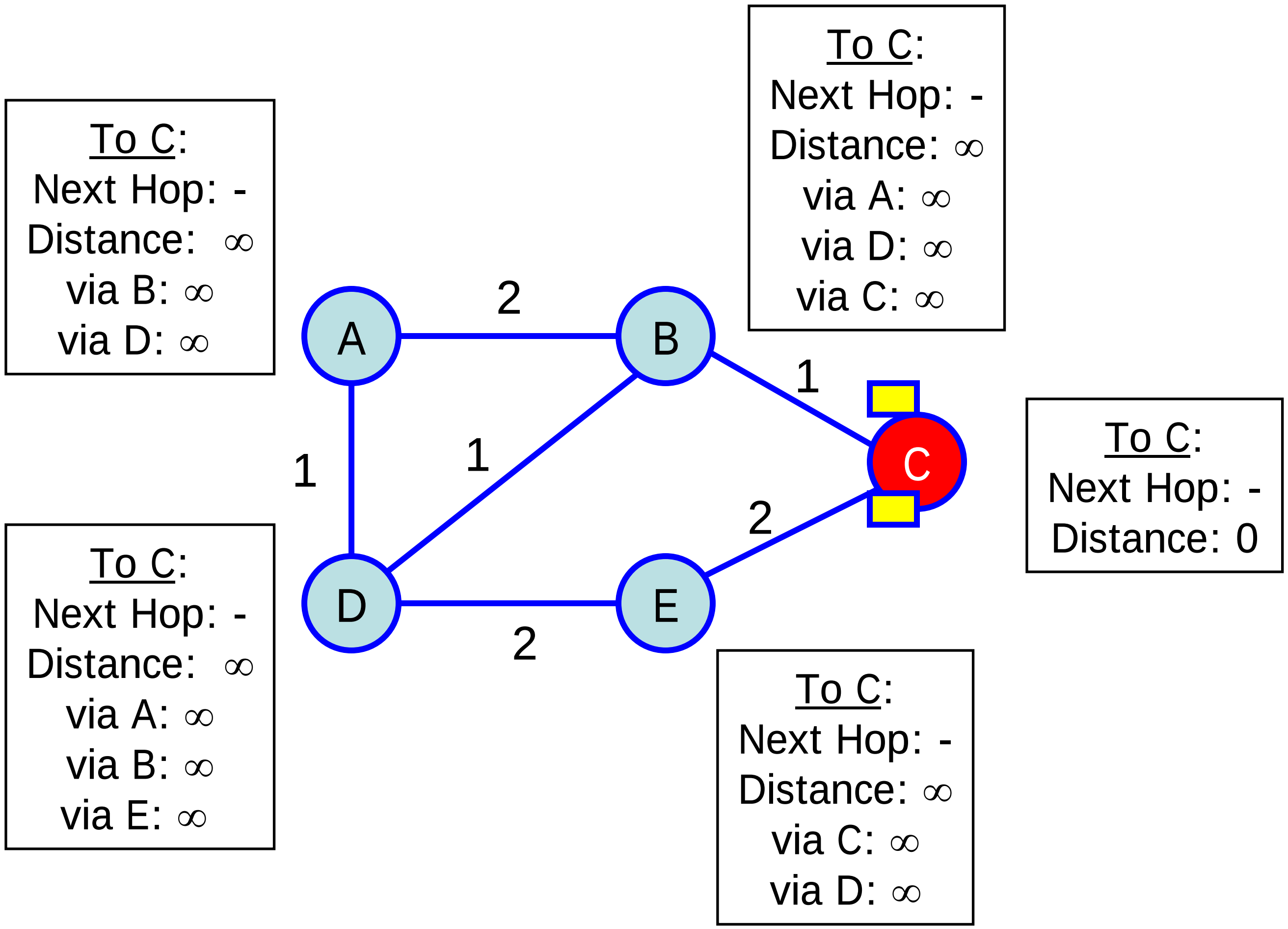

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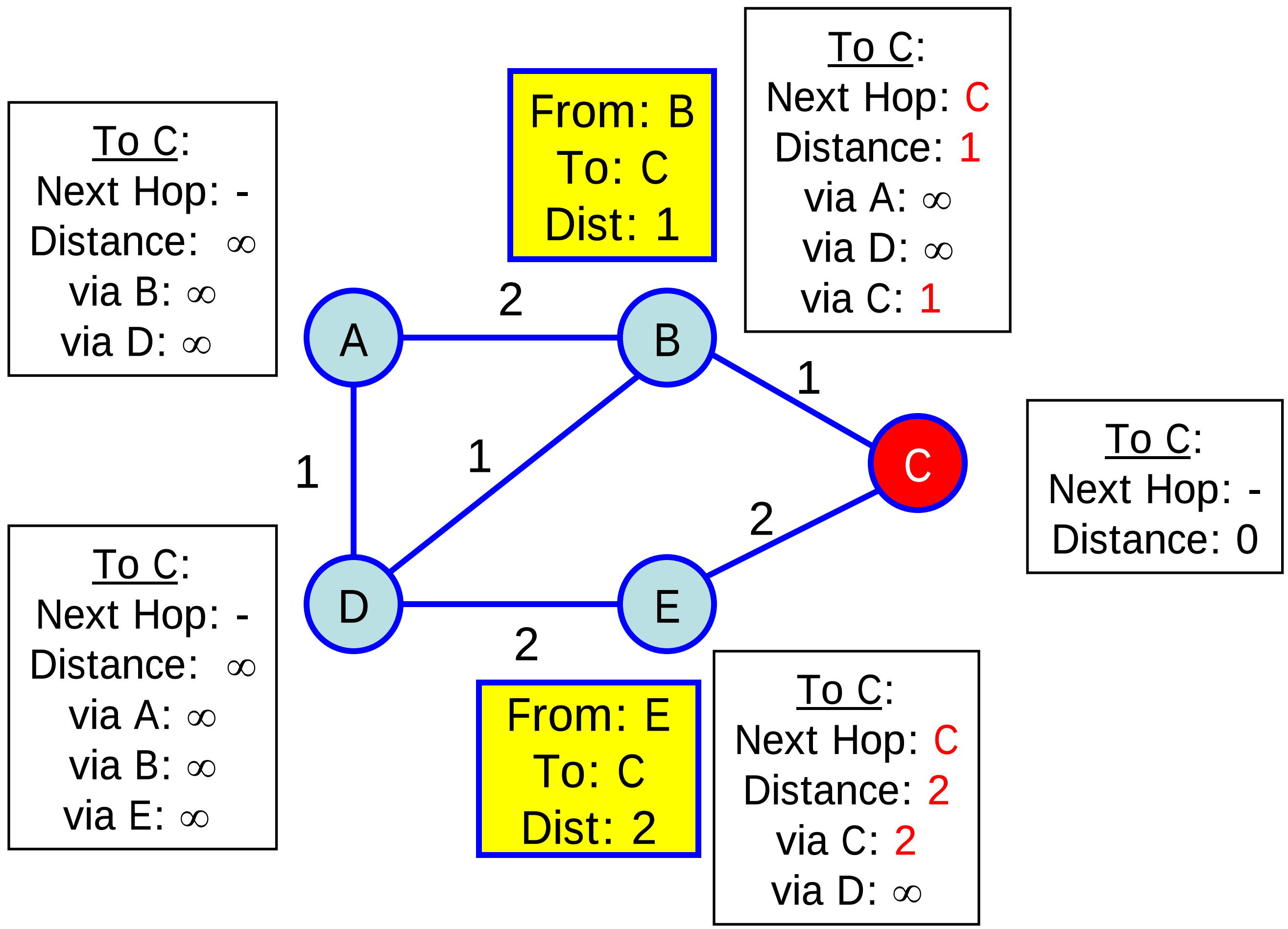

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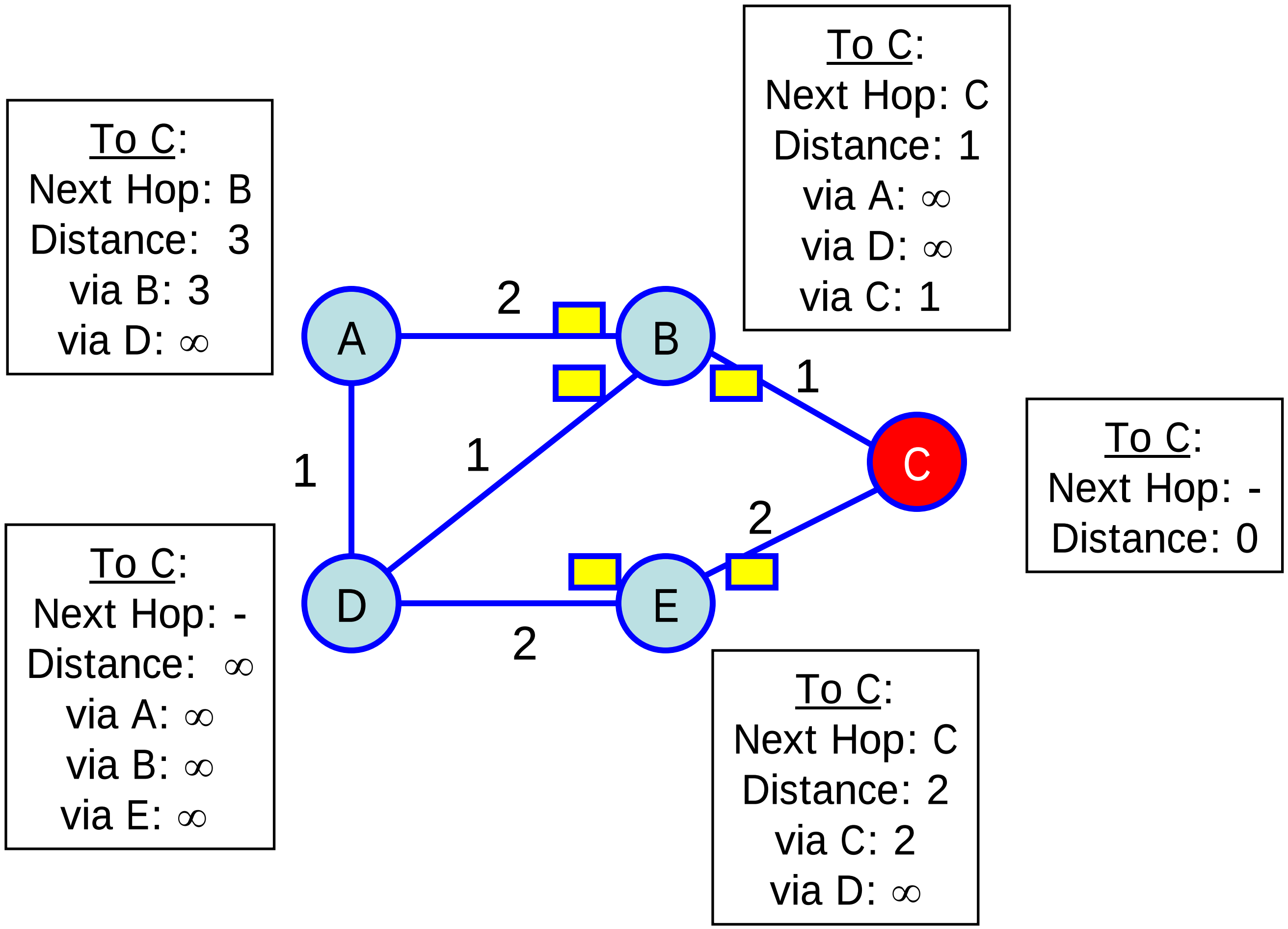

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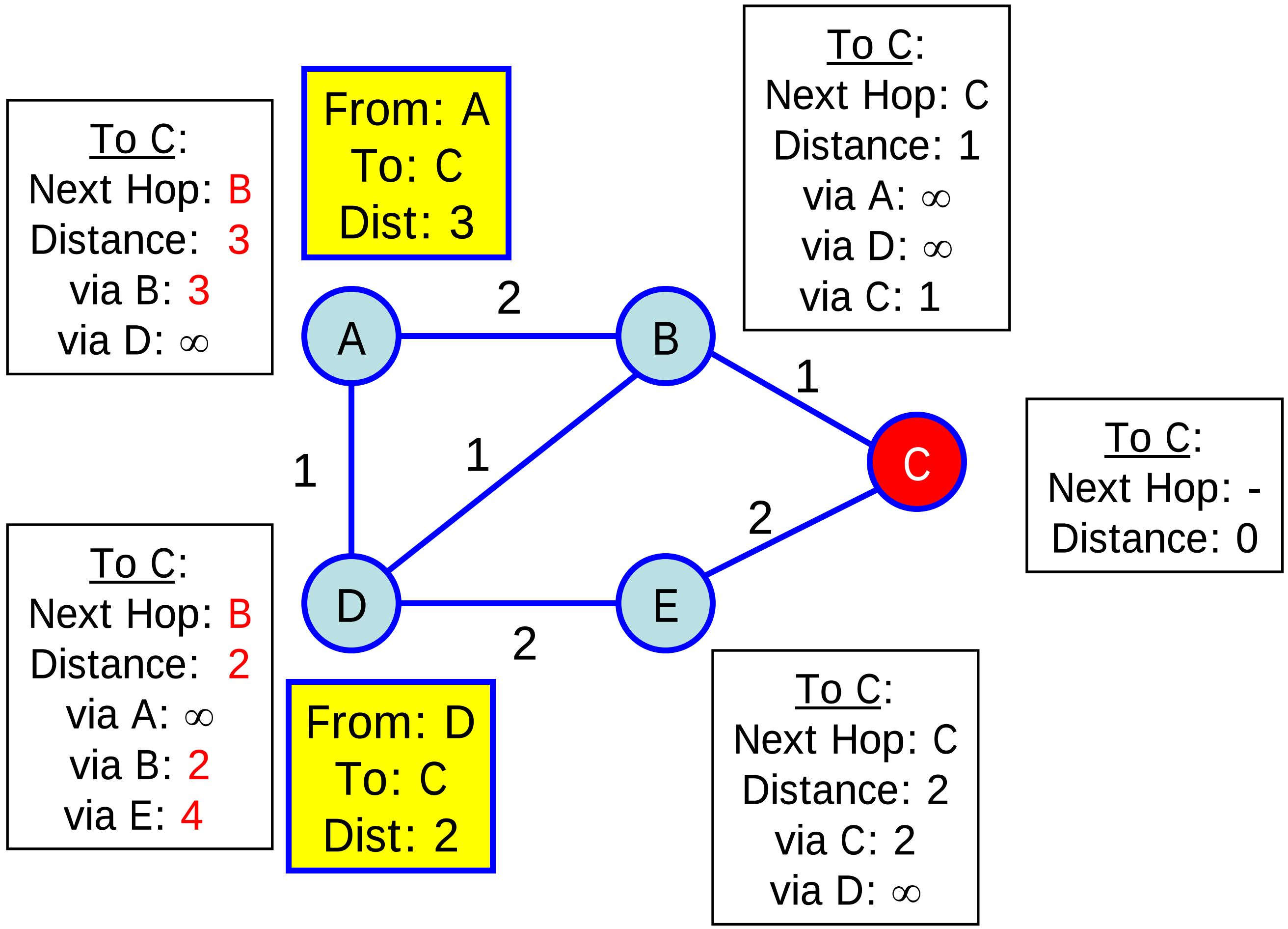

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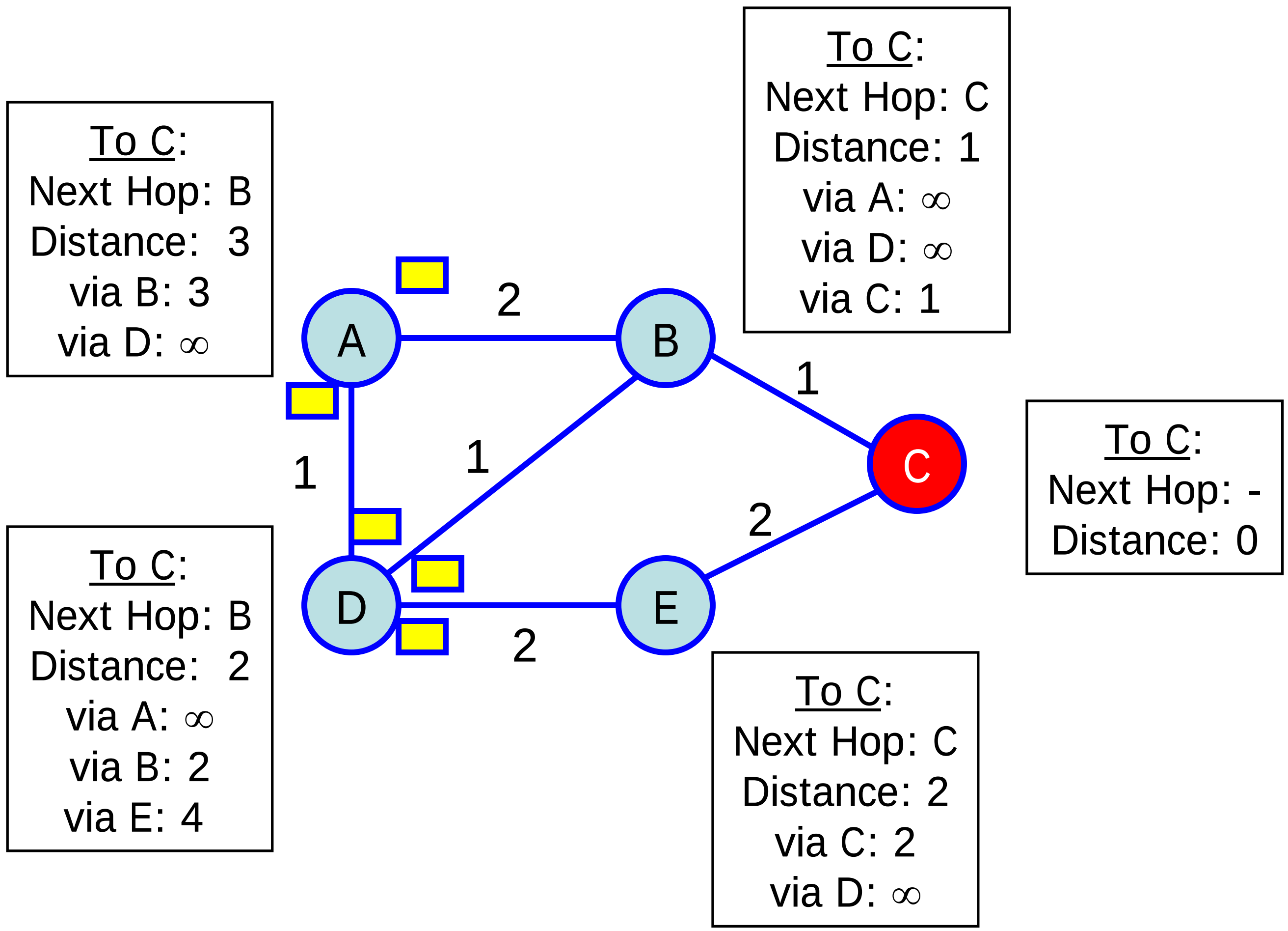

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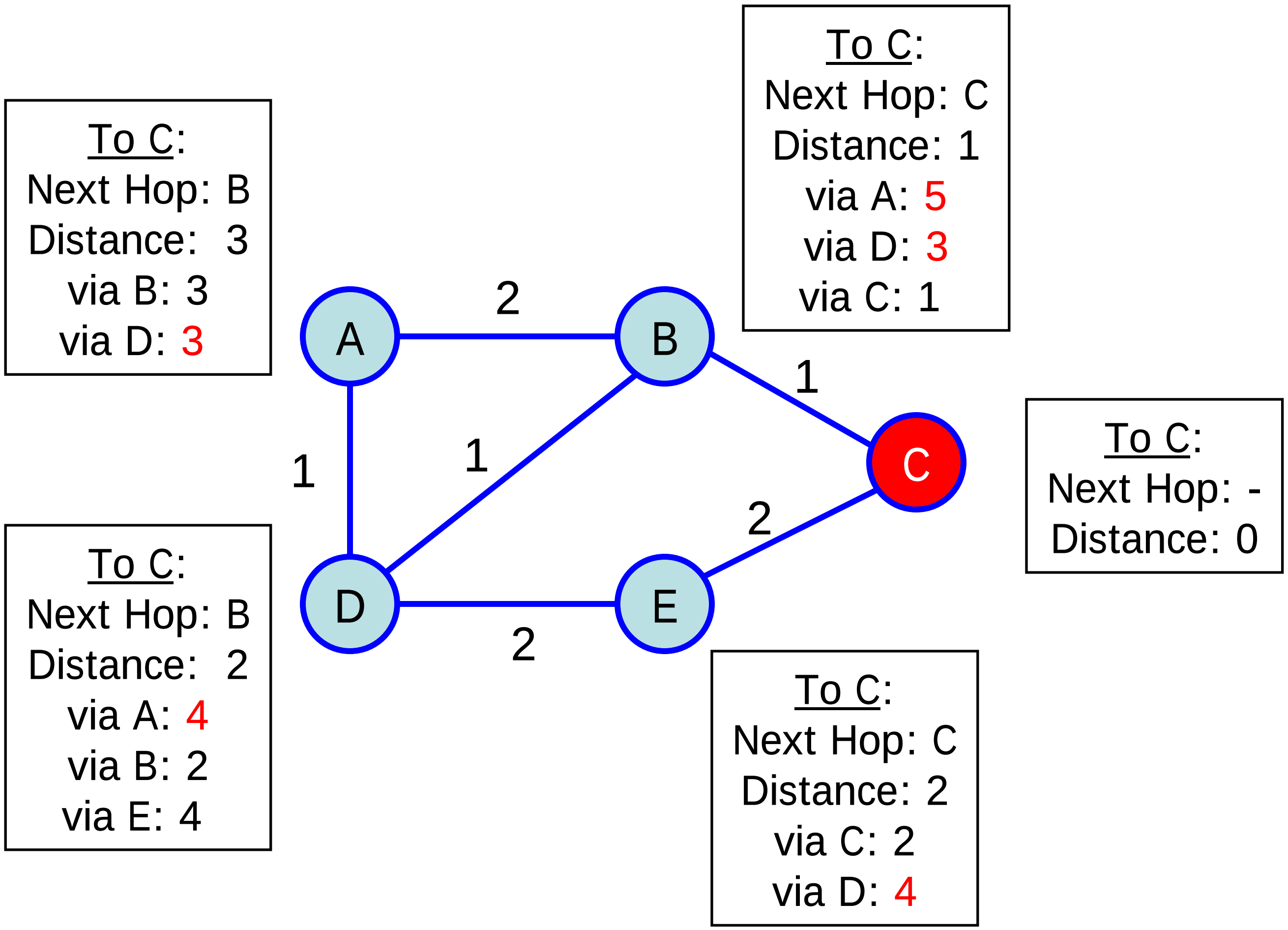
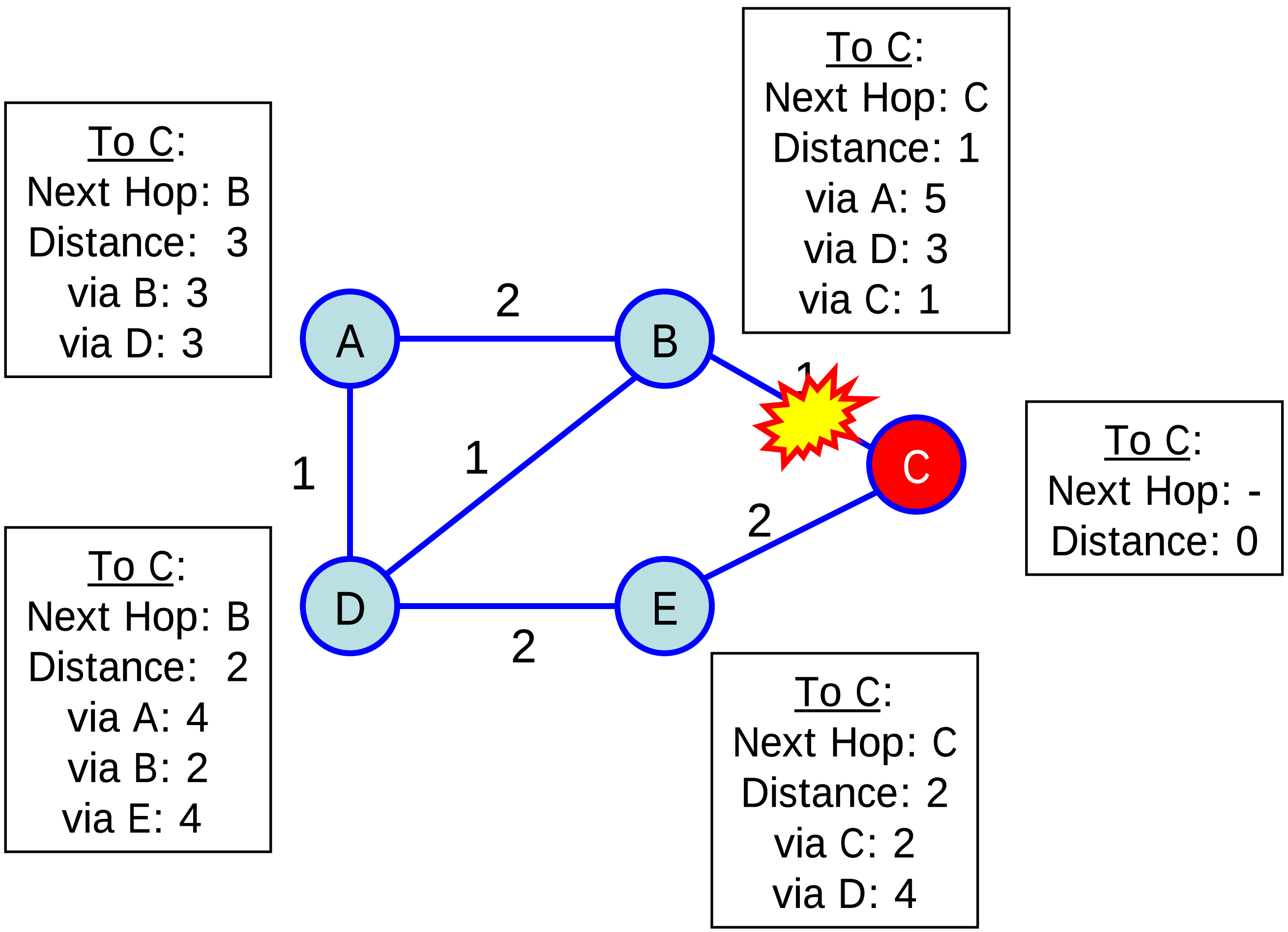


"Bad News Travels Slowly"



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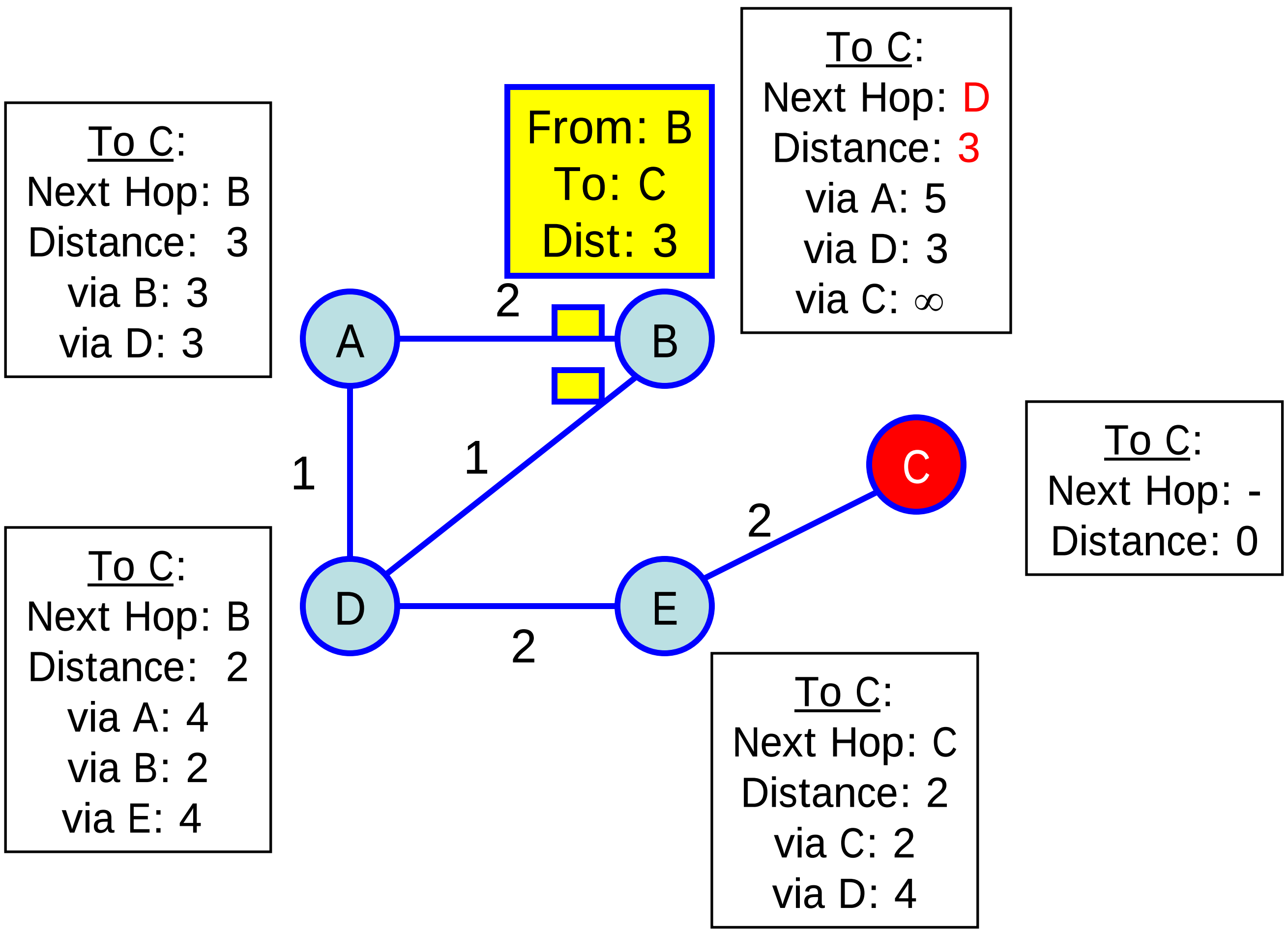

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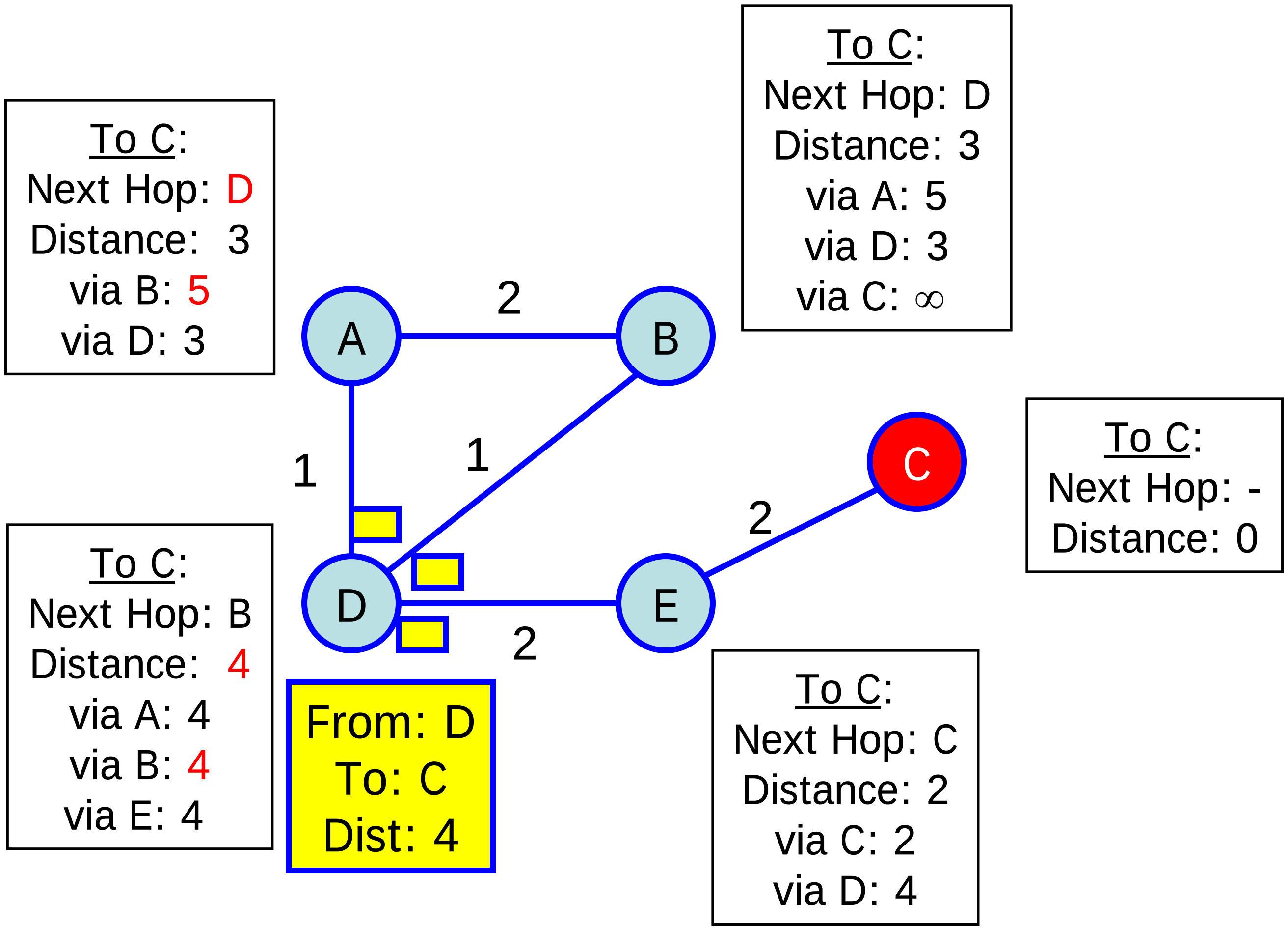

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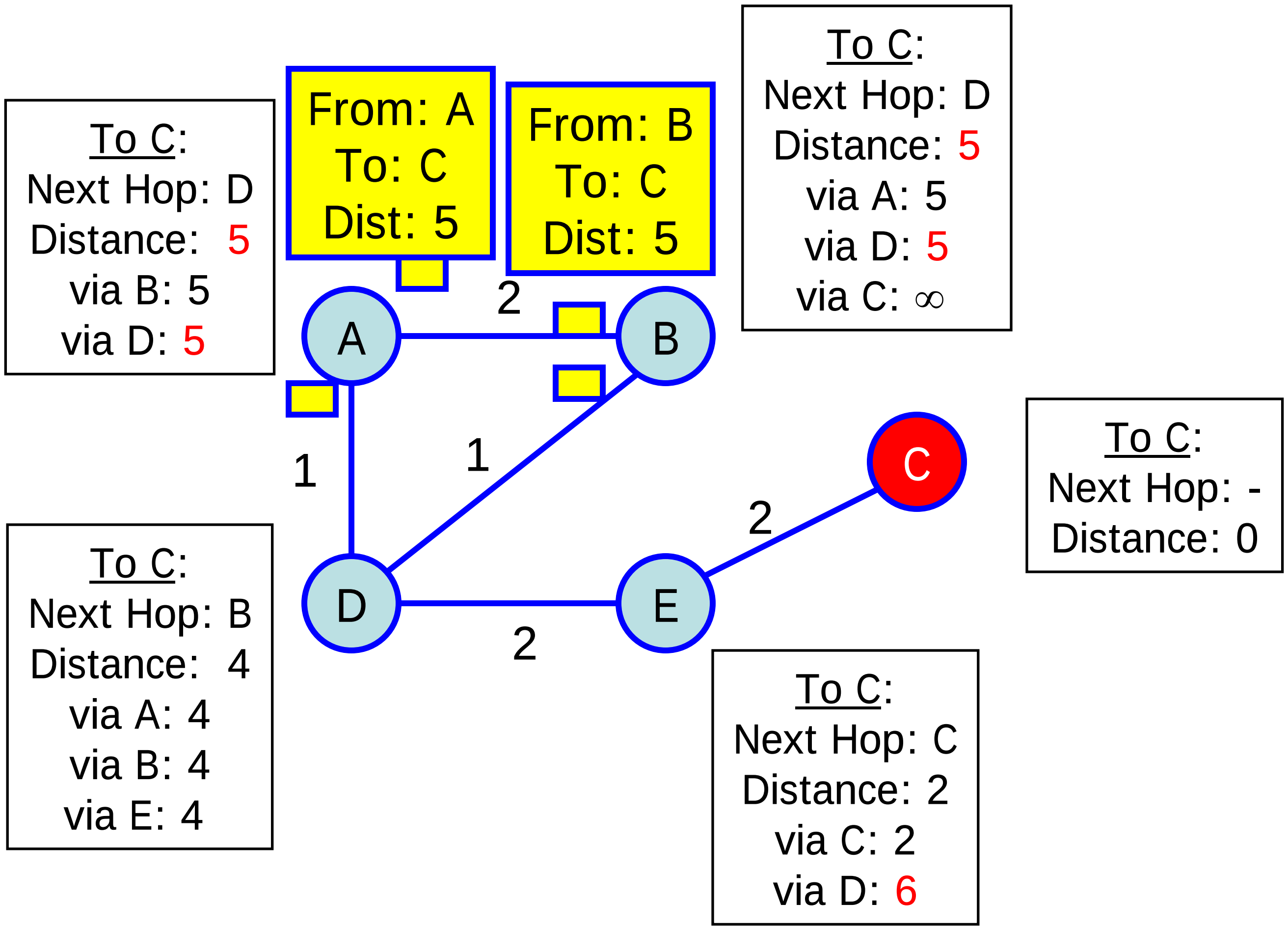

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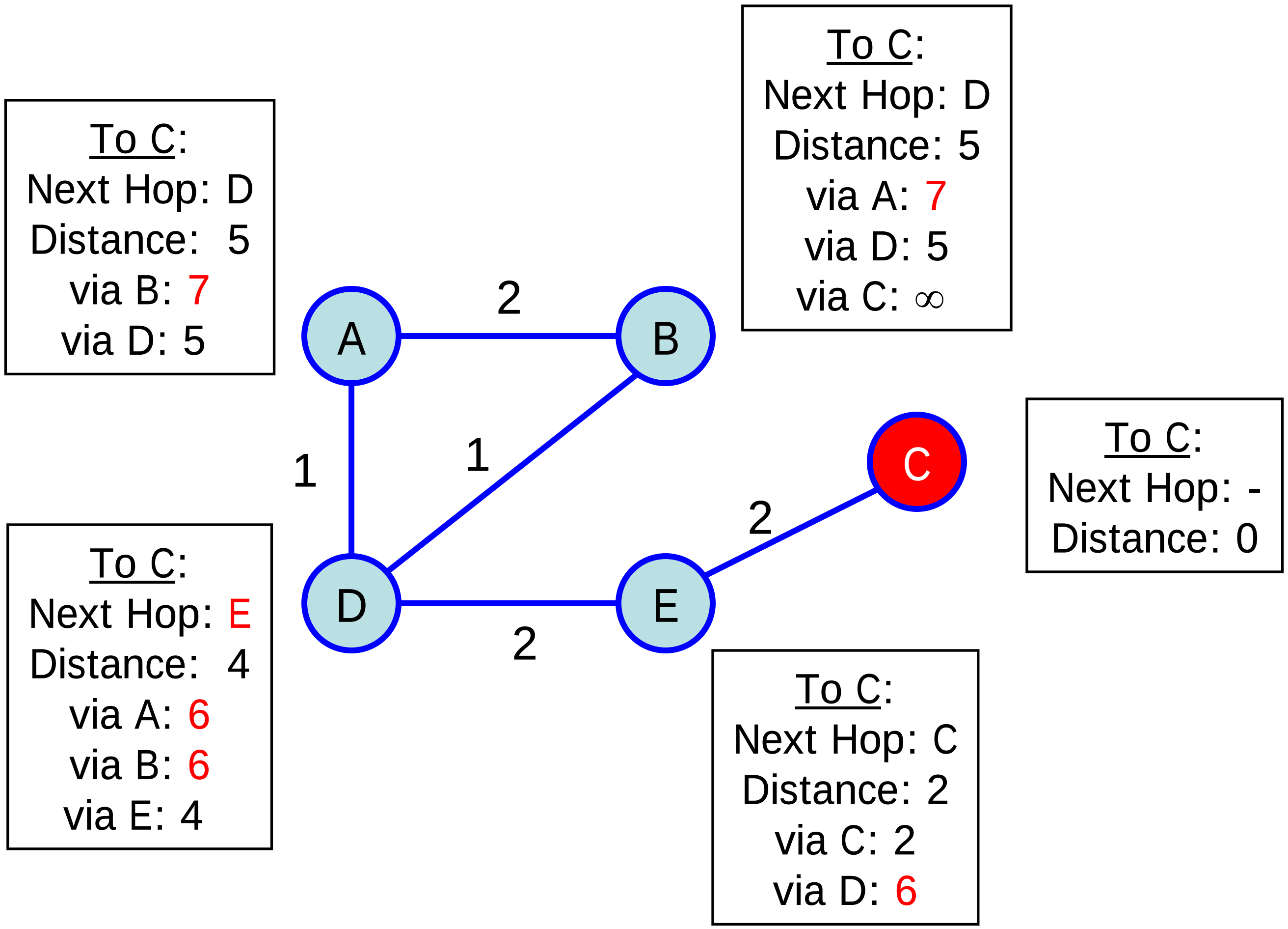


Distance-Vector Algorithms

- Advantage: Simple
- Disadvantage: Convergence time after topology/cost change depends on graph & costs!
  - May take a long time to detect changes & stabilize
  - Especially when the network becomes disconnected
    - "Counting to Infinity" problem: Cost just keeps increasing
      Meanwhile, packets loop!
      - Partial solutions: "split horizon", "poison reverse" (see text)
- Disadvantage: Routing messages can be expensive
  - Dump entire forwarding table in each message!

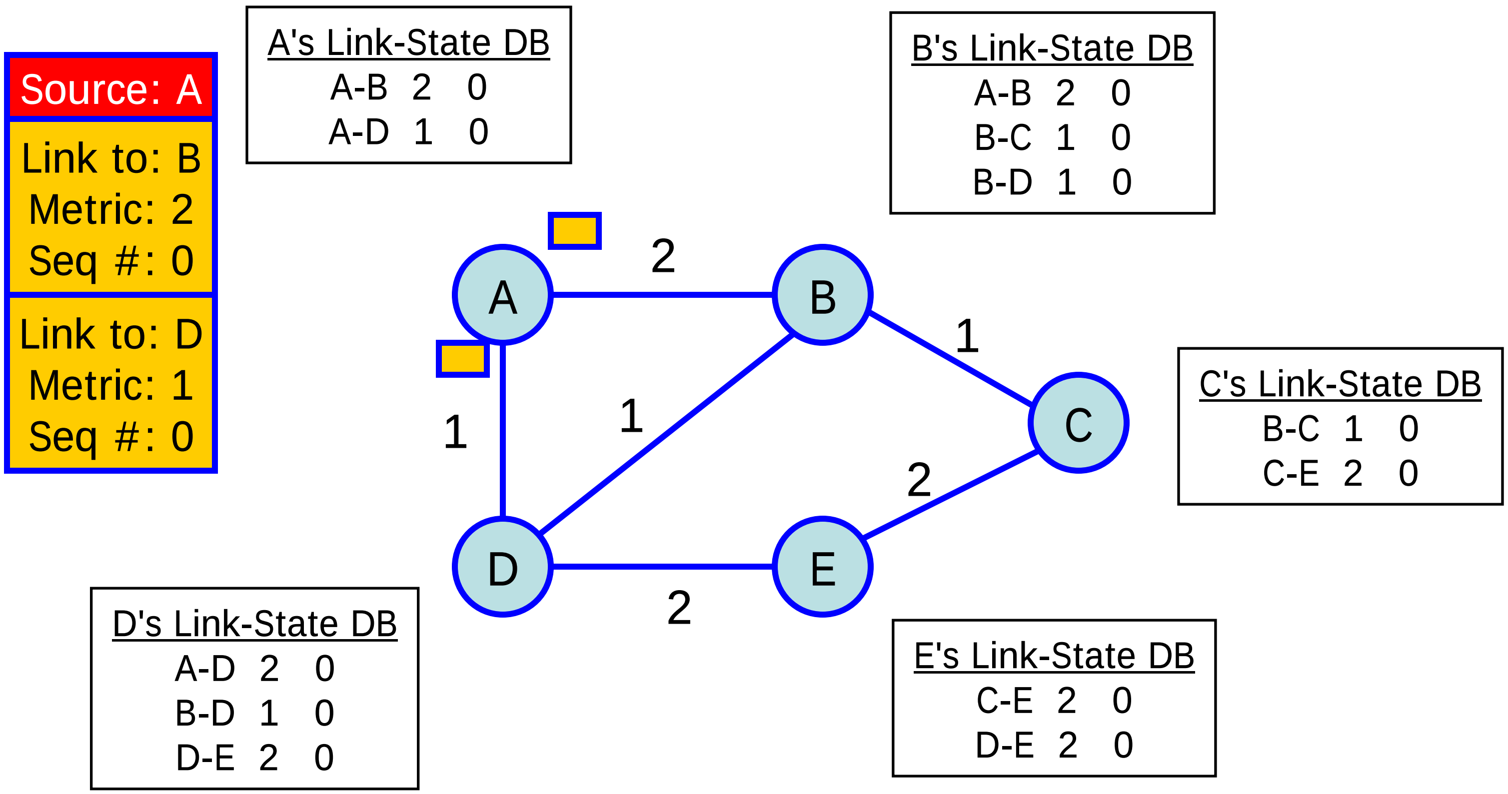
Link-State Algorithms

- Basic Idea:
  - Nodes exchange topology information
    - Each announces the state of its attached links
    - Link-state announcements
  - Link-state announcements are broadcast throughout the network
    - Flooding mechanism implements a broadcast function
  - Each node builds a graph model of the network
    - Collects every other node's link-state announcements
  - Each node runs Dijkstra's all-nodes shortest-path algorithm on its graph
    - Requirement: all nodes have the same graph model!

Flooding Mechansim

- Every node forwards every new flooded message to all of its neighbors
  - "New" = not already in the node's database
- Challenge: distinguishing new from old
  - Solution: sequence numbers on LSAs
    - But: What about wrapping sequence numbers?
- Challenge: lost messages
  - Solution: acknowledge received flooded LSAs
  - Each node retransmits until ack received on each link

Simplified Link-State Example



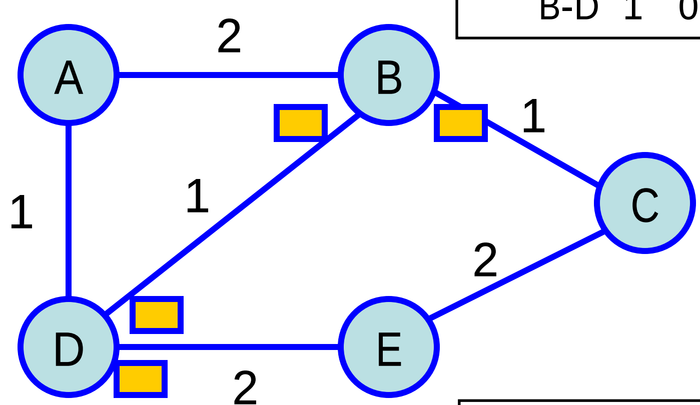
Simplified Link-State Example

A's Link-State DB

A-B	2	0
A-D	1	0

B's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0



C's Link-State DB

B-C	1	0
C-E	2	0

D's Link-State DB

A-B	2	0
A-D	1	0
B-D	1	0
D-E	2	0

E's Link-State DB

C-E	2	0
D-E	2	0

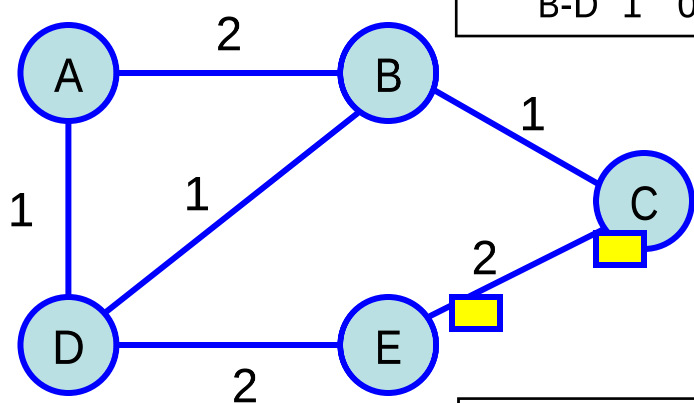
Simplified Link-State Example

A's Link-State DB

A-B	2	0
A-D	1	0

B's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0



C's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
C-E	2	0

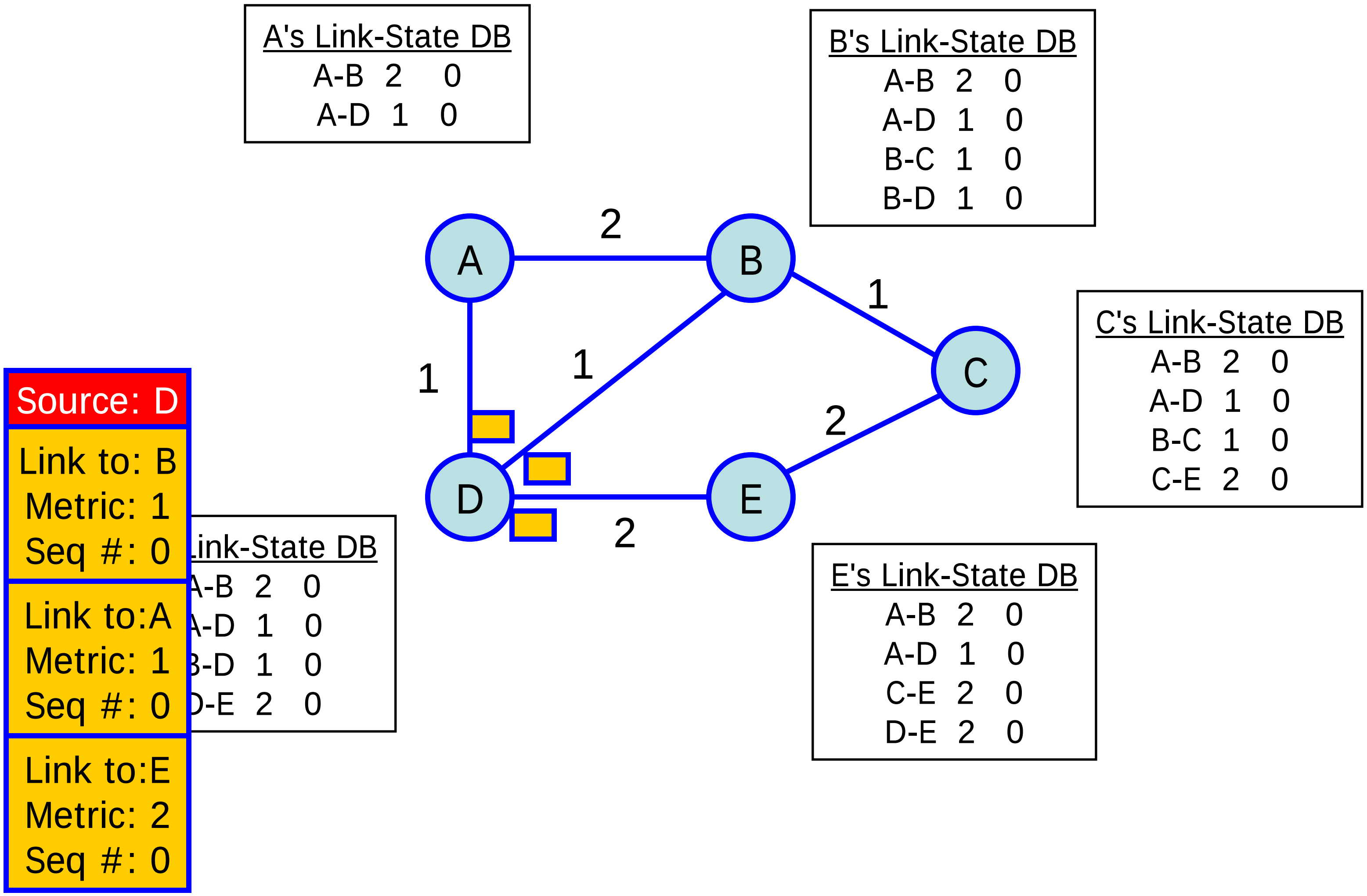
D's Link-State DB

A-B	2	0
A-D	1	0
B-D	1	0
D-E	2	0

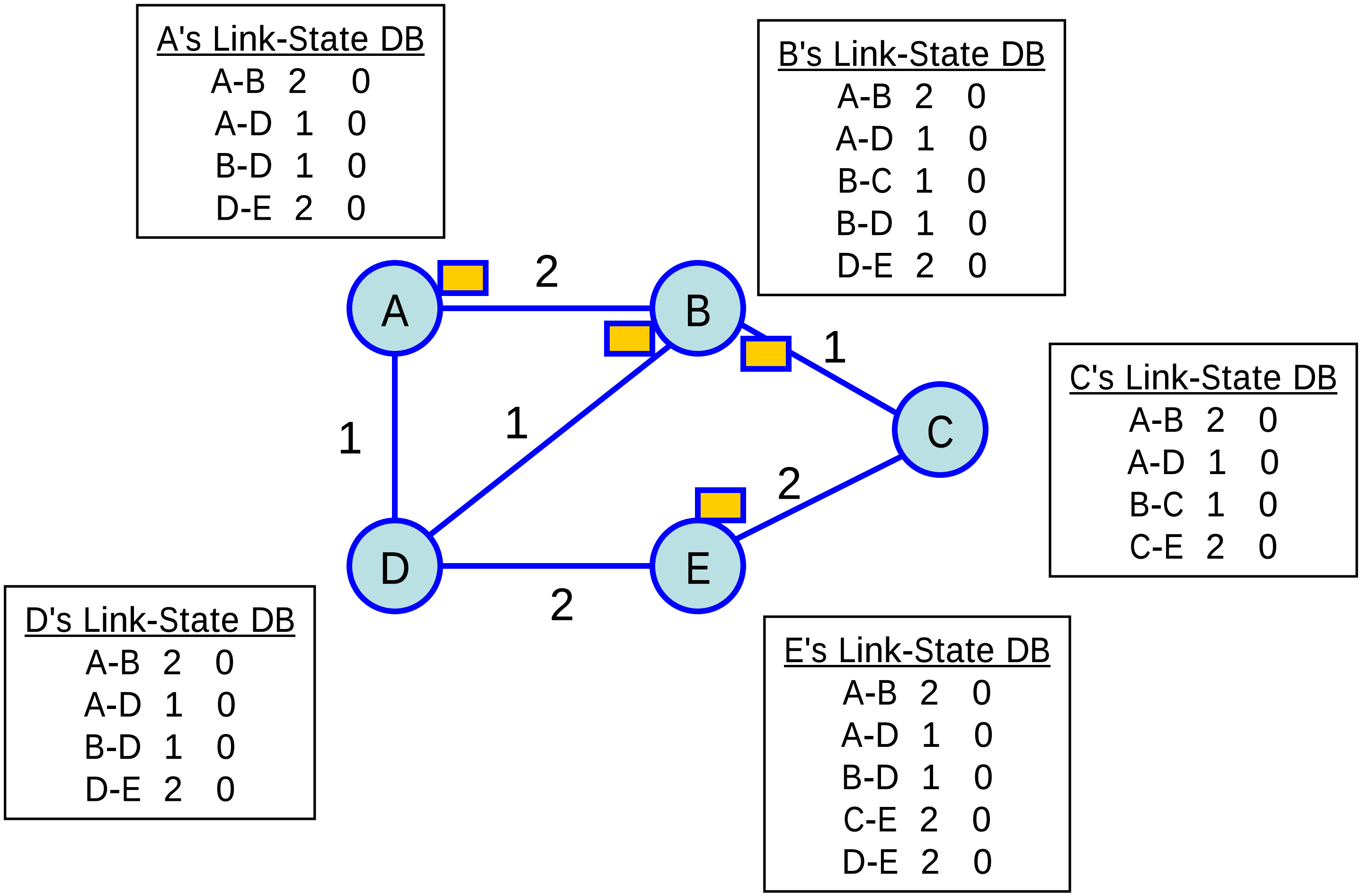
E's Link-State DB

A-B	2	0
A-D	1	0
C-E	2	0
D-E	2	0

Simplified Link-State Example



Simplified Link-State Example



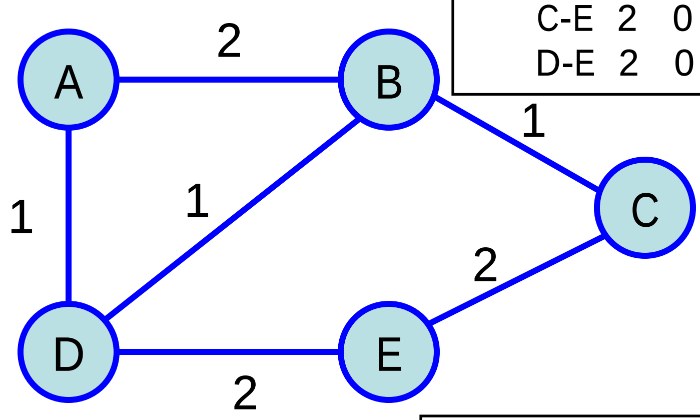
Simplified Link-State Example
...after B, C, & E flood their LSAs

A's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0
C-E	2	0
D-E	2	0

B's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0
C-E	2	0
D-E	2	0



C's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0
C-E	2	0
D-E	2	0

D's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0
C-E	2	0
D-E	2	0

E's Link-State DB

A-B	2	0
A-D	1	0
B-C	1	0
B-D	1	0
C-E	2	0
D-E	2	0

Link-State Algorithms

- Advantages:
  - Nodes send information about only their attached links
  - Fast convergence after change
- Disadvantages:
  - Each node "knows" the whole topology!
  - Dijkstra running time grows with topology
  - Flooding consumes bandwidth