6.033 Spring 2018

Lecture #9

- **Link-state Routing**
- **Distance-vector Routing**

Internet of Problems

How do we **route** (and address) scalably, while dealing with issues of policy and economy?

How do we **transport** data scalably, while dealing with varying application demands?

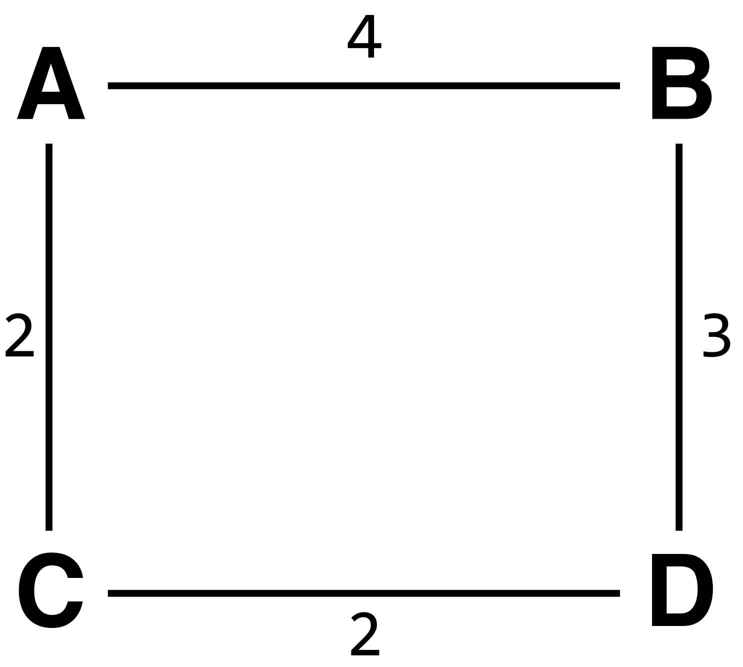
How do we **adapt** new applications and technologies to an inflexible architecture?

goal of a routing protocol: allow each switch to know, for every node `dst` in the network, a **minimum-cost** route to `dst`

goal of a routing protocol: build a routing table at each switch, such that `routing_table[dst]` contains a **minimum-cost route** to `dst`

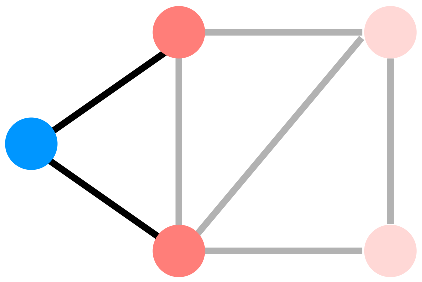
A's routing table

```
routing_table[A] = self ; 0
routing_table[B] = A->B ; 4
routing_table[C] = A->C ; 2
routing_table[D] = A->C ; 4
```

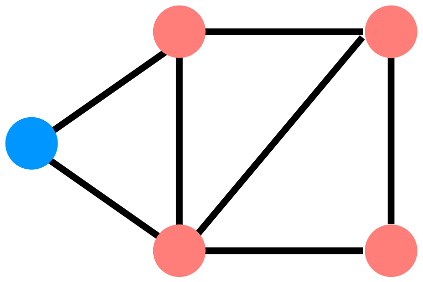


Distributed Routing

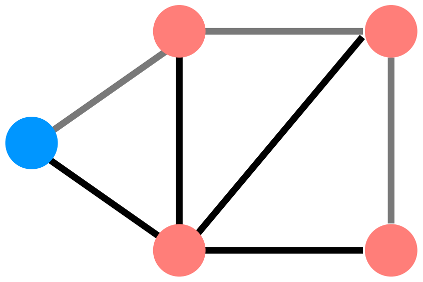
1. Nodes learn about their neighbors via the `HELLO` protocol



2. Nodes learn about other reachable nodes via advertisements



3. Nodes determine the minimum-cost routes (of the routes they know about)



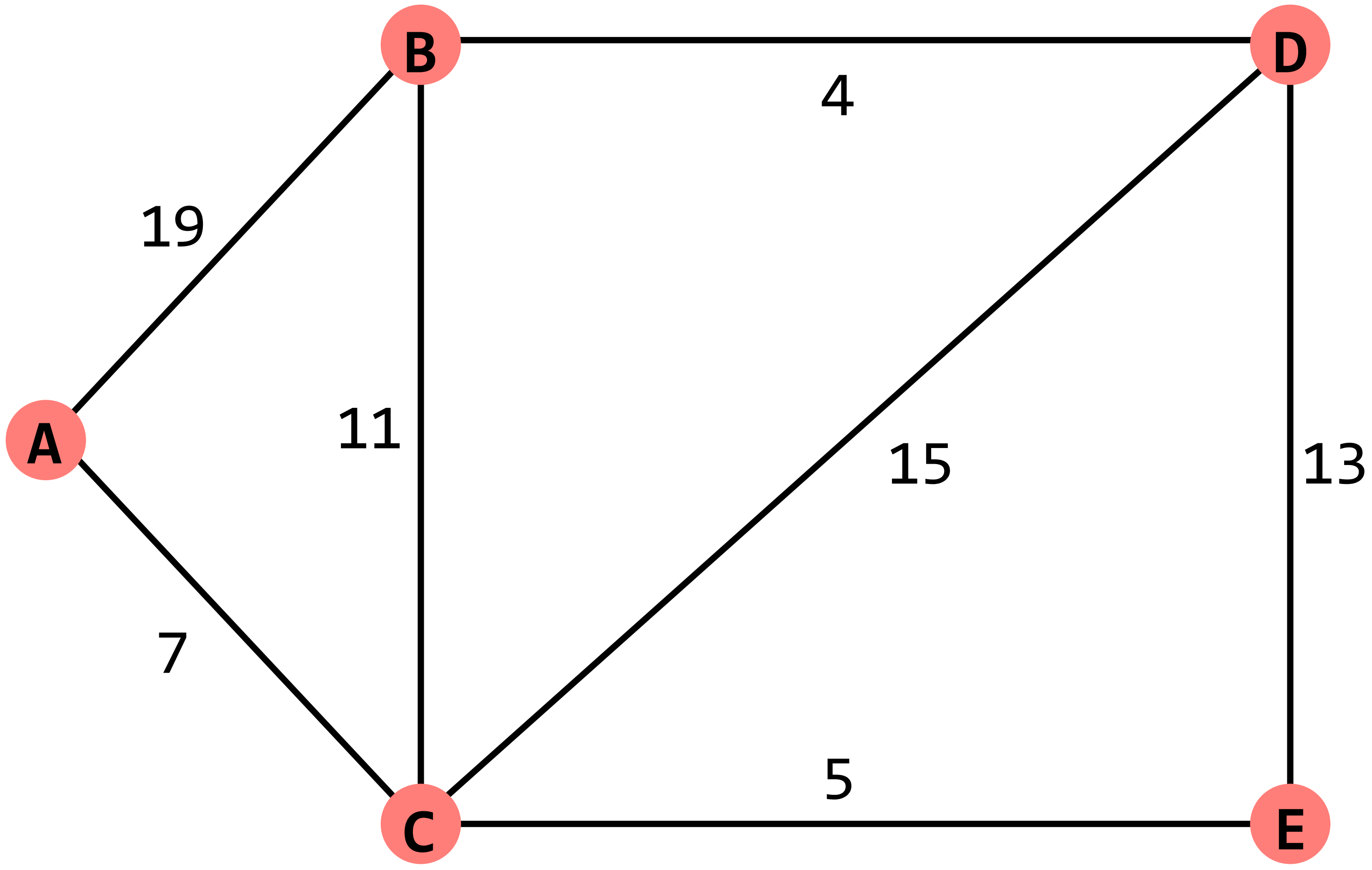
All of these steps happen periodically, which allows the routing protocol to detect and respond to failures

Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

A node's advertisements contain a list of its neighbors and its **link costs** to those nodes

A node effectively sends advertisements to every other node (via flooding)

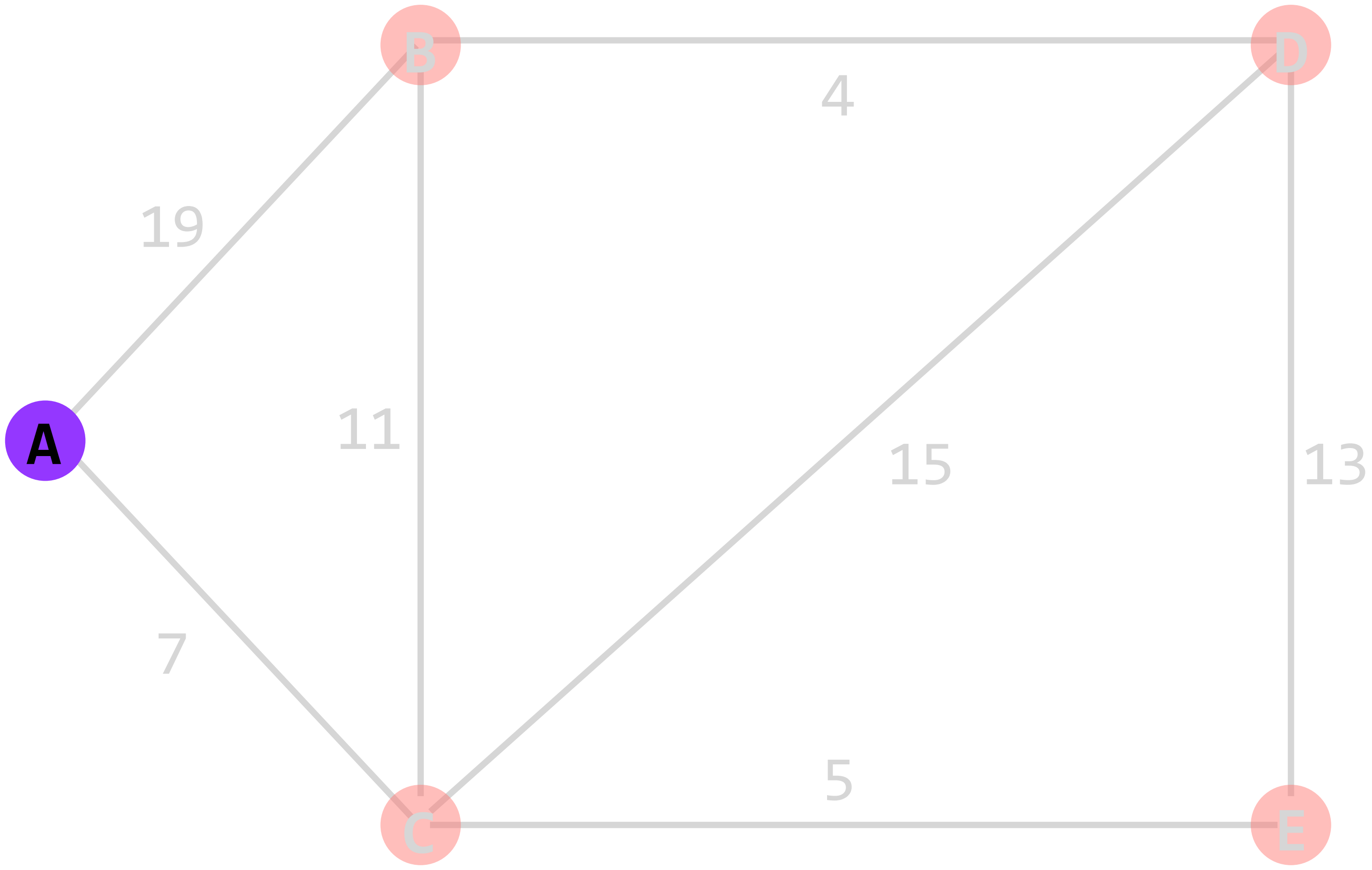


```
From A: [(B,19),(C,7)]
From B: [(A,19),(C,11),(D,4)]
From C: [(A,7),(B,11),(D,15),(E,5)]
From D: [(B,4),(C,15),(E,13)]
From E: [(C,5),(D,13)]
```

Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

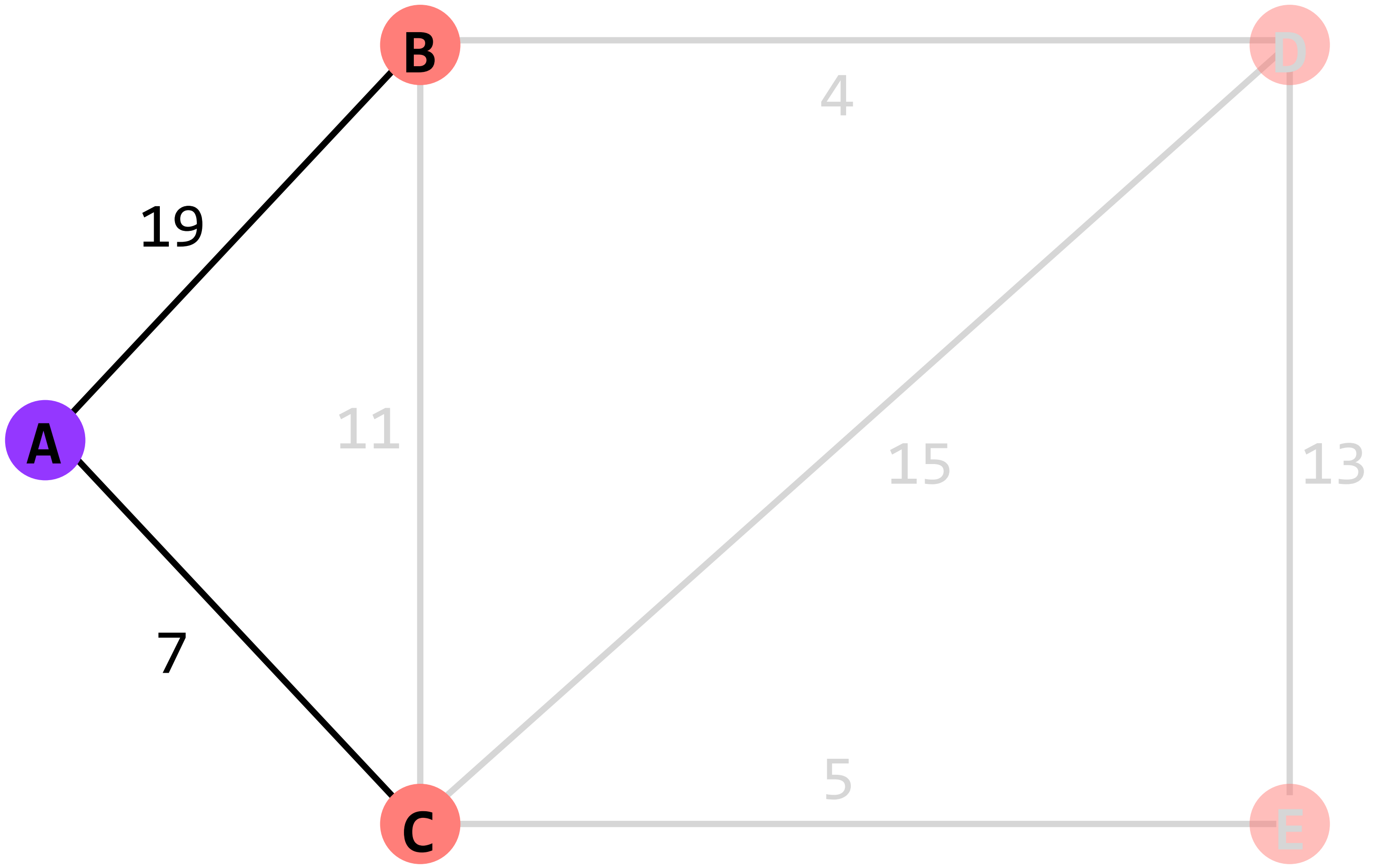
```
A: Self, 0
```



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

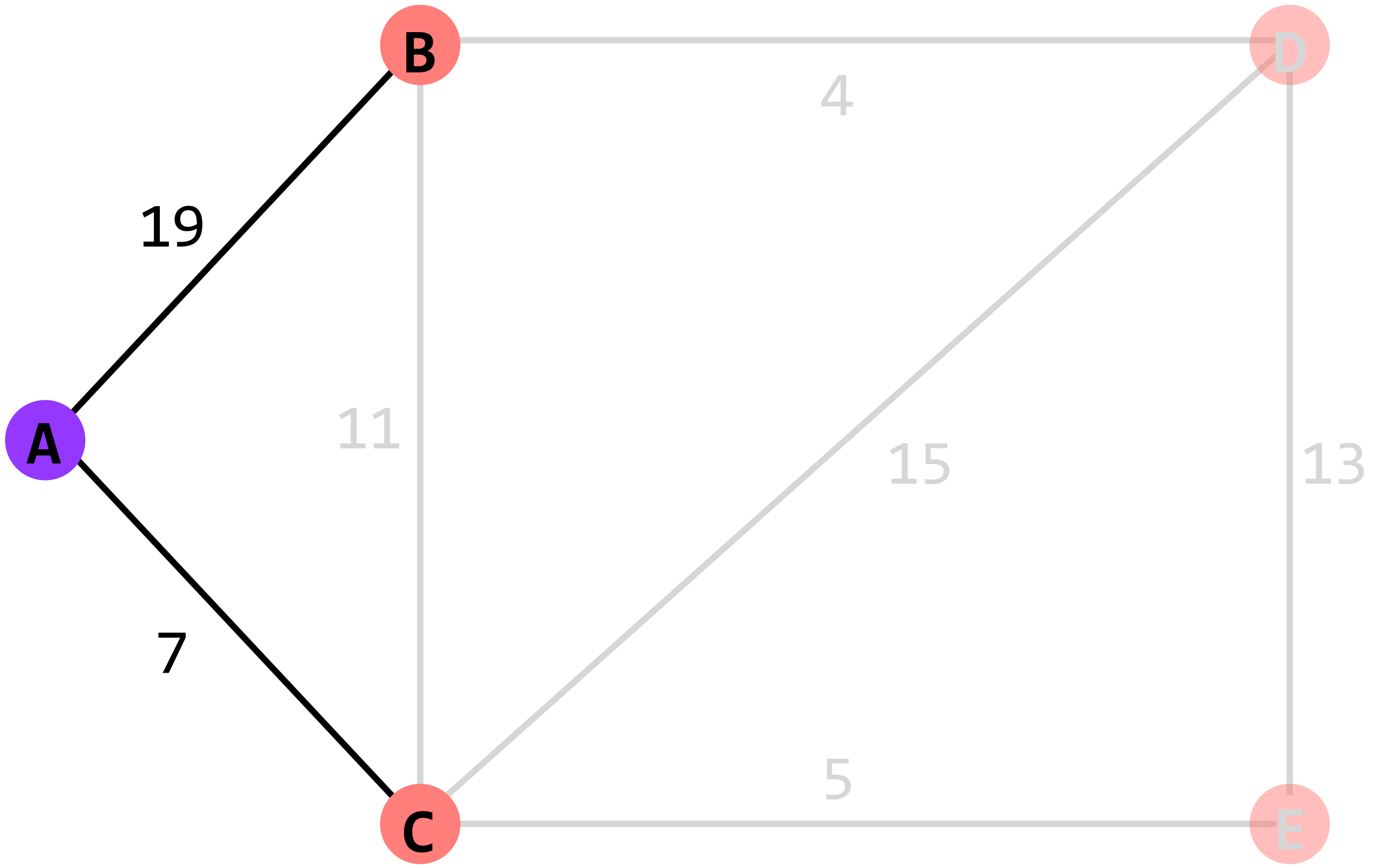
A: Self, 0



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

```
A: Self, 0
B: A->B, 19
C: A->C, 7
```



Link-state Routing

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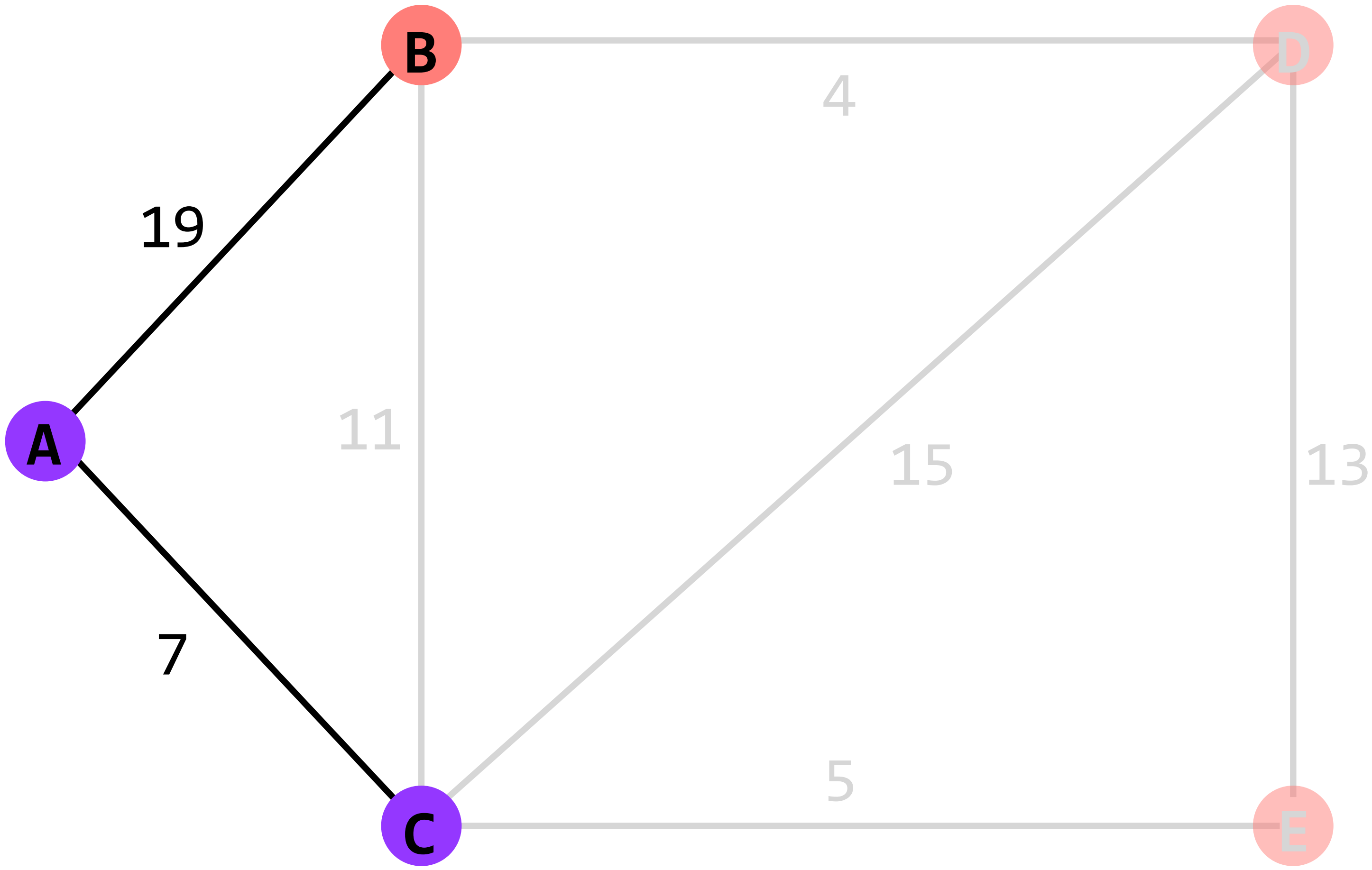

Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

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B: A->B, 19
C: A->C, 7
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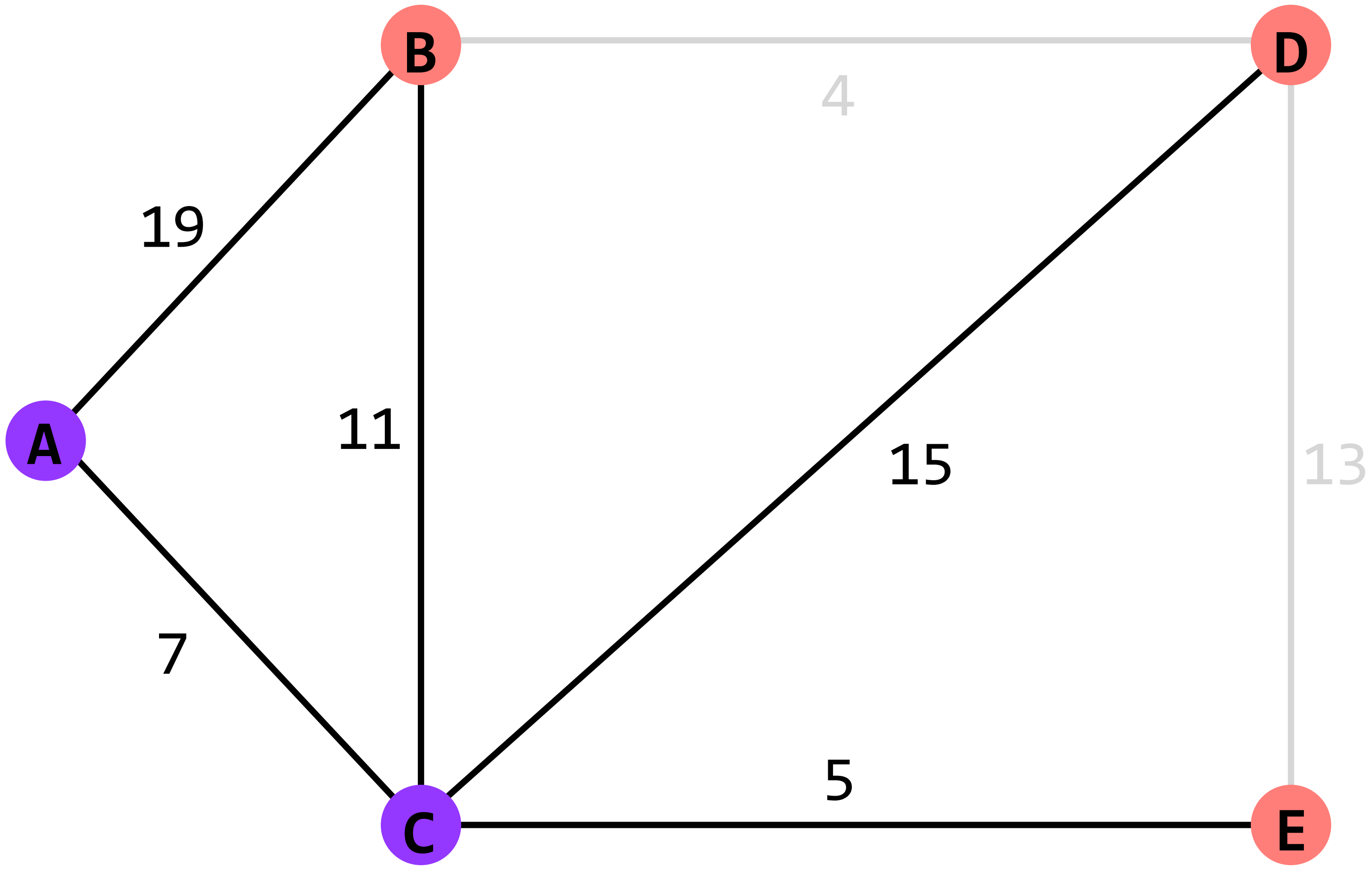
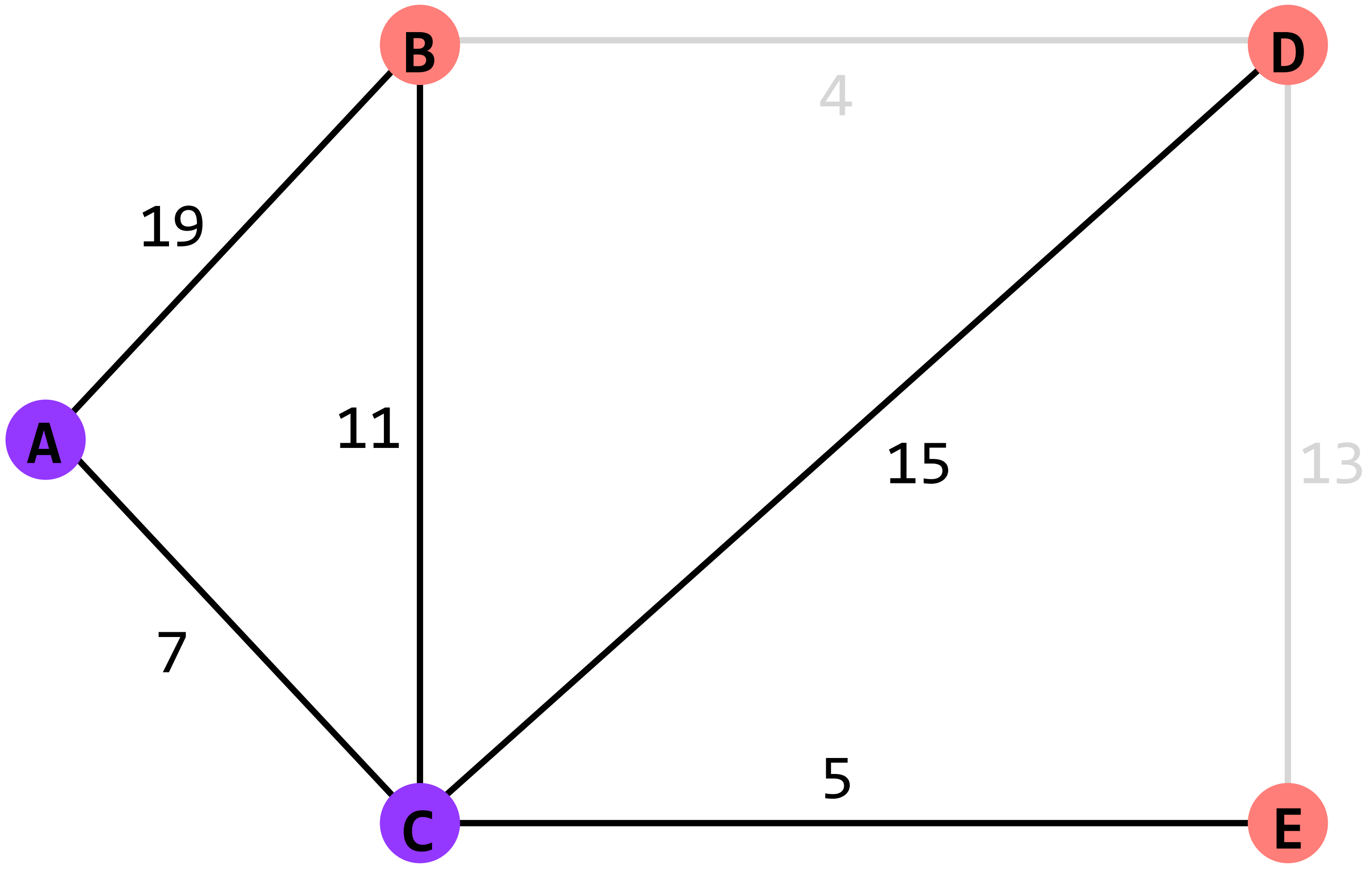


Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

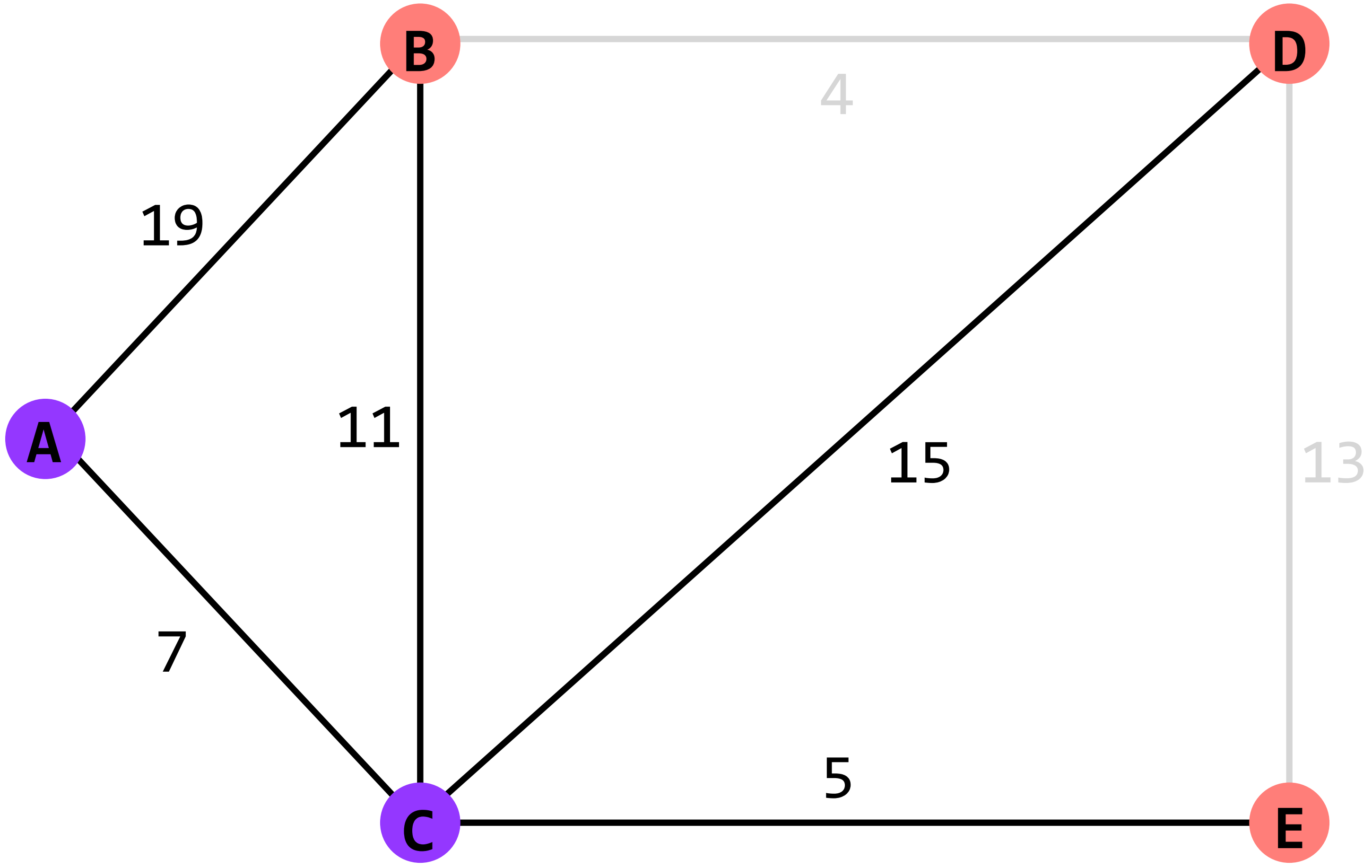
```
A: Self, 0
B: A->B, 19
C: A->C, 7
D: A->C, 22
E: A->C, 12
```



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

```
A: Self, 0
B: A->C, 18
C: A->C, 7
D: A->C, 22
E: A->C, 12
```



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

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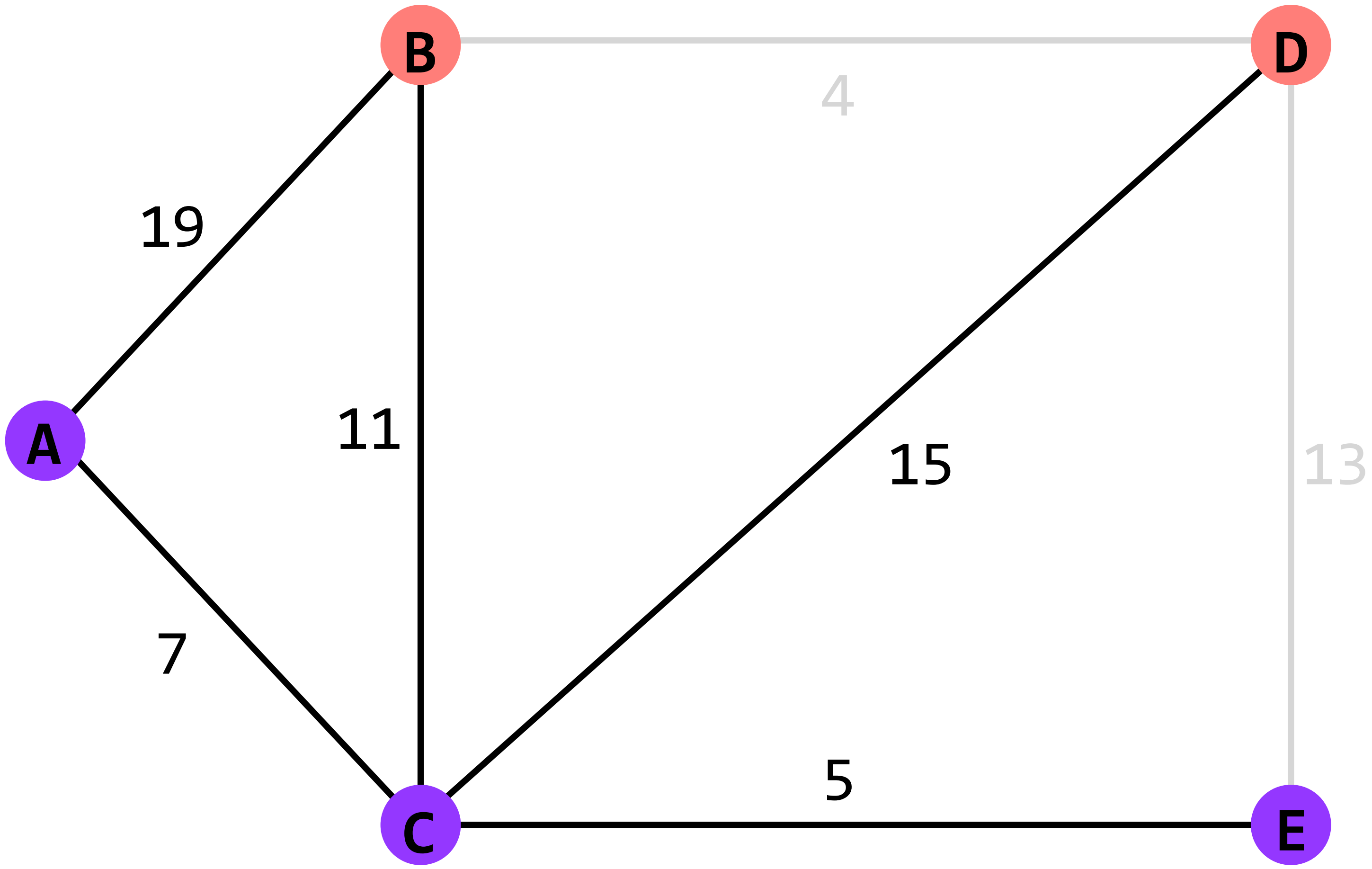

Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

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A: Self, 0
B: A->C, 18
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E: A->C, 12
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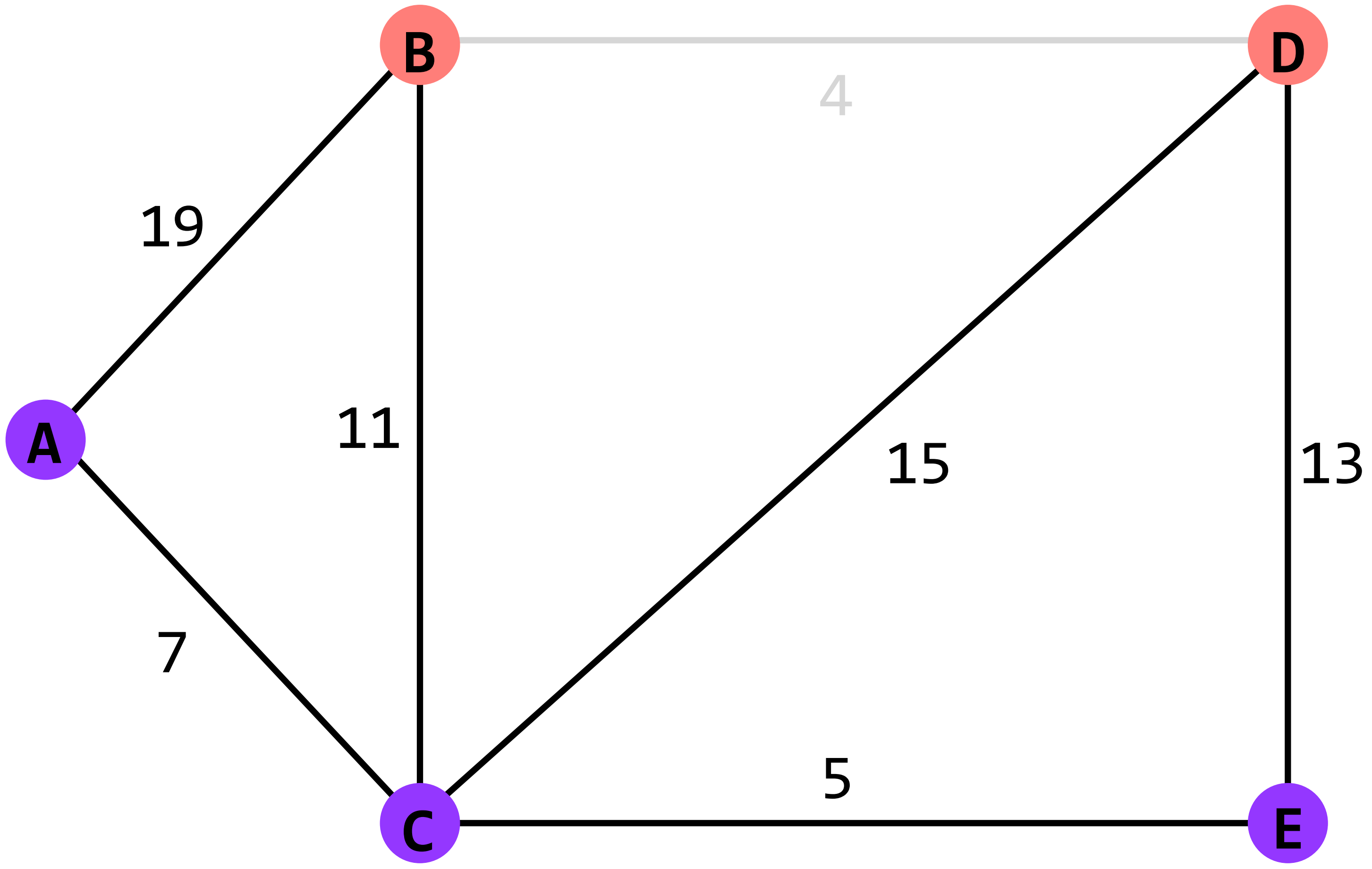
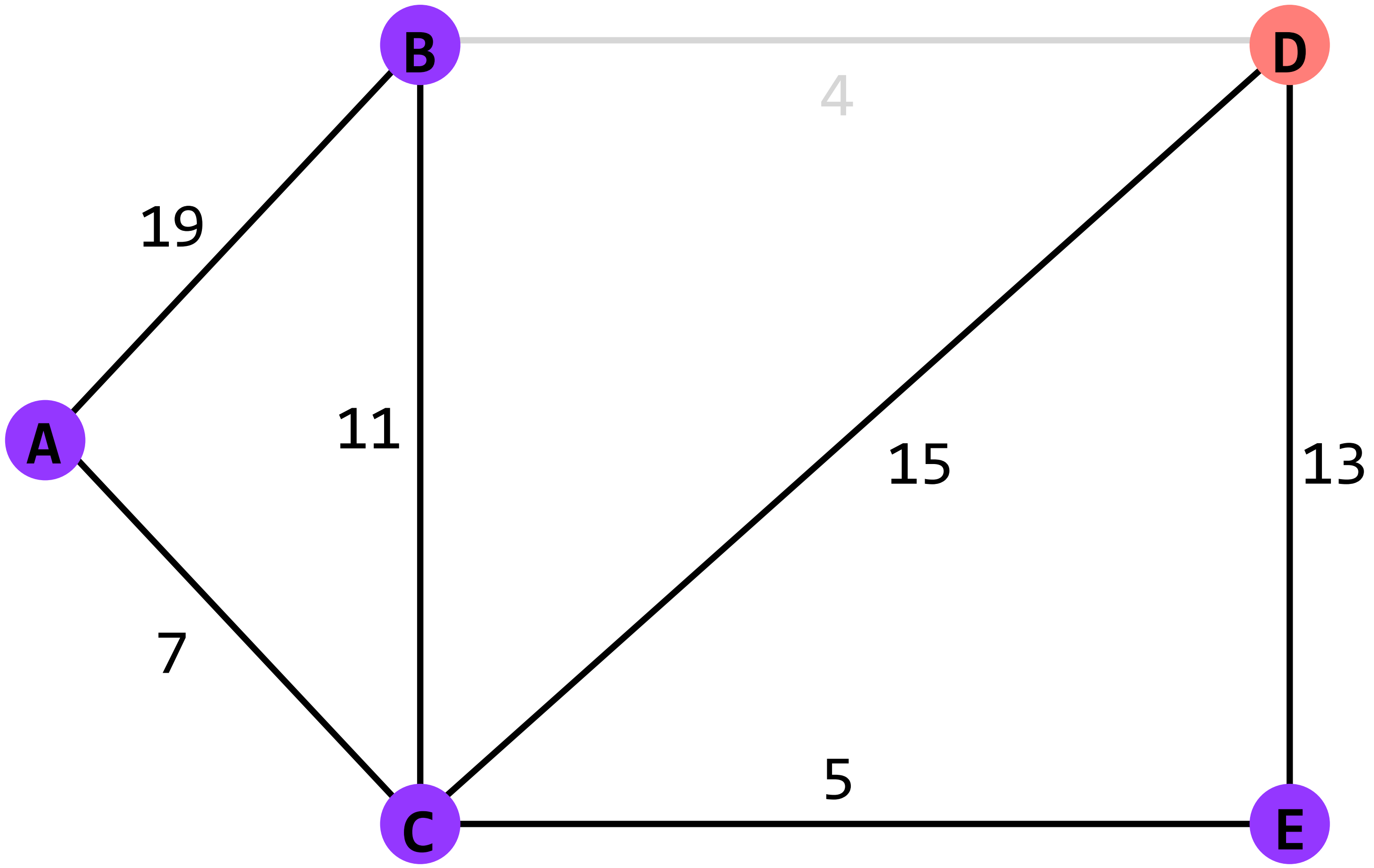


Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

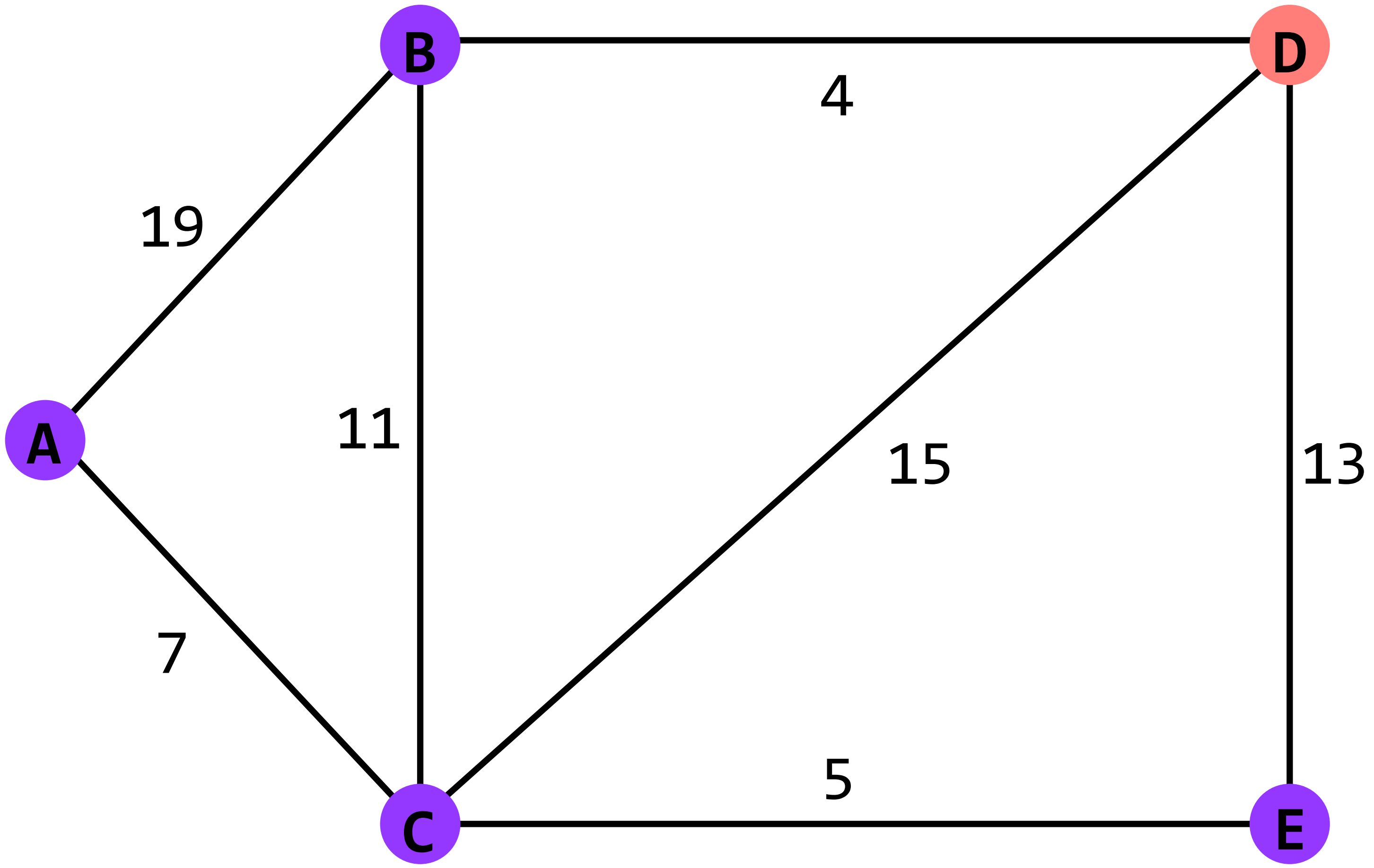
```
A: Self, 0
B: A->C, 18
C: A->C, 7
D: A->C, 22
E: A->C, 12
```



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

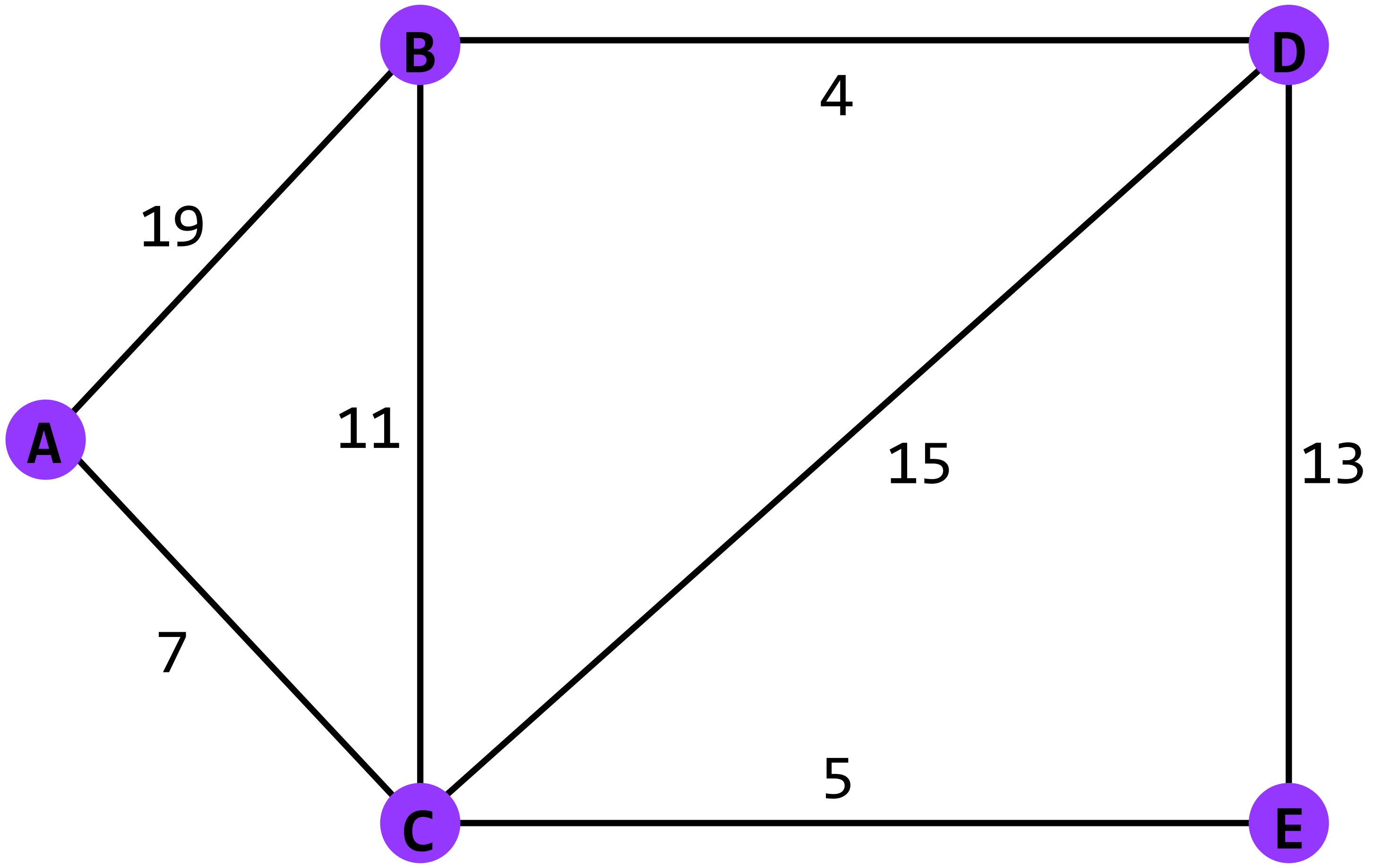
```
A: Self, 0
B: A->C, 18
C: A->C, 7
D: A->C, 22
E: A->C, 12
```



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

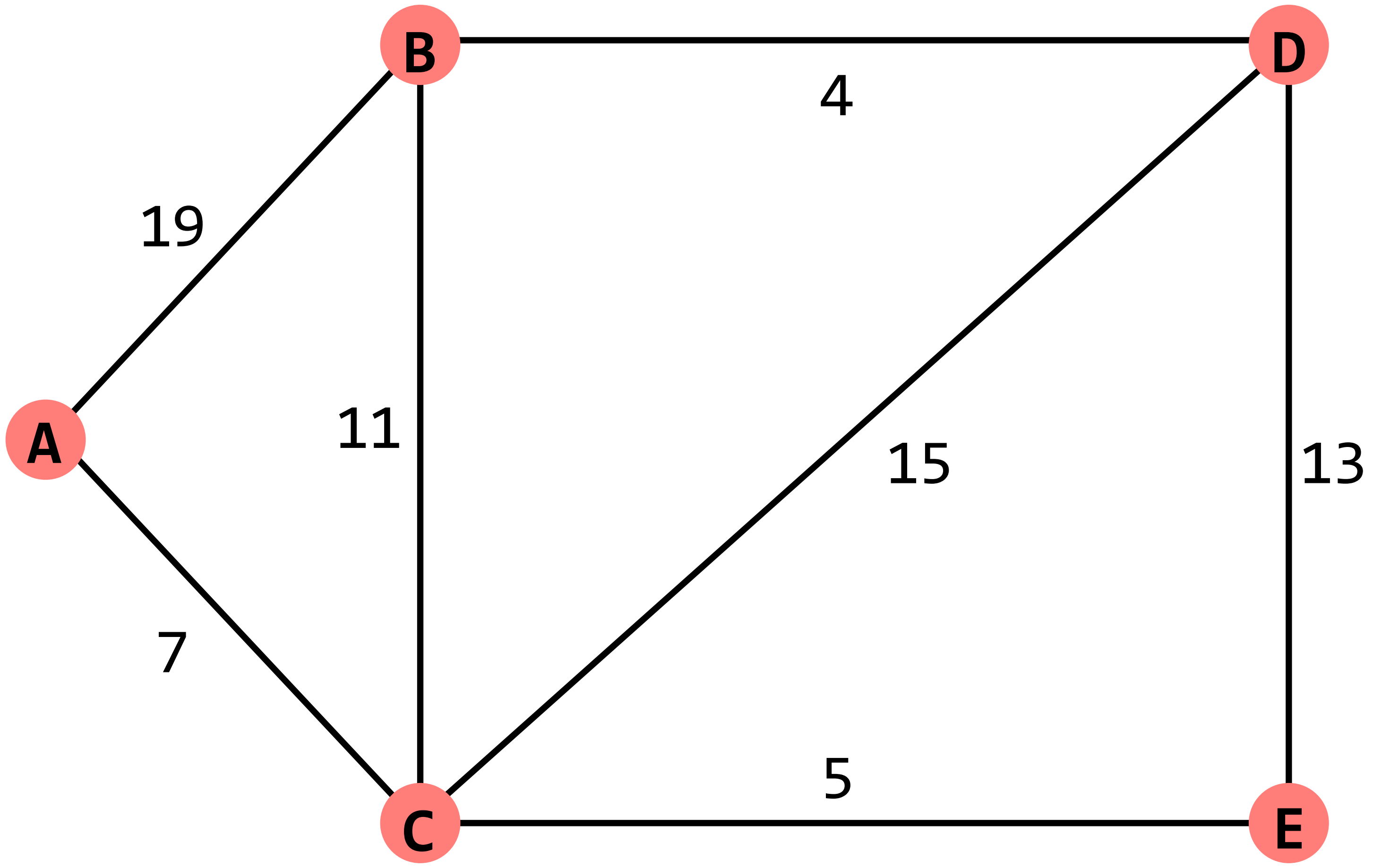
```
A: Self, 0
B: A->C, 18
C: A->C, 7
D: A->C, 22
E: A->C, 12
```



Link-state Routing

disseminate topology information so that nodes can run a shortest-path algorithm

A node's advertisements contain a list of its neighbors and its **link costs** to those nodes



A node effectively sends advertisements to every other node (via flooding)

Because advertisements are **flooded**, link-state routing performs well when there are failures. However, the **overhead** of flooding limits scale

Distance-vector Routing

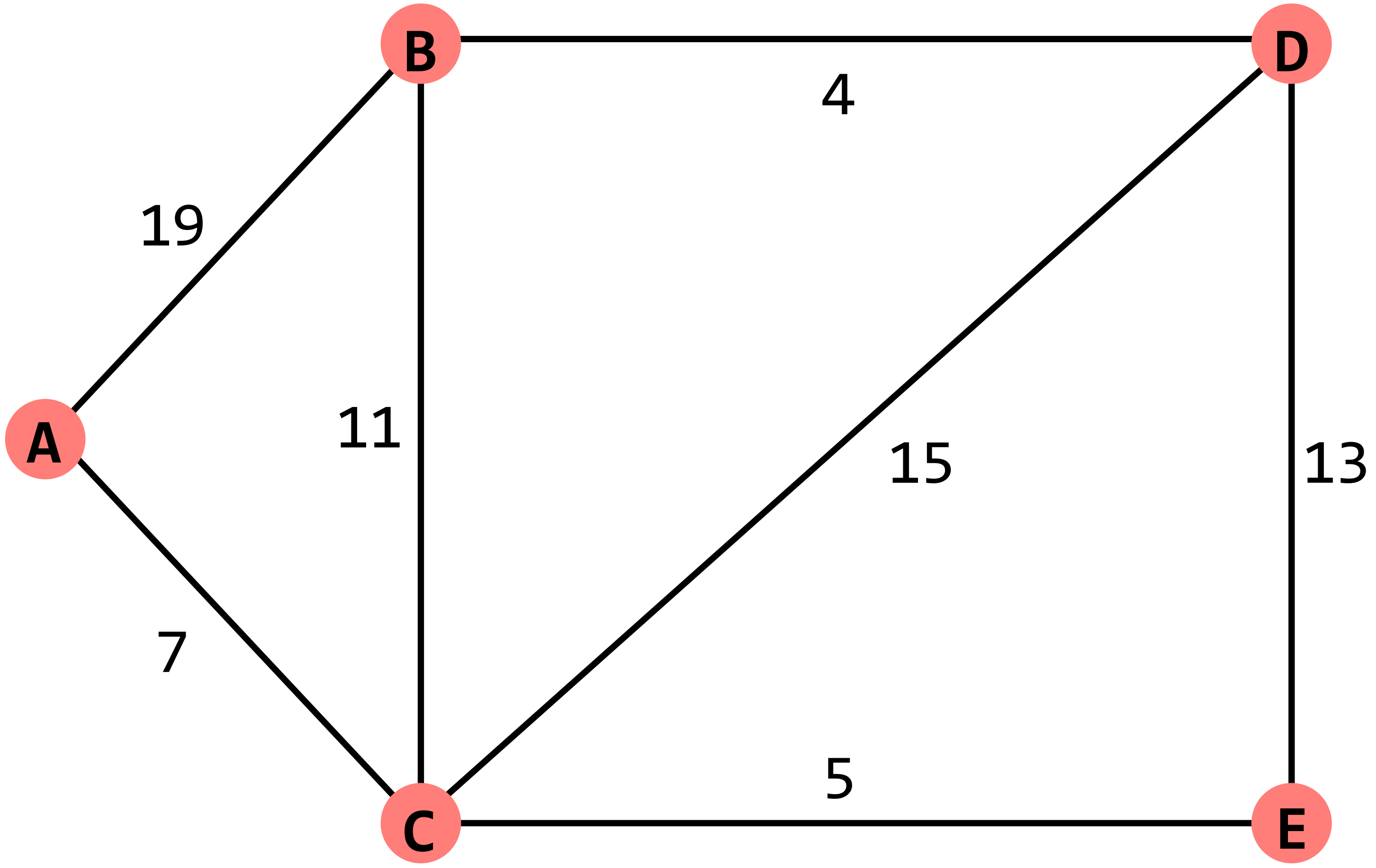
disseminate information about the current *costs* to each node, rather than the actual topology

A node’s advertisements contain a list of all the nodes it knows about and its **current costs** to those nodes

```
A: Self, 0
B: A->B, 19
C: A->C, 7
```

A node sends advertisements only to its neighbors

`From A: [(A,0),(B,19),(C,7)]`



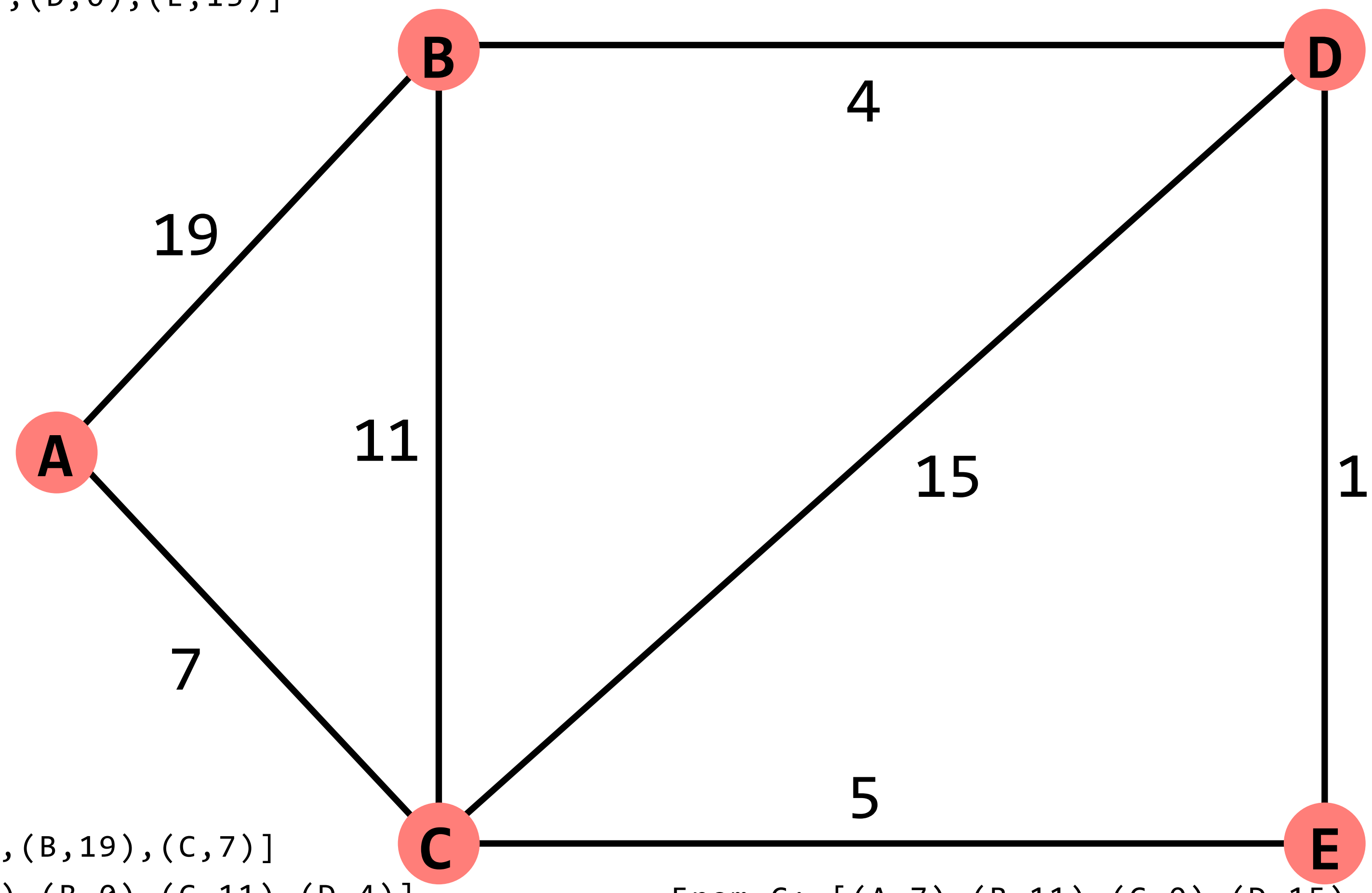
`From A: [(A,0),(B,19),(C,7)]`

Distance-vector Routing

disseminate information about the current *costs* to each node, rather than the actual topology

```
From A: [(A,0),(B,19),(C,7)]
From C: [(A,7),(B,11),(C,0),(D,15),(E,5)]
From D: [(B,4),(C,15),(D,0),(E,13)]
```

```
From B: [(A,19),(B,0),(C,11),(D,4)]
From C: [(A,7),(B,11),(C,0),(D,15),(E,5)]
From E: [(C,5),(D,13),(E,0)]
```



```
From B: [(A,19),(B,0),(C,11),(D,4)]
From C: [(A,7),(B,11),(C,0),(D,15),(E,5)]
```

```
From A: [(A,0),(B,19),(C,7)]
From B: [(A,19),(B,0),(C,11),(D,4)]
From D: [(B,4),(C,15),(D,0),(E,13)]
From E: [(C,5),(D,13),(E,0)]
```

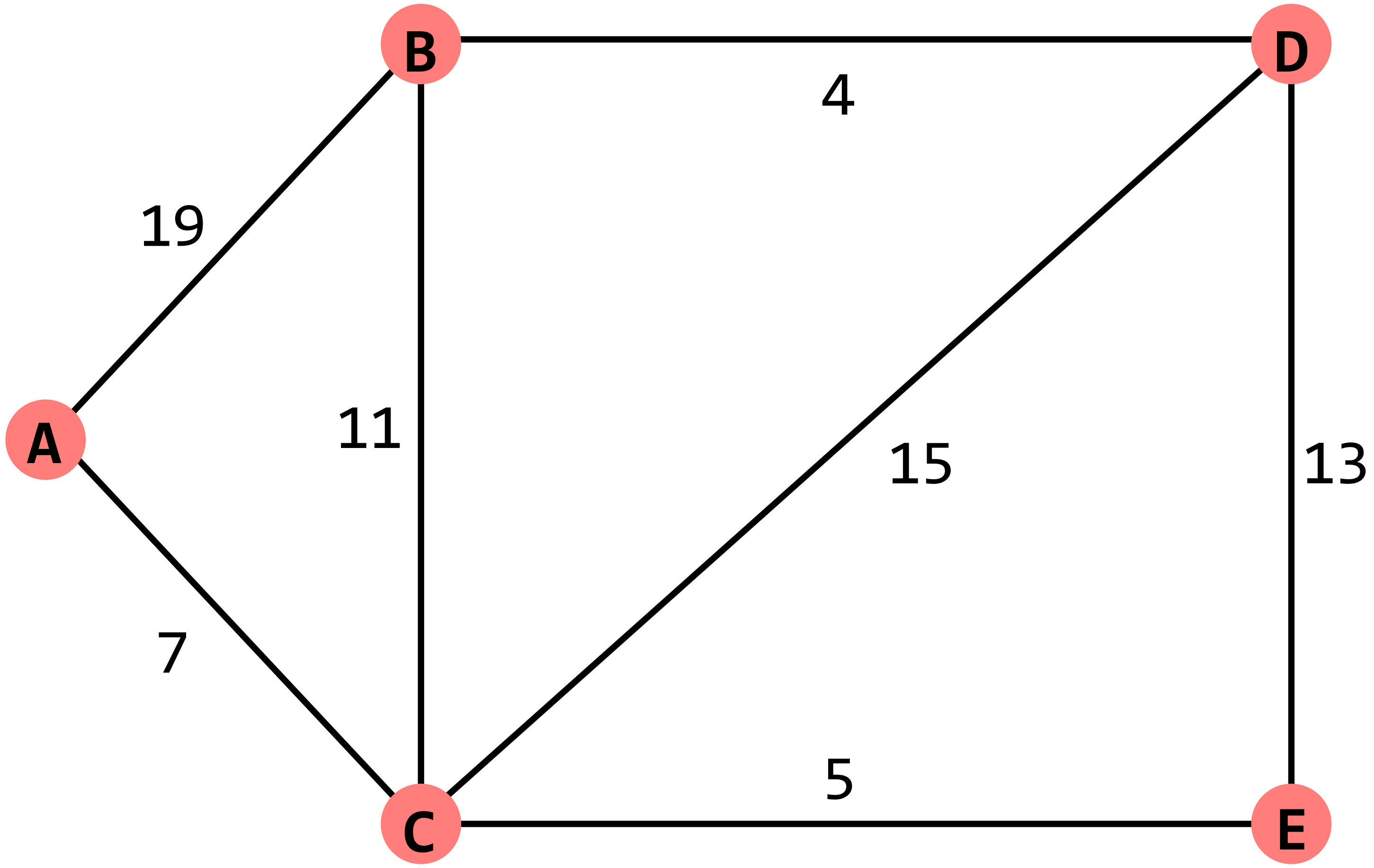
```
From C: [(A,7),(B,11),(C,0),(D,15),(E,5)]
From D: [(B,4),(C,15),(D,0),(E,13)]
```

Distance-vector Routing

disseminate information about the current *costs* to each node, rather than the actual topology

From A: [(A,0),(B,19),(C,7)]

From B: [(A,19),(B,0),(C,11),(D,4)]
From C: [(A,7),(B,11),(C,0),(D,15),(E,5)]



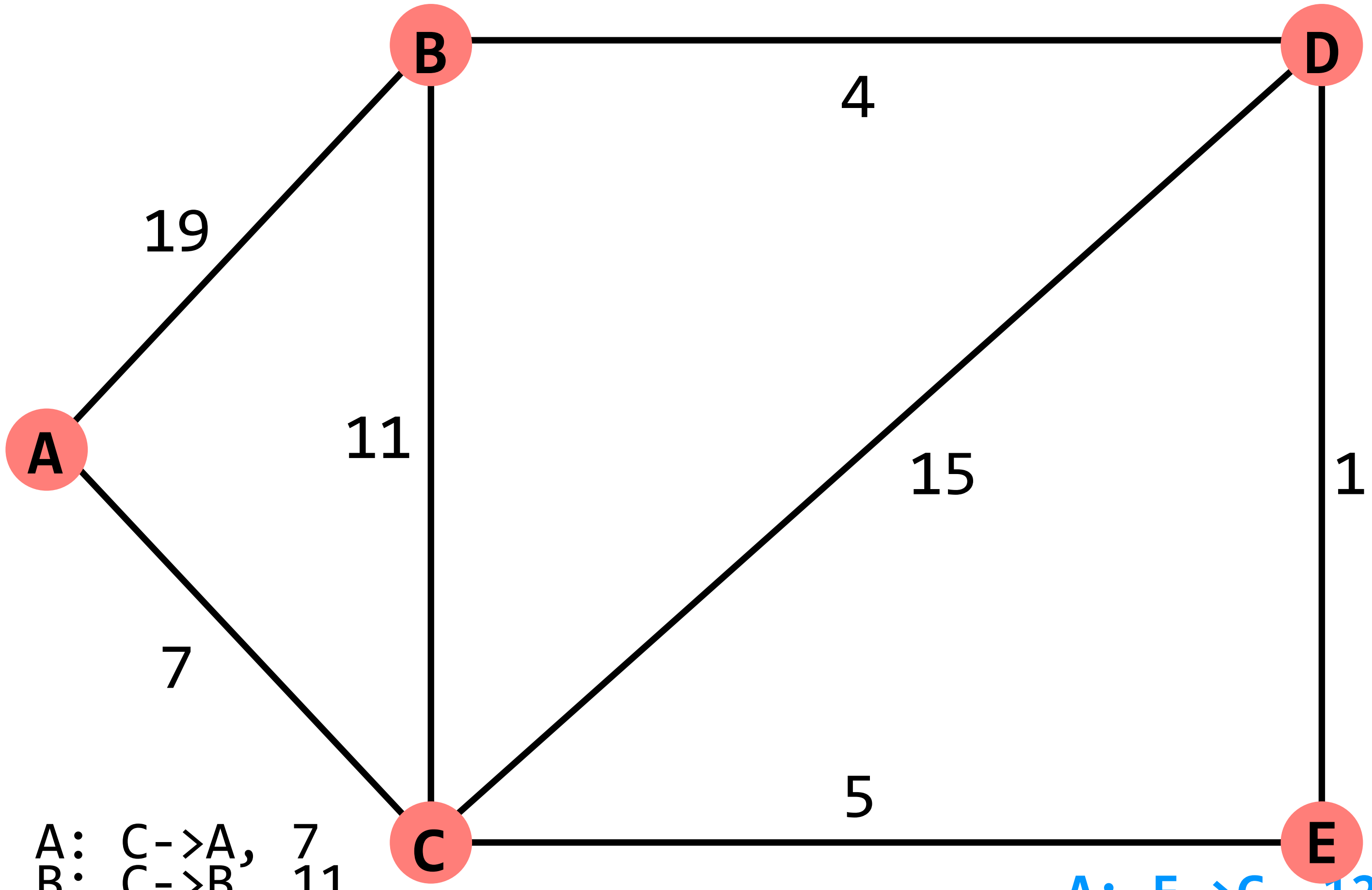
From A: [(A,0),(B,19),(C,7)]

Distance-vector Routing

disseminate information about the current *costs* to each node, rather than the actual topology

A: B->C, 18
B: Self, 0
C: B->C, 11
D: B->D, 4
E: B->C, 16

A: D->C, 22
B: D->B, 4
C: D->C, 15
D: Self, 0
E: D->E, 13



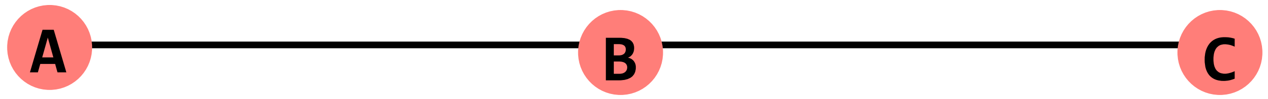
A: Self, 0
B: A->C, 18
C: A->C, 7
D: A->C, 22
E: A->C, 12

A: C->A, 7
B: C->B, 11
C: Self, 0
D: C->D, 15
E: C->E, 5

A: E->C, 12
B: E->C, 16
C: E->C, 5
D: E->D, 13
E: Self, 0

INFINITY

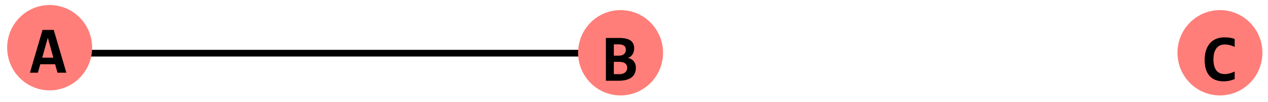
A sends advertisements at t=0, 10, 20,..; B sends advertisements at t=5, 15, 25,..



```
A: Self, 0    A: B->A, 1
B: A->B, 1    B: Self, 0
C: A->B, 2    C: B->C, 1
```

INFINITY

A sends advertisements at t=0, 10, 20,..; B sends advertisements at t=5, 15, 25,..

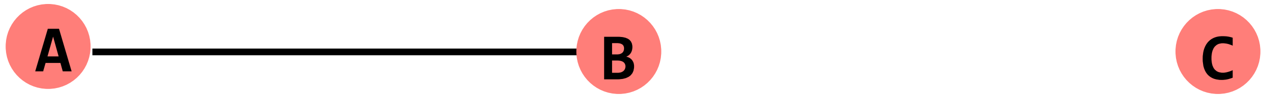


A: Self, 0 B: A->B, 1 C: A->B, 2	A: B->A, 1 B: Self, 0 C: None, inf		t=9: B<->C fails
A: Self, 0 B: A->B, 1 C: A->B, 2	A: B->A, 1 B: Self, 0 C: B->A, 3	(2+1)	t=10: B receives the following advertisement from A: [(A,0),(B,1),(C,2)]
A: Self, 0 B: A->B, 1 C: A->B, 4	A: B->A, 1 B: Self, 0 C: B->A, 3		t=15: A receives the following advertisement from B: [(A,1),(B,0),(C,3)]
A: Self, 0 B: A->B, 1 C: A->B, 4	A: B->A, 1 B: Self, 0 C: B->A, 5		t=20: B receives the following advertisement from A: [(A,0),(B,1),(C,4)]

continues until both costs to C are INFINITY

Split Horizon

A sends advertisements at t=0, 10, 20,..; B sends advertisements at t=5, 15, 25,..



```
A: Self, 0    A: B->A, 1
B: A->B, 1    B: Self, 0
C: A->B, 2    C: None, inf
```

t=9: B<->C fails

```
A: Self, 0    A: B->A, 1
B: A->B, 1    B: Self, 0
C: A->B, 2    C: None, inf
```

t=10: B receives the following advertisement from A: [(A,0)]

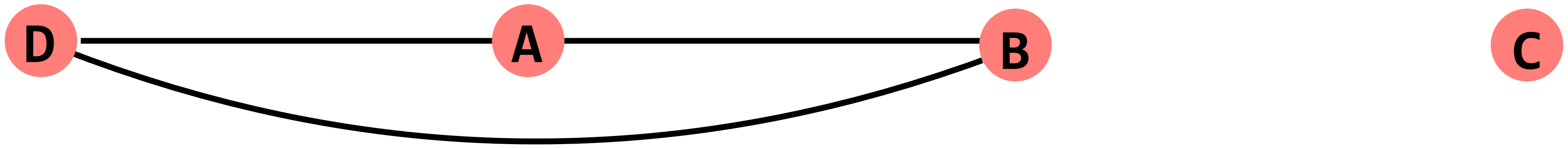
```
A: Self, 0    A: B->A, 1
B: A->B, 1    B: Self, 0
C: None, inf  C: None, inf
```

t=15: A receives the following advertisement from B: [(B,0),(C,inf)]

split horizon takes care of this particular case

Split-horizon

Don’t send advertisements about a route to the node providing the route



C: D->B, 2	C: A->B, 2	C: None, inf	B<->C fails
C: None, inf	C: A->B, 2	C: None, inf	B’s advertisement to A gets lost (so A makes no changes)
C: D->A, 3	C: A->B, 2	C: None, inf	A advertises about C to D (not to B because of split horizon)
C: D->A, 3	C: A->B, 2	C: B->D, 4	D advertises about C to B
C: D->A, 3	C: A->B, 5	C: B->D, 4	B advertises about C to A

continues until all costs to C are INFINITY

problem: neither distance-vector nor link-state routing will scale to the size of the Internet

- **Link-state routing** works by disseminating full topology information to all nodes. It’s quite robust to failures, but the **overhead** of flooding limits its scale.

- **Distance-vector routing** works by disseminating information about the cost of the actual routes. It has less overhead, but is not as robust to failures; the way in which it handles **failures** limits its scale.

- Neither of these protocols is appropriate for routing across the entire Internet. Link-state routing works well for MIT-sized networks, but we still need a means to route outside of MIT.