Wireless Networks II: Mesh Network Routing
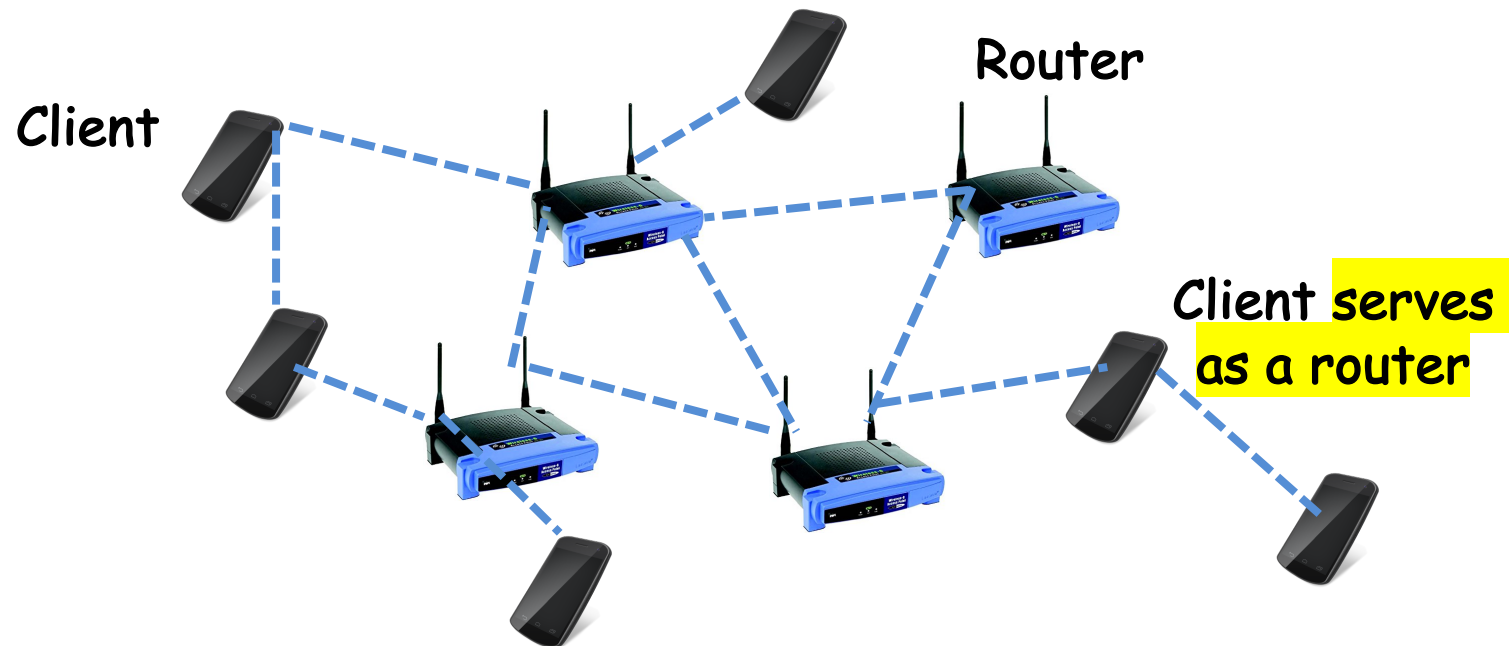
COS 461: Computer Networks
Lecture 19

Kyle Jamieson

Wireless Mesh Networks: Motivation

- Most wireless network traffic goes through **APs**

- Mesh networks **remove this restriction**

  - **Multiple paths** between most pairs: **Mesh topology**

- <u>Big Impact:</u> **Home Mesh, Satellite/Balloon Internet**

Router

Client

Client serves as a router

Today

1. **Review Distance Vector Routing**
   - **New node join**
   - Route changes
   - Broken link

2. Destination Sequenced Distance-Vector Routing (DSDV)
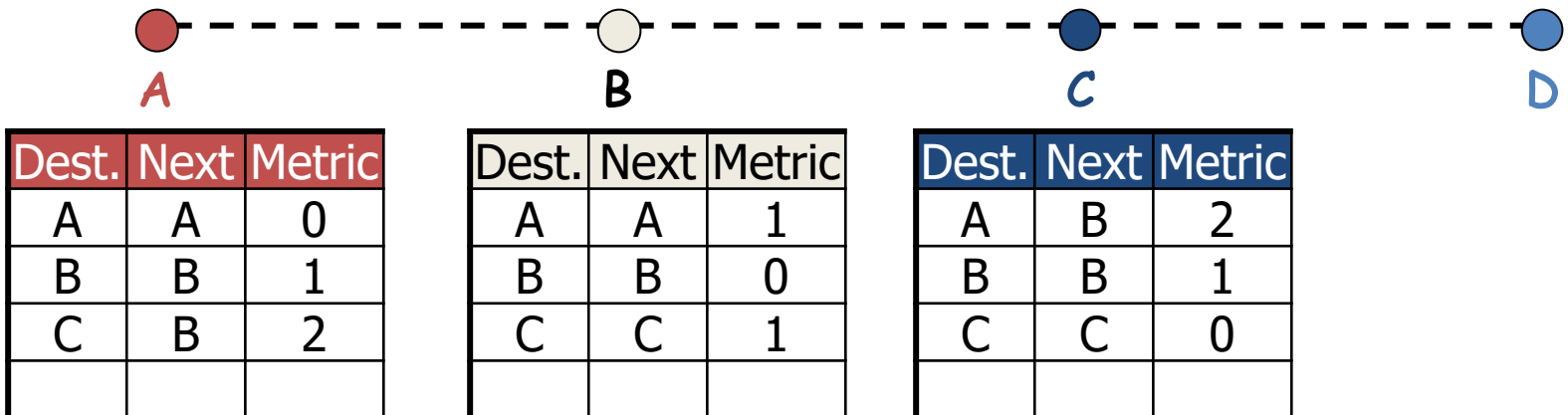
3. Dynamic Source Routing (DSR)

Distance Vector Routing: Review

- Every node maintains a ==*routing table*==
  - For each *destination* node in the mesh:
    - The **number of hops** to reach the destination (metric)
    - The **next** node on the path towards the destination

- All nodes periodically, locally broadcast routing table, ==learn about every destination in network==
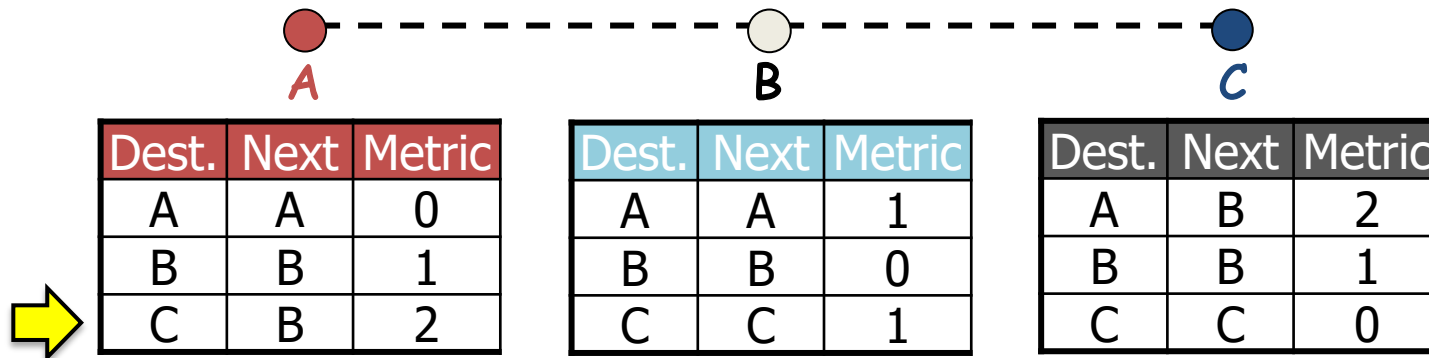
Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

A

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1

B

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0

C

Distance Vector – New Node Join

- D joins the network

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0

Distance Vector – New Node Join

- D joins the network
- D's broadcast first **updates C's table** with new entry for D

D's routing table

(D, D, 0)

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

A

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1

B

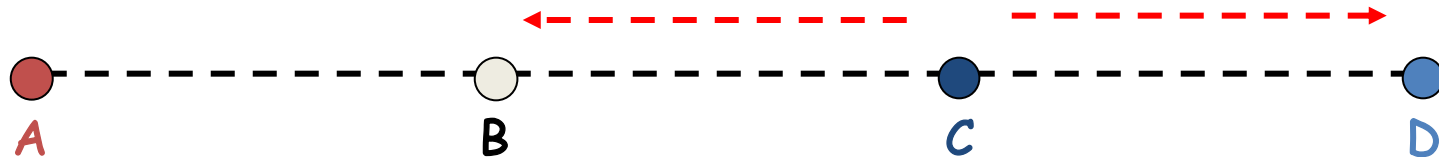| Dest.	Next	Metric
A	B	2
B	B	1
C	C	0
D	D	1

C

D
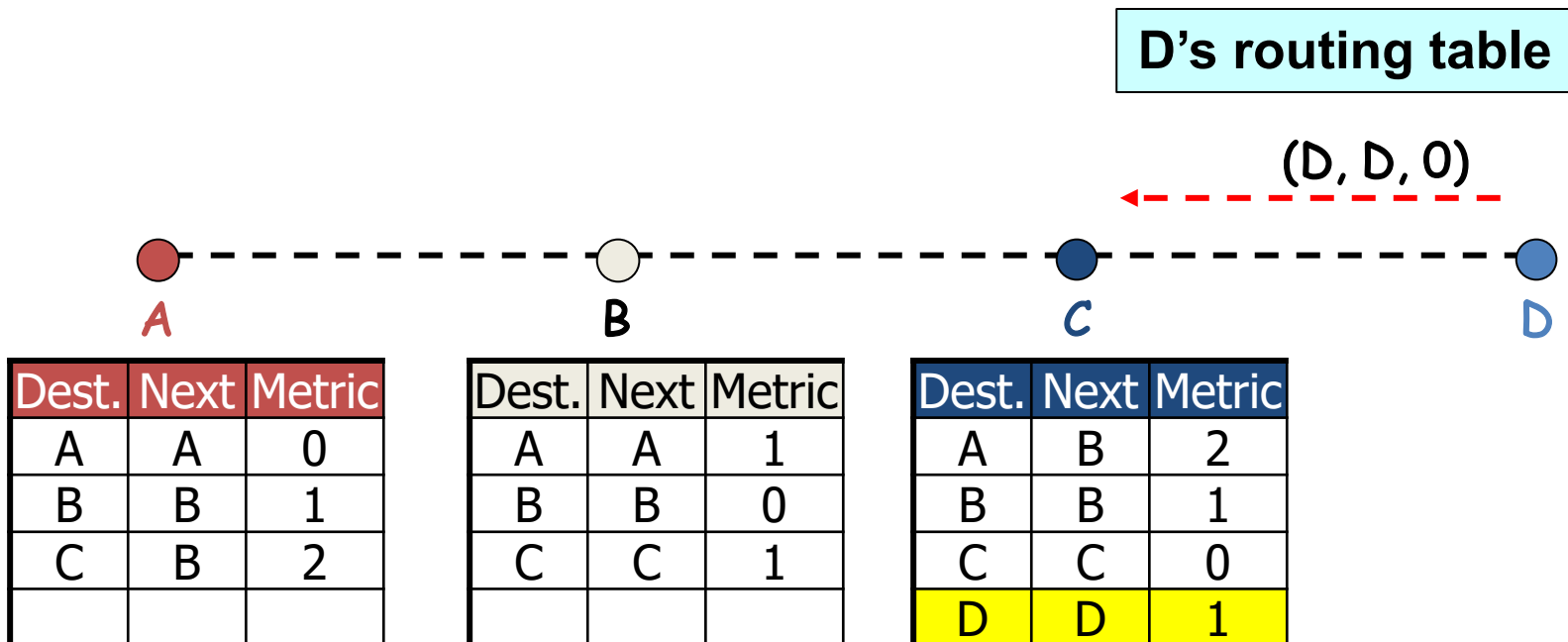
Distance Vector – New Node Join

- Now C broadcasts its routing table
  - B and D hear and add new entries, incrementing metric

C's routing table

(A, B, 2)   (A, B, 2)
(B, B, 1)   (B, B, 1)
(C, C, 0)   (C, C, 0)
(D, D, 1)   (D, D, 1)

A   B   C   D

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	C	2

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0
D	D	1

Dest.	Next	Metric
A	C	3
B	C	2
C	C	1
D	D	0

Distance Vector – New Node Join

- Now **B** broadcasts its routing table
  - **A and C hear** and add new entries, if shorter route

B's routing table

(A, A, 1)   (A, A, 1)
(B, B, 0)   (B, B, 0)
(C, C, 1)   (C, C, 1)
(D, C, 2)   (D, C, 2)
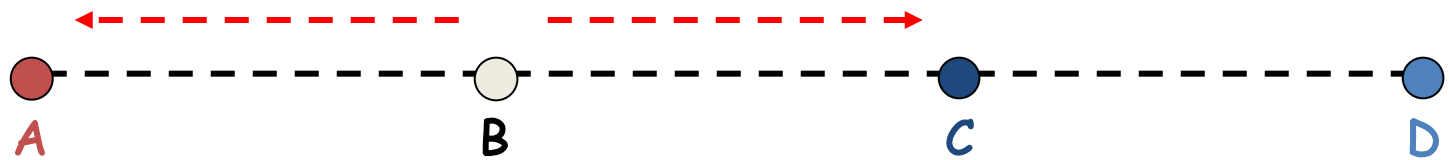
A   B   C   D

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2
D	B	3

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	C	2

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0
D	D	1

Dest.	Next	Metric
A	C	3
B	C	2
C	C	1
D	D	0

Today

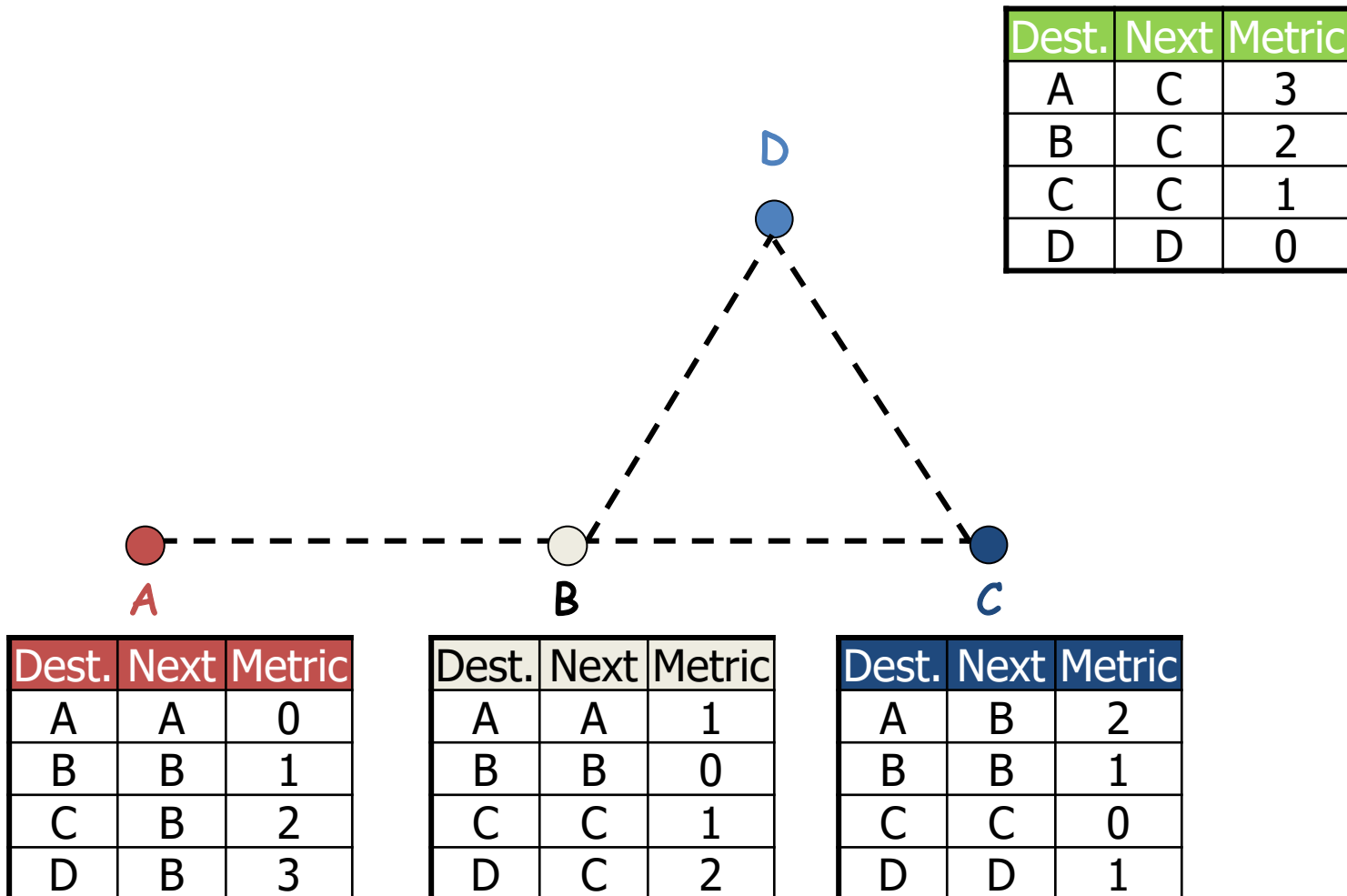1. **Review Distance Vector Routing**
   - New node join
   - **Route changes**
   - Broken link

2. Destination Sequenced Distance-Vector Routing (DSDV)
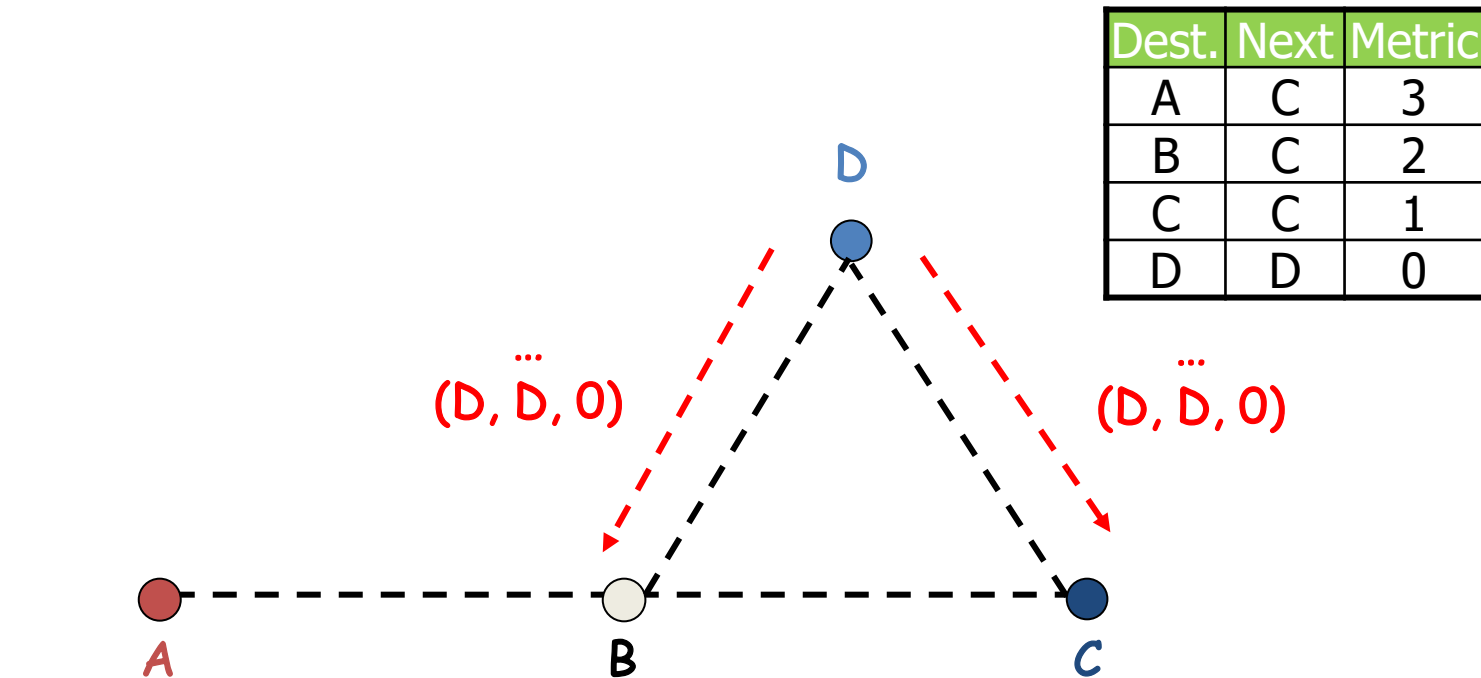
3. Dynamic Source Routing (DSR)

Distance Vector – Route Change

- D moves to another place and broadcast its routing table

Dest.	Next	Metric
A	C	3
B	C	2
C	C	1
D	D	0

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2
D	B	3

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	C	2

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0
D	D	1

Distance Vector – Route Change

- D moves to another place and broadcast its routing table

Dest.	Next	Metric
A	C	3
B	C	2
C	C	1
D	D	0

(D, D, 0)   (D, D, 0)

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2
D	B	3

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	D	1

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0
D	D	1

Distance Vector – Route Change

- **D** moves to another place and broadcast its routing table
- **B** broadcasts its routing table

Dest.	Next	Metric
A	B	2
B	B	1
C	C	1
D	D	0

D

...
(D, D, 1)

...
(D, D, 1)

...
(D, D, 1)

A

B

C

Dest.	Next	Metric
A	A	0
B	B	1
C	B	2
D	B	2

Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	D	1

Dest.	Next	Metric
A	B	2
B	B	1
C	C	0
D	D	1

Today

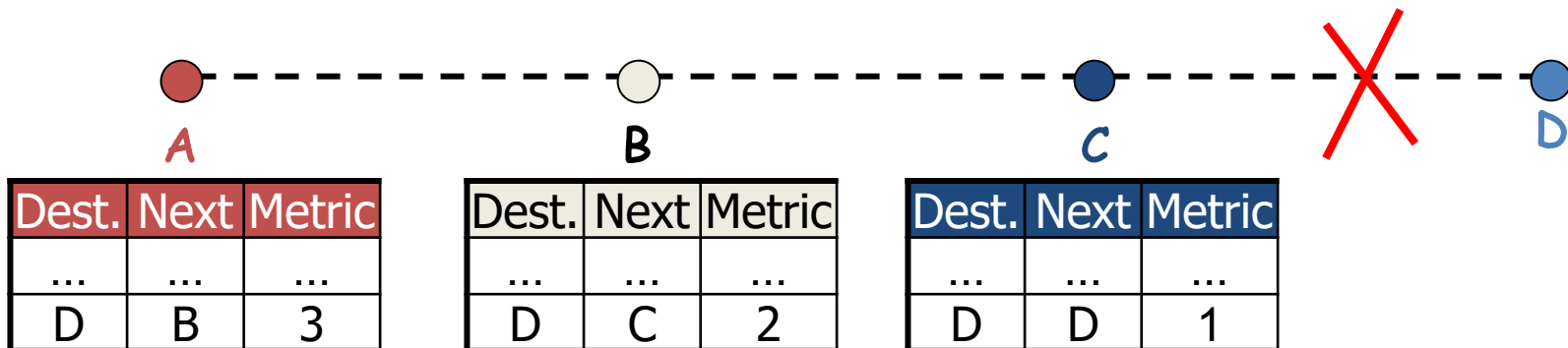1. **Review Distance Vector Routing**
   – New node join
   – Route changes
   – **Broken link**

2. Destination Sequenced Distance-Vector Routing (DSDV)
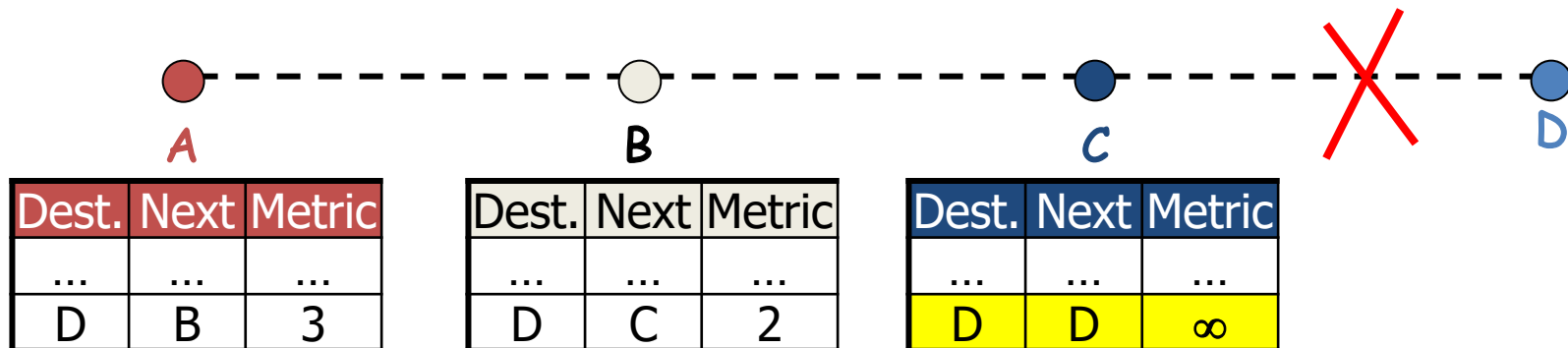
3. Dynamic Source Routing (DSR)

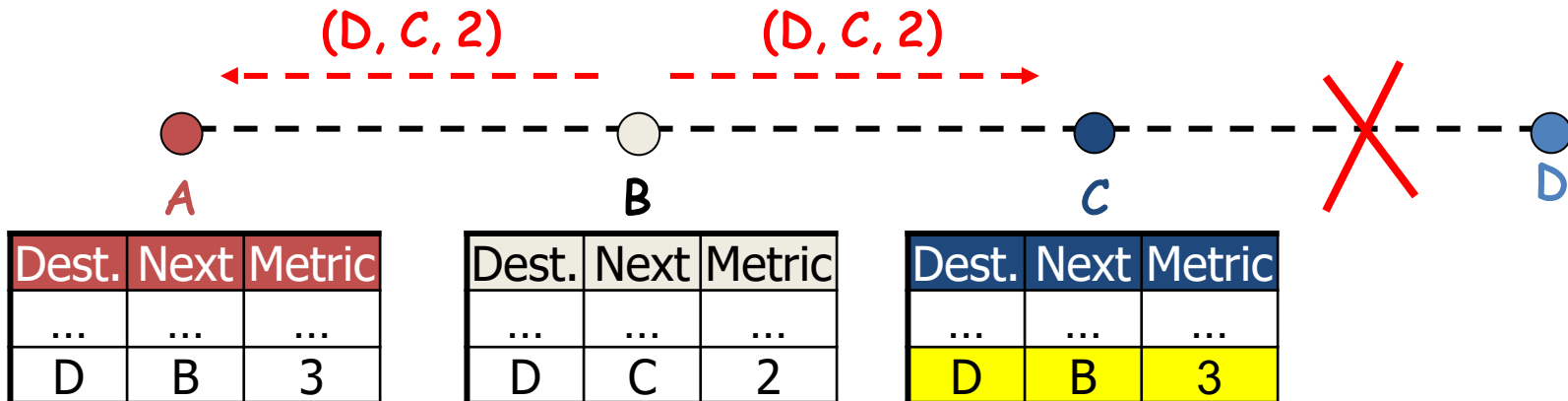# Distance Vector – Broken Link

- **Suppose link C ←→ D breaks**

Dest.	Next	Metric
...	...	...
D	B	3

A

Dest.	Next	Metric
...	...	...
D	C	2

B

Dest.	Next	Metric
...	...	...
D	D	1

C

Distance Vector – Broken Link

1. C hears no advertisement from D for a *timeout period*
   - C sets D's metric to ∞

Dest.	Next	Metric
...	...	...
D	B	3

Dest.	Next	Metric
...	...	...
D	C	2

Dest.	Next	Metric
...	...	...
D	D	∞

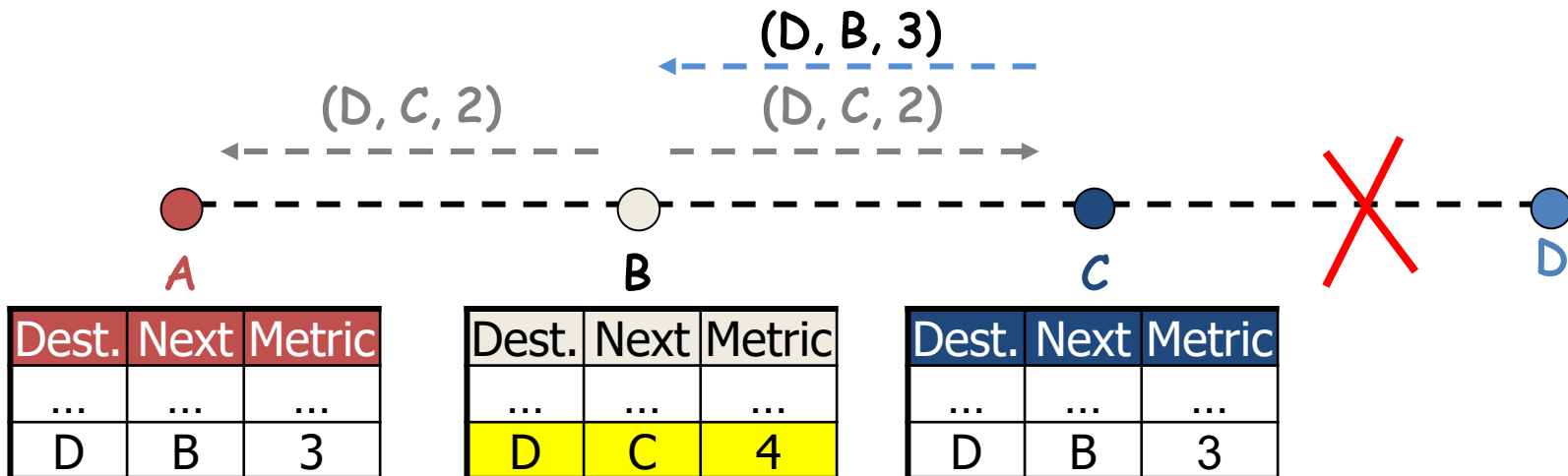# Distance Vector – Broken Link

1. C sets D's metric to ∞
2. B broadcasts its routing table
   - C **now accepts** B's entry for D (3 < ∞)

(D, C, 2)   (D, C, 2)

A

Dest.	Next	Metric
...	...	...
D	B	3

B

Dest.	Next	Metric
...	...	...
D	C	2

C

| Dest.	Next	Metric
...	...	...
D	B	3

Broken Link: Counting to Infinity

1. C sets D's metric to ∞
2. B broadcasts its routing table
3. C broadcasts its routing table
   – B **accepts** C's **new metric** (B's previous next-hop was C)

(D, B, 3)

(D, C, 2)   (D, C, 2)

A

Dest.	Next	Metric
...	...	...
D	B	3

B

Dest.	Next	Metric
...	...	...
D	C	4

C

Dest.	Next	Metric
...	...	...
D	B	3

Broken Link: Counting to Infinity

1. **C** sets **D's** metric to ∞
2. **B** broadcasts its routing table
3. **C** broadcasts its routing table
4. **B** broadcasts its routing table
   - A, C accept **B's** new metric (previous next-hops: **B**)
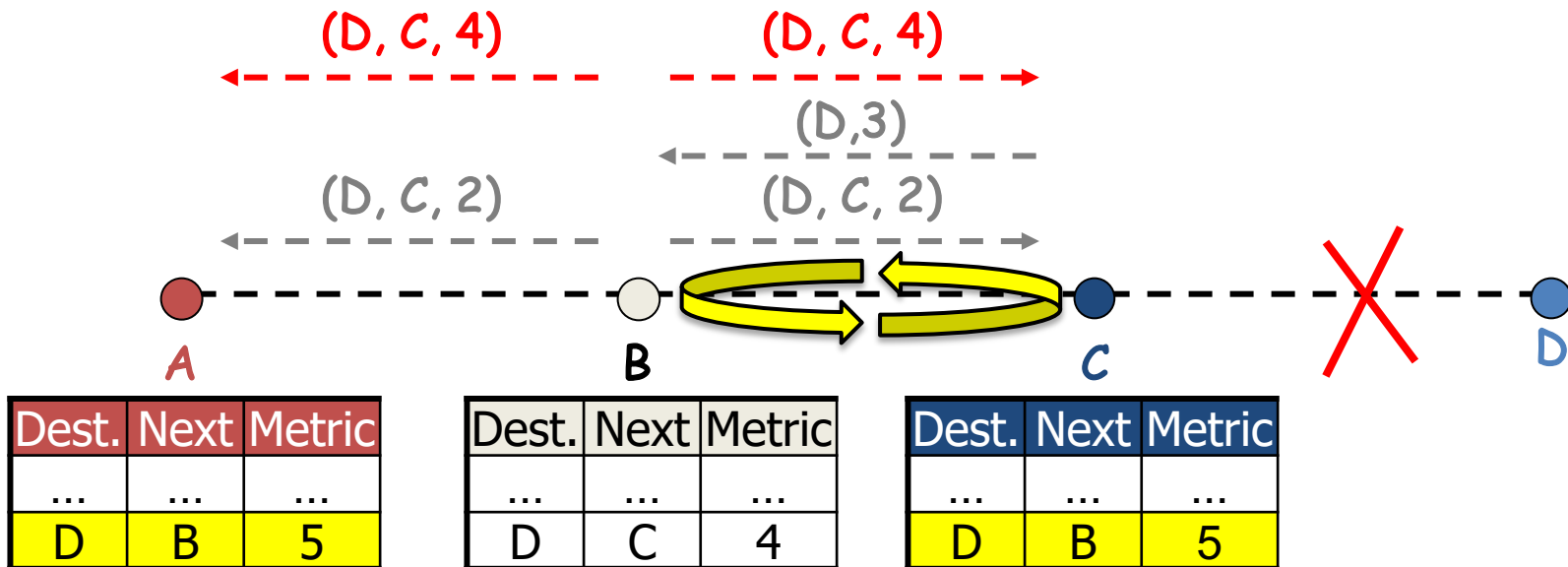
Dest.	Next	Metric
...	...	...
D	B	5

Dest.	Next	Metric
...	...	...
D	C	4

Dest.	Next	Metric
...	...	...
D	B	5

Today

1. Review Distance Vector Routing

2. Destination Sequenced Distance-Vector Routing (DSDV)
   – New node join
   – Broken link
   – Route change

3. Dynamic Source Routing (DSR)

Destination Sequenced Distance-Vector (DSDV) Routing

- Guarantees loop freeness

- New routing table information: *Sequence number*
  - Sequence number is per-destination information
    - Originated by destination

  - Included and propagated in routing advertisements

Destination	Next	Metric	Seq. Nr
A	A	0	550
B	B	1	102
C	B	3	588
D	B	4	312

DSDV: Route Advertisement Rule

Rules to set sequence number:

- Just before **node** N's broadcast advertisement:
  - **Node N** sets:
    - $Seq(N) \leftarrow Seq(N) + 2$

- **Node N** thinks neighbor P is no longer directly reachable
  - **Node N** sets:
    - $Seq(P) \leftarrow Seq(P) + 1$
    - $Metric(P) \leftarrow \infty$

DSDV – New Node

- D joins the network

- D's broadcast first **updates C's table** w/ new entry for D

1. D broadcast for first time
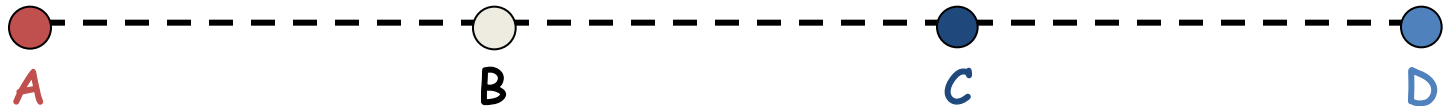Send Sequence number 000

(D, D, 0, 000)

A   B   C   D

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	104
C	B	2	590

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	104
C	C	1	590

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	104
C	C	0	590
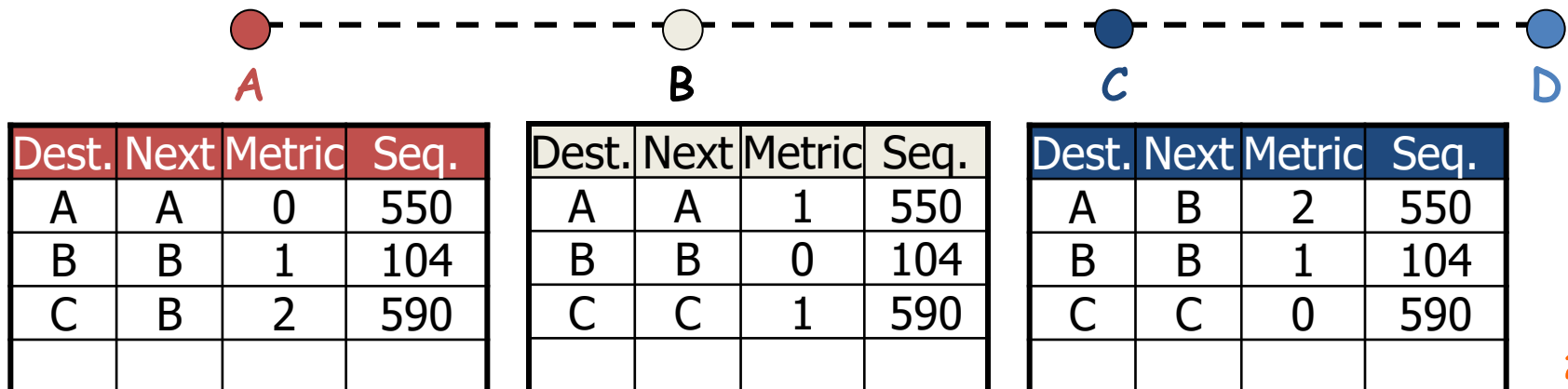
DSDV – New Node

2.1: Insert entry for D with **same** sequence number 000
2.2: Triggered broadcast of its own table

1. D broadcast for first time
Send Sequence number 000

(D, D, 0, 000)

A   B   C   D

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	104
C	B	2	590

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	104
C	C	1	590

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	104
C	C	0	590
D	D	1	000

23

DSDV – New Node

4. B gets C's update and updates its table

3. C increases its sequence number to 592 then broadcasts its new table.

(A, B, 2, 550)
(B, B, 1, 104)
(C, C, 0, 592)
(D, D, 1, 000)

(A, B, 2, 550)
(B, B, 1, 104)
(C, C, 0, 592)
(D, D, 1, 000)

A   B   C   D

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	104
C	B	2	590

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	104
C	C	1	592
D	C	2	000

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	104
C	C	0	592
D	D	1	000

24
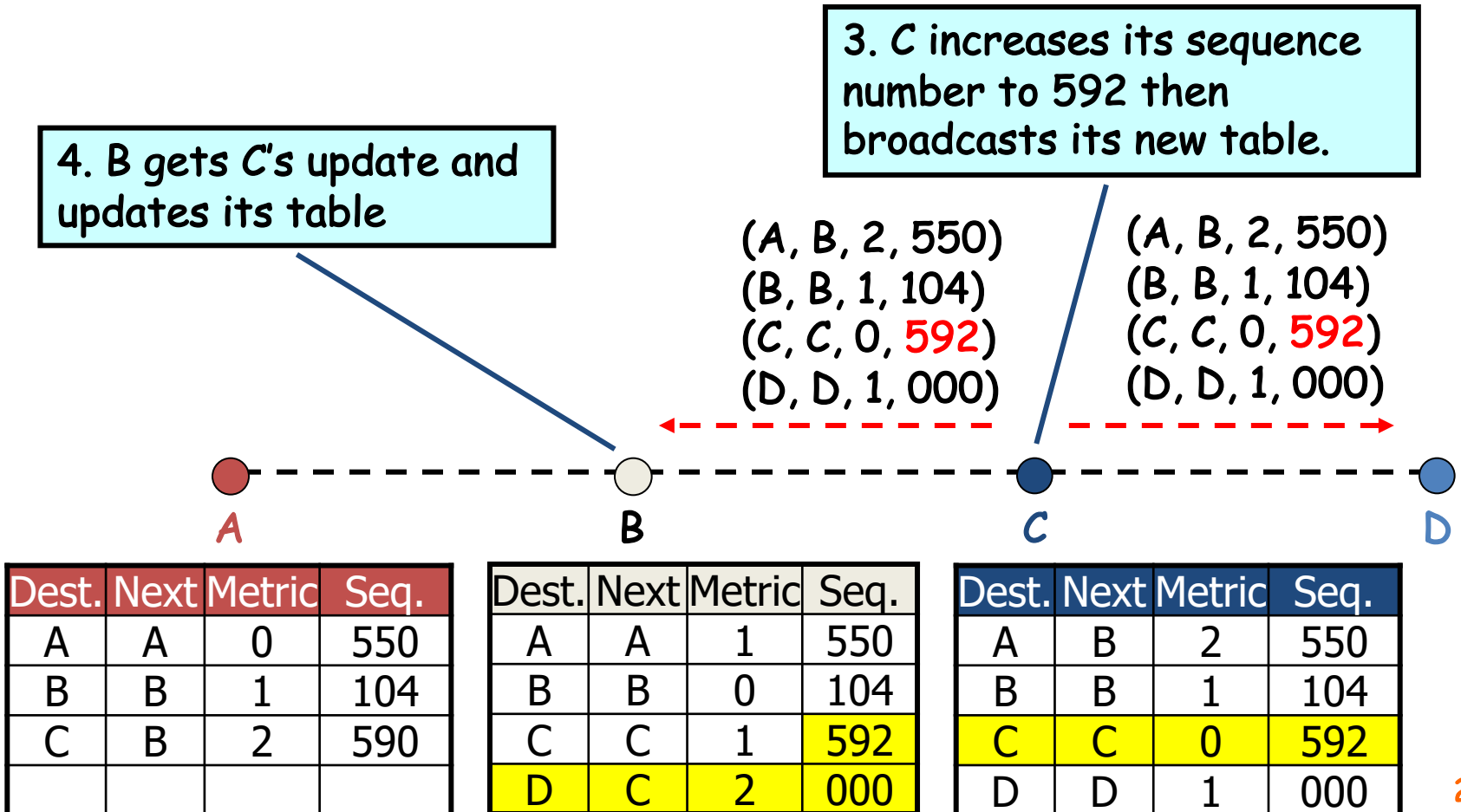
DSDV – New Node

4. B increases its own seqno and broadcasts its new table

(A, B, 1, 550)
(B, B, 0, 106)
(C, C, 1, 592)
(D, C, 2, 000)

(A, B, 1, 550)
(B, B, 0, 106)
(C, C, 1, 592)
(D, C, 2, 000)

A

B

C

D

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	106
C	B	2	592
D	B	3	000

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	106
C	C	1	592
D	C	2	000

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	106
C	C	0	592
D	D	1	000

Today

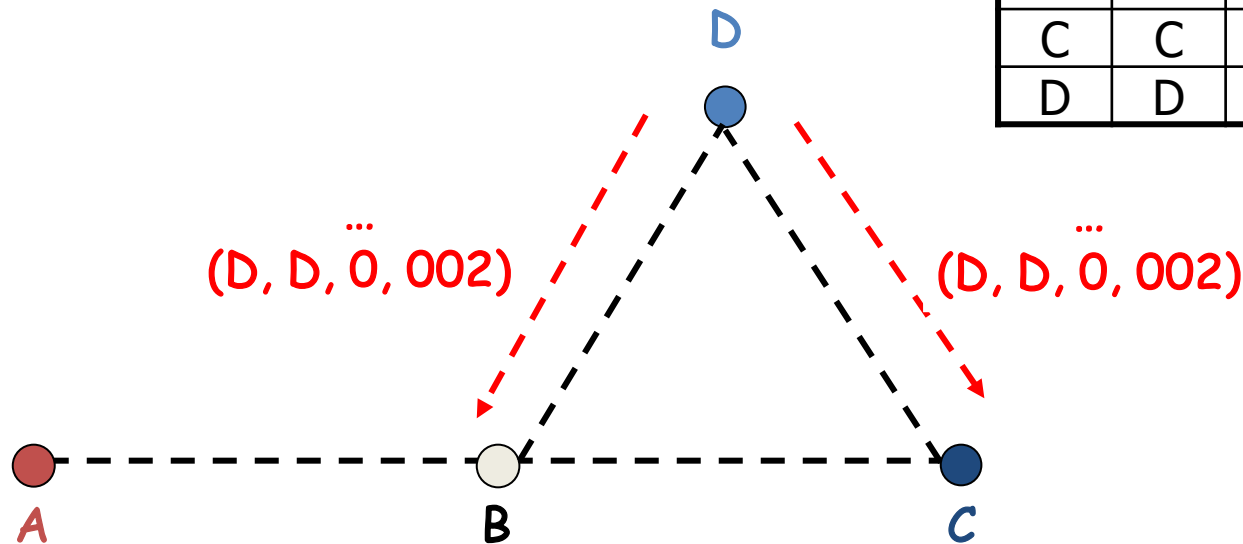1. Review Distance Vector Routing

2. **Destination Sequenced Distance-Vector Routing (DSDV)**
   – New node join
   – **Broken link**
   – Route change

3. Dynamic Source Routing (DSR)

DSDV – Broken Link

- Suppose link C ←→ D **breaks**

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	106
C	B	2	592
D	B	3	000

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	106
C	C	1	592
D	C	2	000

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	106
C	C	0	592
D	D	1	000
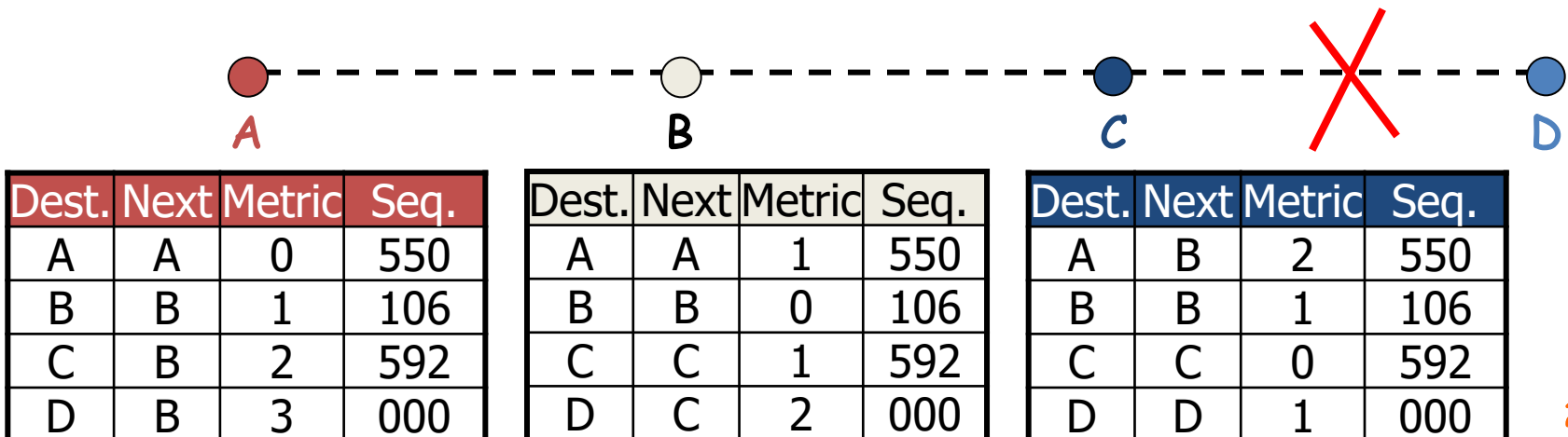
DSDV – Broken Link

1. Node C detects broken Link:
→ Increase Seq. No. by 1
(only case where not the destination sets the sequence number → odd number)
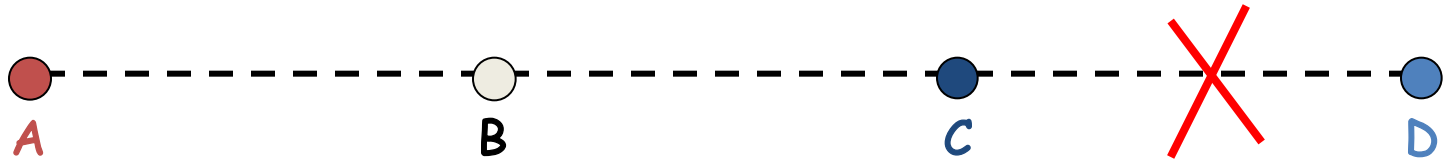
Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	106
C	B	2	592
D	B	3	000

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	106
C	C	1	592
D	C	2	000

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	106
C	C	0	592
D	D	∞	001

28

DSDV: Routing Table Update Rule

Rules to update routing table entry:

- **Node N** gets routing advertisement from neighbor **Node P**:

Dest.	Next	Metric	Seq.
E	-	-	Seq(E)

N

P
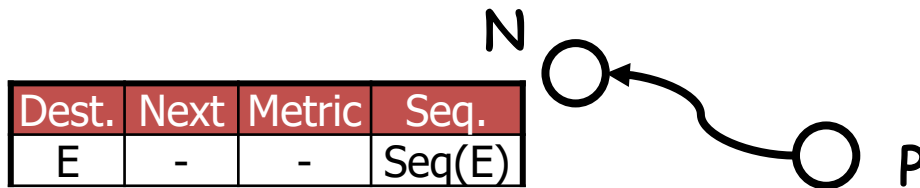
  – Update routing table entry for **node E when:**
    - Seq(E) in P's <u>advertisement</u> > Seq(E) in N's table

- B next broadcasts its routing table

> - **No effect** on <u>C's entry for D</u>
>
>   (because 000 isn't greater than 001)
>
> - No loop → **no count to infinity**
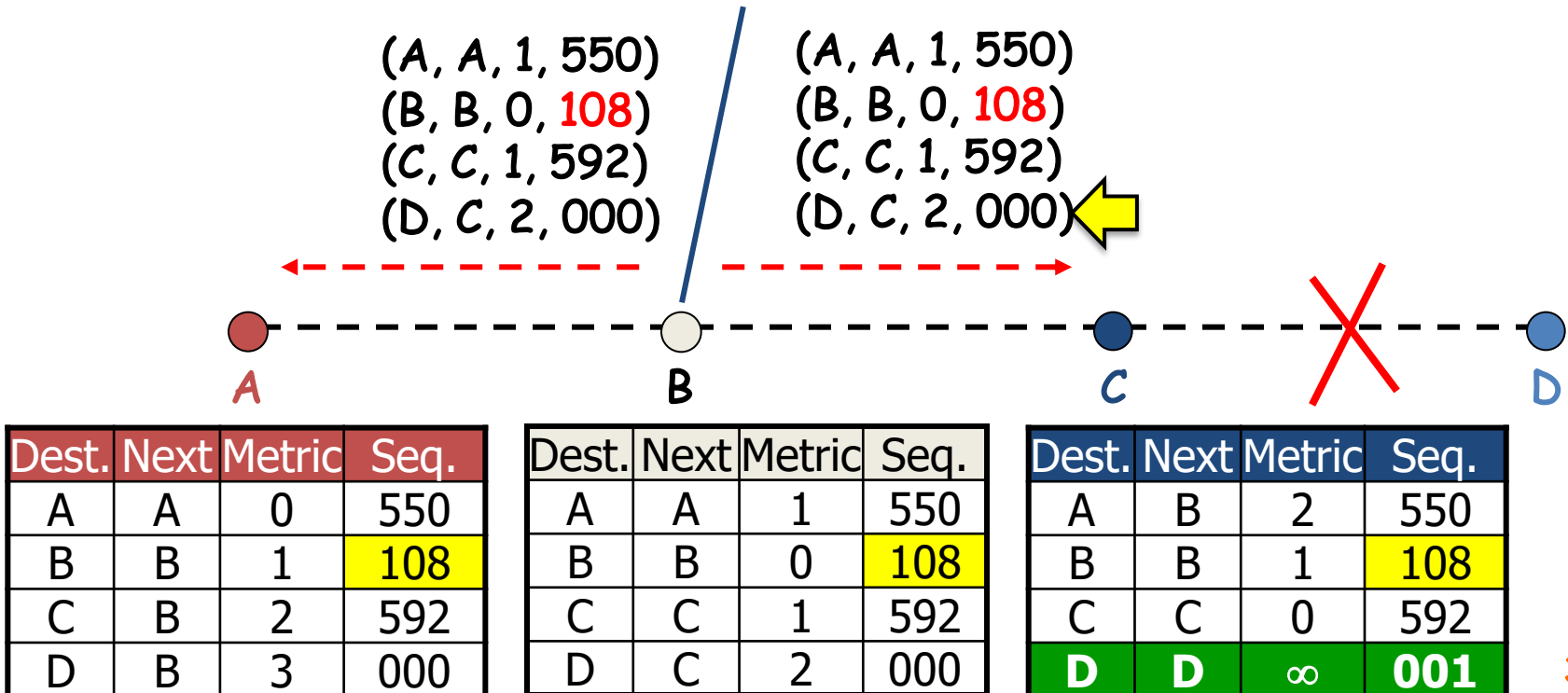
(A, A, 1, 550)
(B, B, 0, **108**)
(C, C, 1, 592)
(D, C, 2, 000)

(A, A, 1, 550)
(B, B, 0, **108**)
(C, C, 1, 592)
(D, C, 2, 000)

A

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	108
C	B	2	592
D	B	3	000

B

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	108
C	C	1	592
D	C	2	000

C

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	108
C	C	0	592
D	**D**	**∞**	**001**

30

Today

1. Review Distance Vector Routing

2. **Destination Sequenced Distance-Vector Routing (DSDV)**
    – New node join
    – Broken link
    – **Route change**

3. Dynamic Source Routing (DSR)

Distance Vector – Route Change

- D moves to another place and broadcasts its routing table

Dest.	Next	Metric	Seq.
A	C	3	550
B	C	2	108
C	C	1	592
D	D	0	002

D

(D, D, 0, 002)   (D, D, 0, 002)

A   B   C

Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	108
C	B	2	592
D	B	3	000

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	108
C	C	1	592
D	D	1	002

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	108
C	C	0	592
D	D	1	002

Distance Vector – Route Change

- **D** moves to another place and broadcasts its routing table
- **B** broadcasts its routing table

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	110
C	C	1	592
D	D	0	002

D

...
(B, B, 0, 110)

...
(B, B, 0, 110)

...
(B, B, 0, 110)

A

B

C
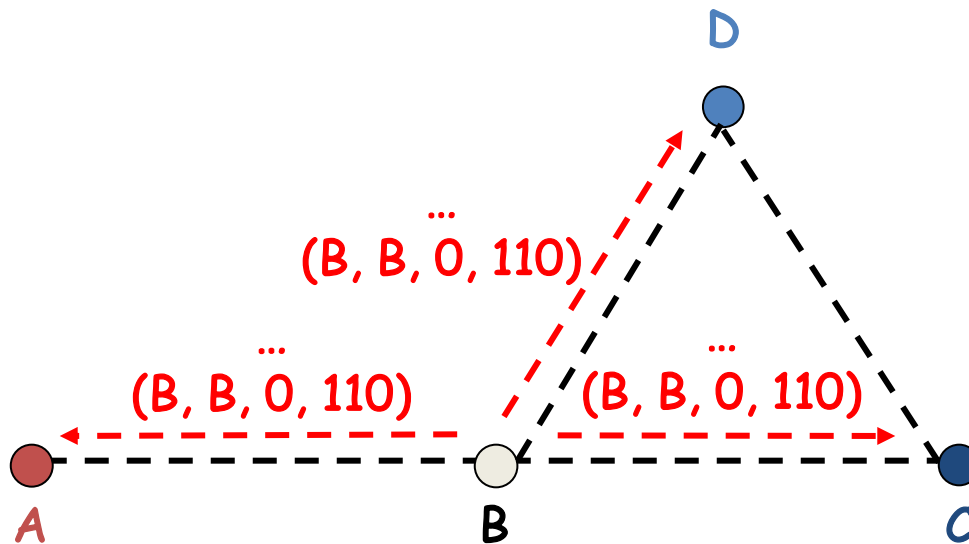
Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	110
C	B	2	592
D	B	2	002

Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	110
C	C	1	592
D	D	1	002

Dest.	Next	Metric	Seq.
A	B	2	550
B	B	1	110
C	C	0	592
D	D	1	002

Today

1. Review Distance Vector Routing

2. Destination Sequenced Distance-Vector Routing (DSDV)

3. **Dynamic Source Routing (DSR)**

Dynamic Source Routing (DSR)

- No periodic "beaconing" from all nodes

- When node **S** wants to send a packet to node **D** (but doesn't know a route to D), **S** initiates a route discovery

- S network-floods a *Route Request (RREQ)*

    - Each node appends its own id when forwarding RREQ

Route Discovery in DSR
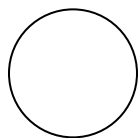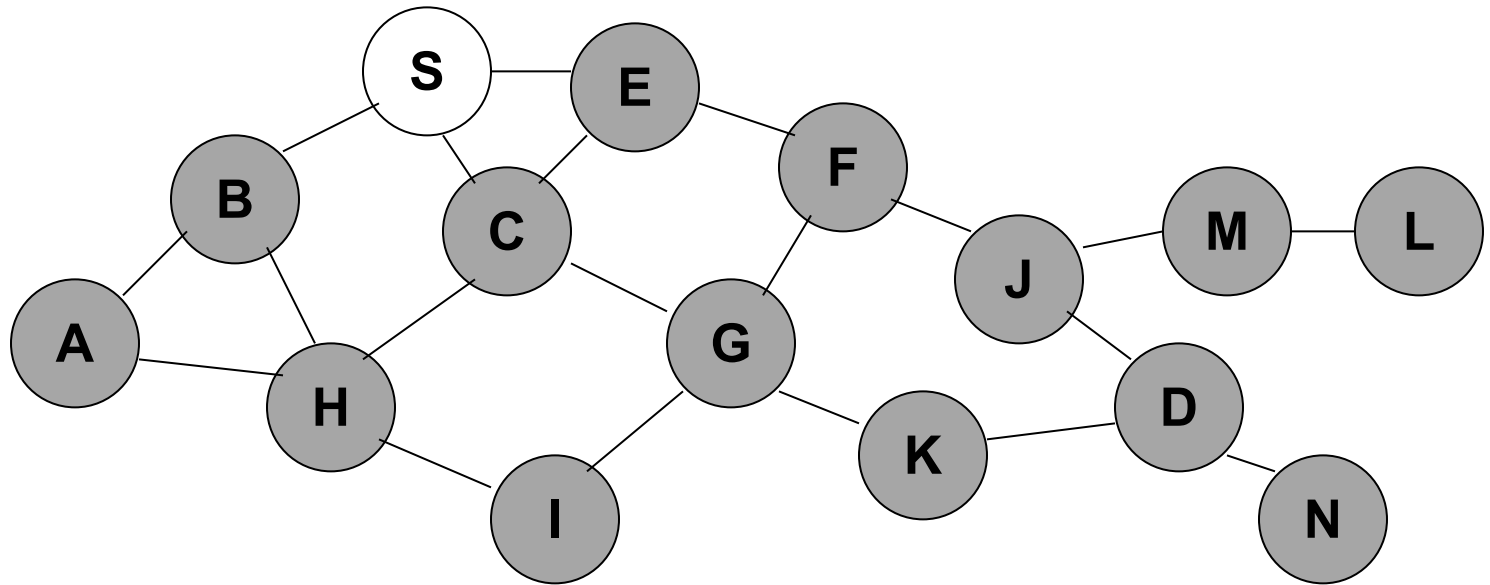
Represents a node that has received RREQ for D from S

Route Discovery in DSR

Broadcast transmission
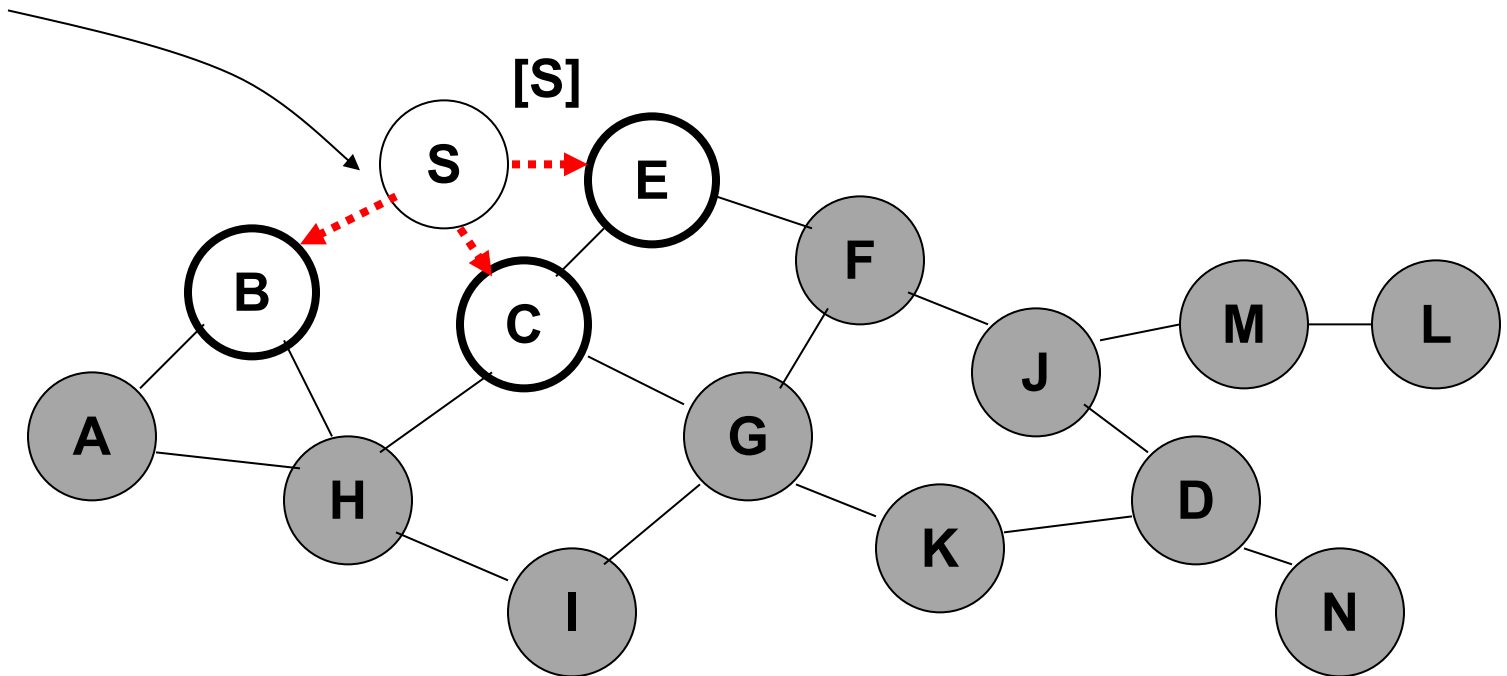
[S]

Represents transmission of RREQ

[X,Y]   **Represents list of identifiers appended to RREQ**

Route Discovery in DSR
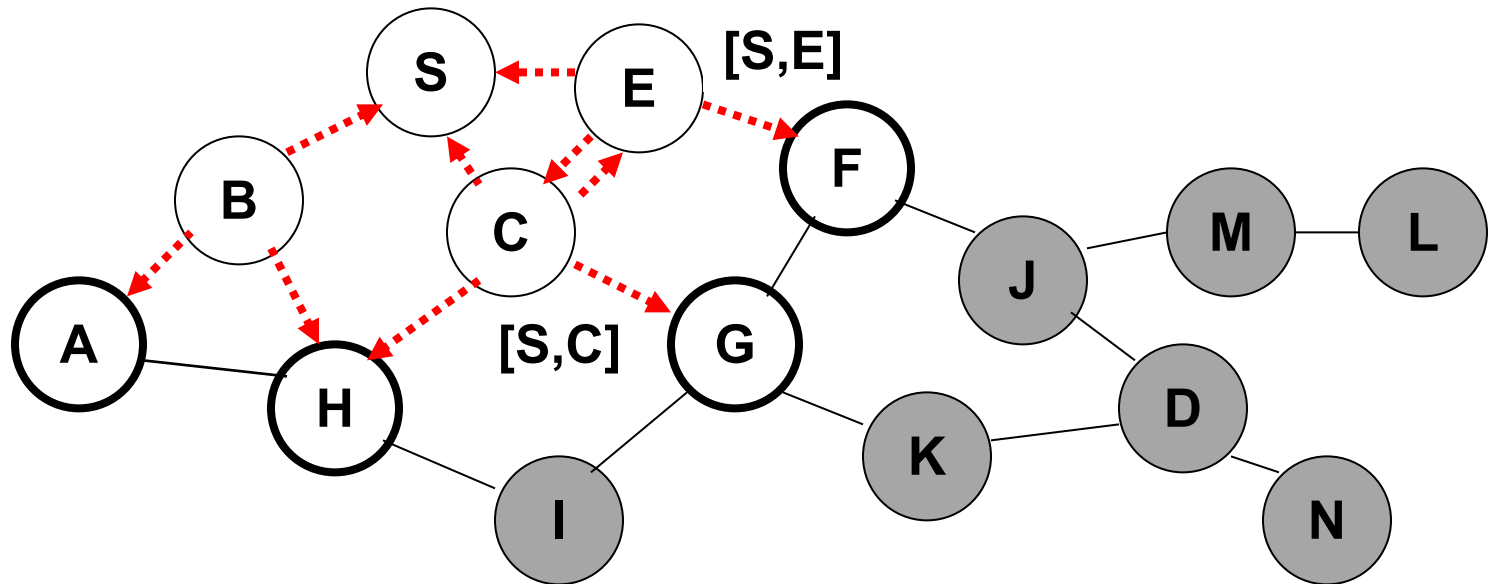
------> **Represents transmission of RREQ**

[X,Y] **Represents list of identifiers appended to RREQ**

Route Discovery in DSR
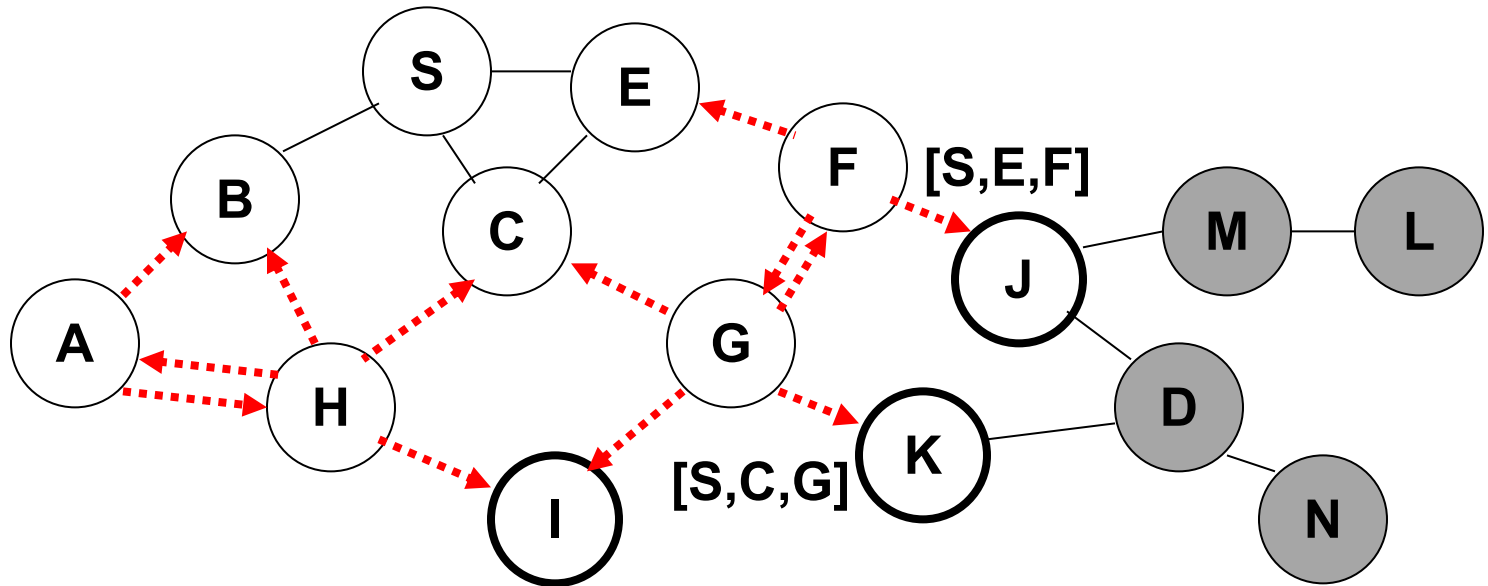
·····▶ **Represents transmission of RREQ**

• **Node C receives RREQ from G and H, but does not forward it again, because node C has already forwarded RREQ once**

Route Discovery in DSR
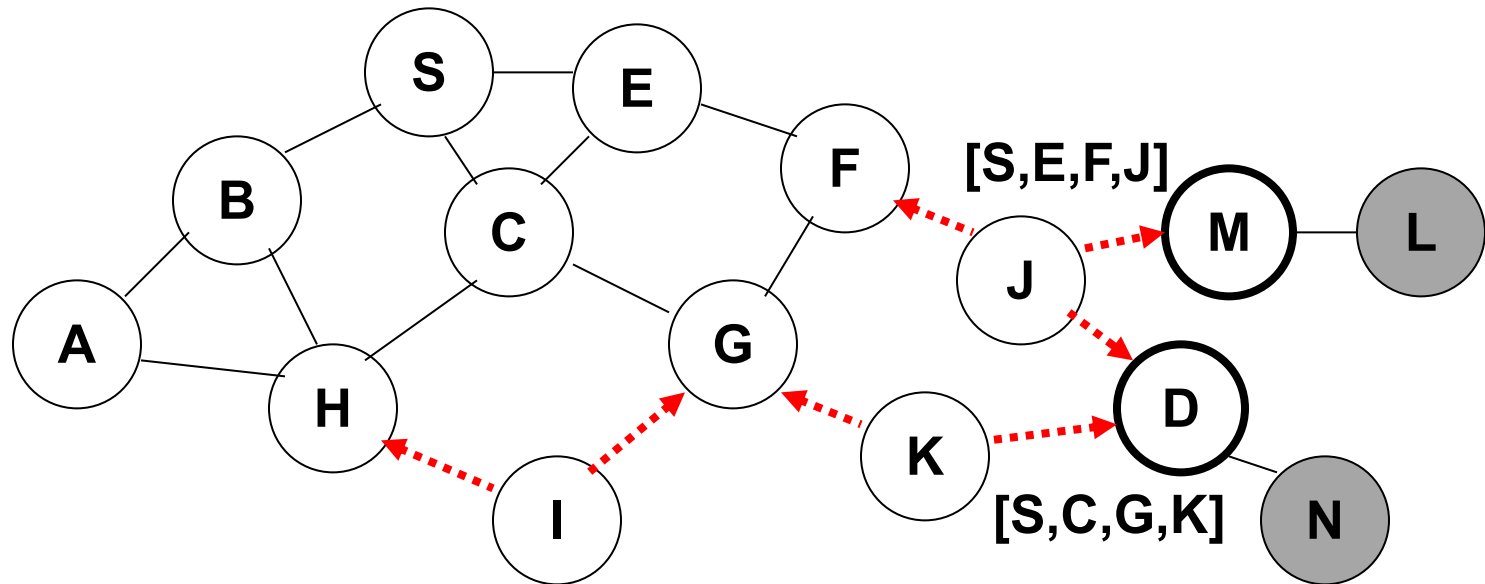
·······▶ **Represents transmission of RREQ**

- **Nodes J and K both broadcast RREQ to node D**
- **Since nodes J and K are hidden from each other, their transmissions may collide**

Route Discovery in DSR
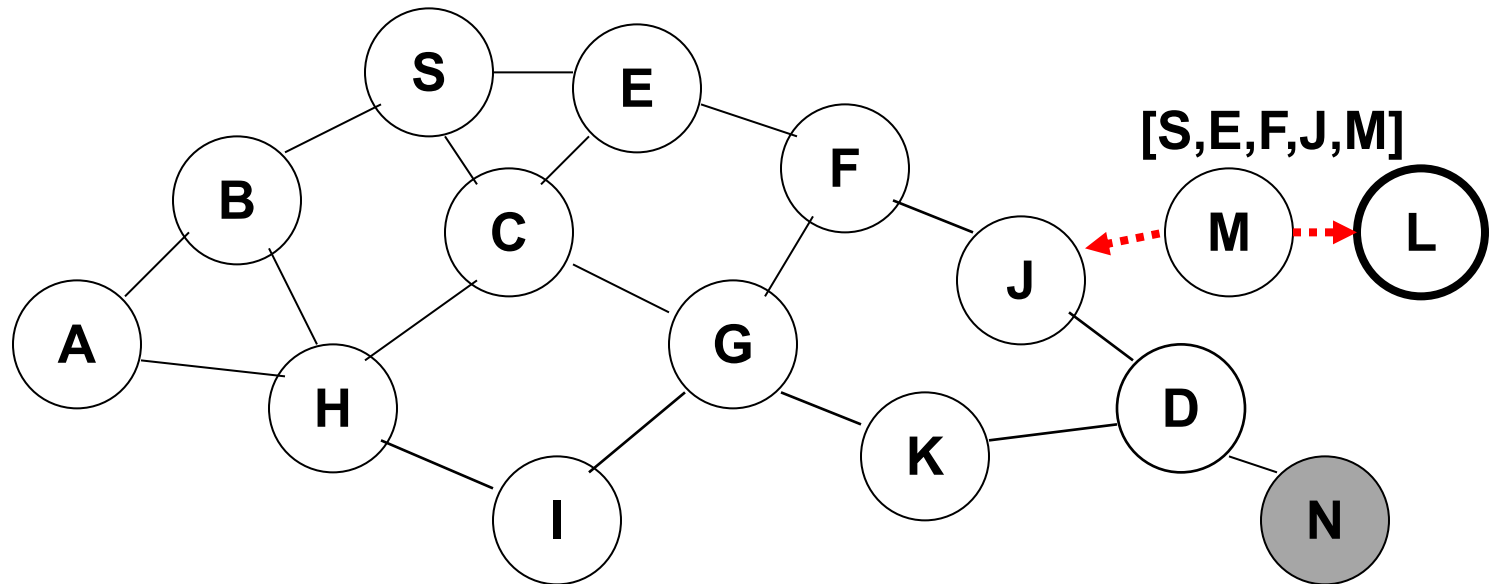
Represents transmission of RREQ

- Node D **does not forward** RREQ, because node D is the **intended target** of the route discovery

Route Reply in DSR

- On receiving **first** RREQ, D sends a *Route Reply* (RREP)
  - RREP sent on route obtained by **reversing** the route in the received RREQ
  - RREP **includes the route** from **S** to **D** over which D received the RREQ

RREP [S,E,F,J,D]

← Represents RREP control message
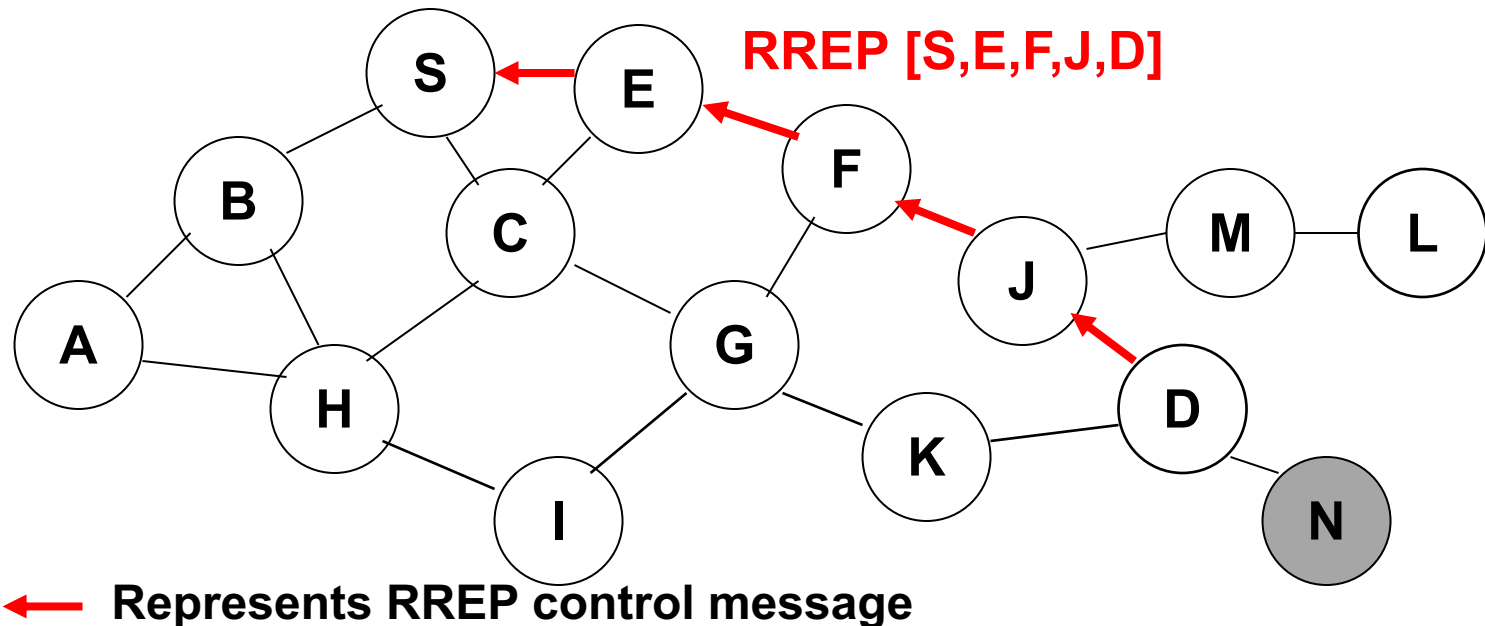
Dynamic Source Routing (DSR)

- On receiving RREP, **S** caches route included therein
- When **S** sends a data packet to **D**, includes entire route in packet header
- Intermediate nodes use the source route included in packet to determine to whom packet should be forwarded

DATA [S,E,F,J,D]
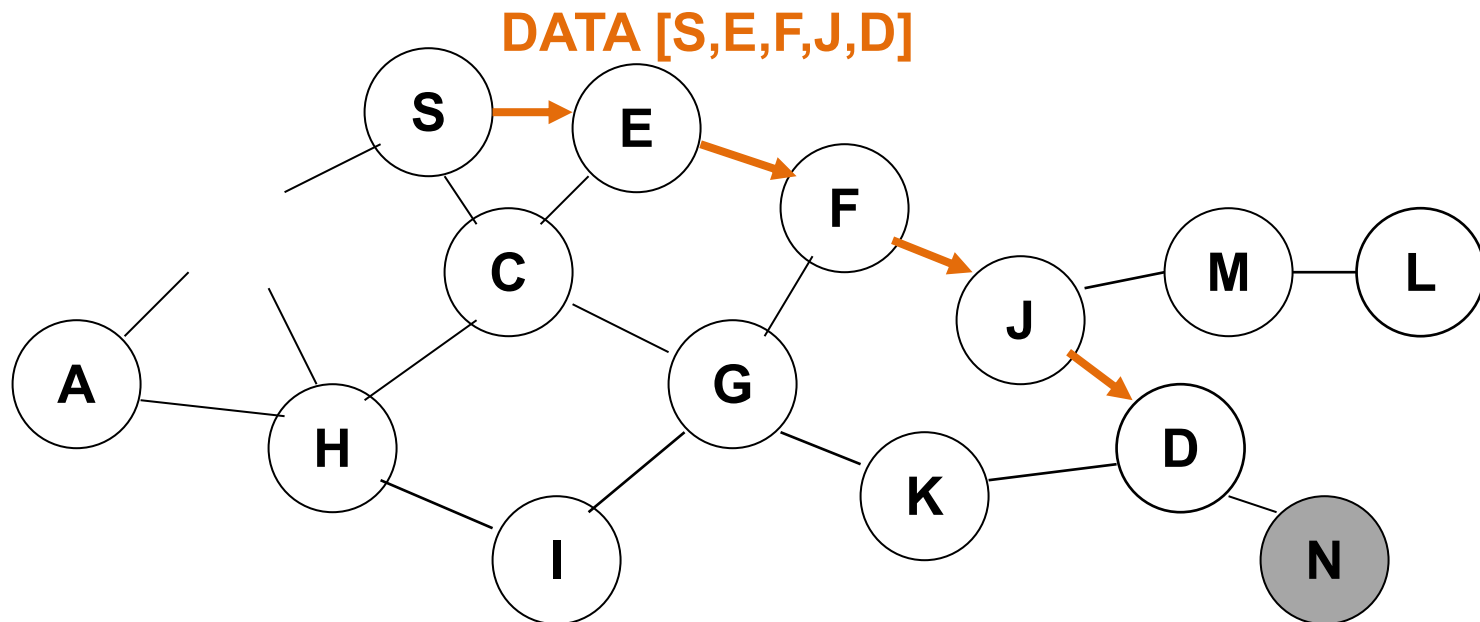
Summary

- DV reacts poorly to link failures, which are frequent in wireless

- DSDV is a proactive routing protocol, DSR reactive

- Enable wireless mesh routing, w/appl. in recent/future
  - Home mesh products
  - Satellite internet service providers
  - Balloon/UAV internet service providers

This week's precepts:
5G Wireless!

Next few lectures' topic:
Security