Wireless Networks II: Mesh Network Routing

COS 461: Computer Networks
Lecture 18

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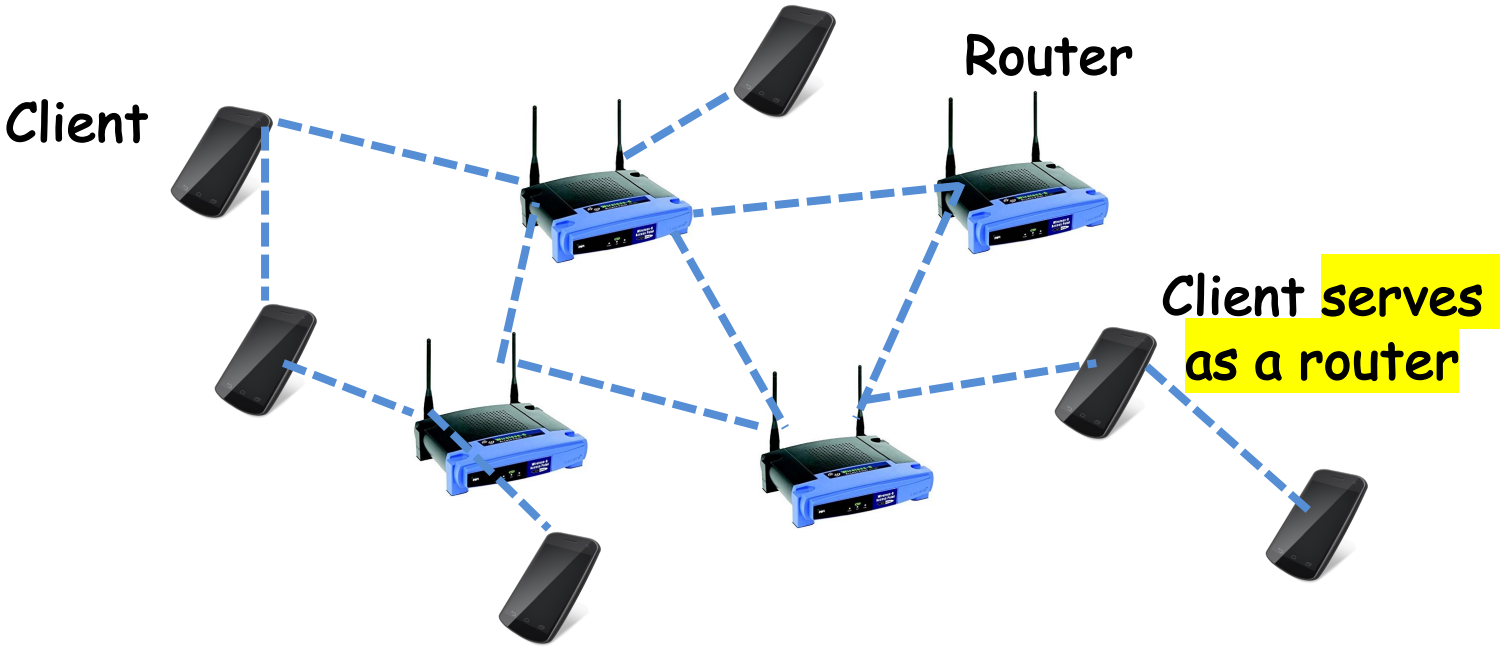
[Parts adapted from I. F. Akyildiz, B. Karp]

Wireless Mesh Networks: Motivation

- Most wireless network traffic goes through **APs**
- Mesh networks **remove this restriction**
  - **Multiple paths** between most pairs: **Mesh topology**
- **Big Impact:** **Home Mesh, Satellite/Balloon Internet**



Today

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

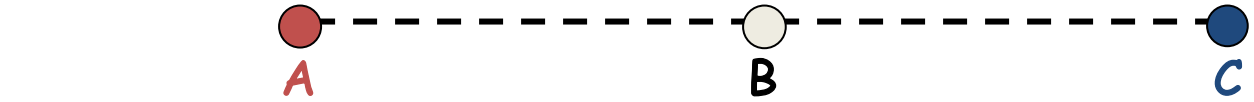
2. Destination Sequenced Distance-Vector Routing (DSDV)

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



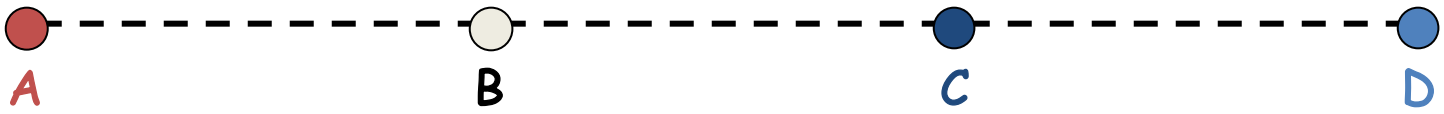
Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

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



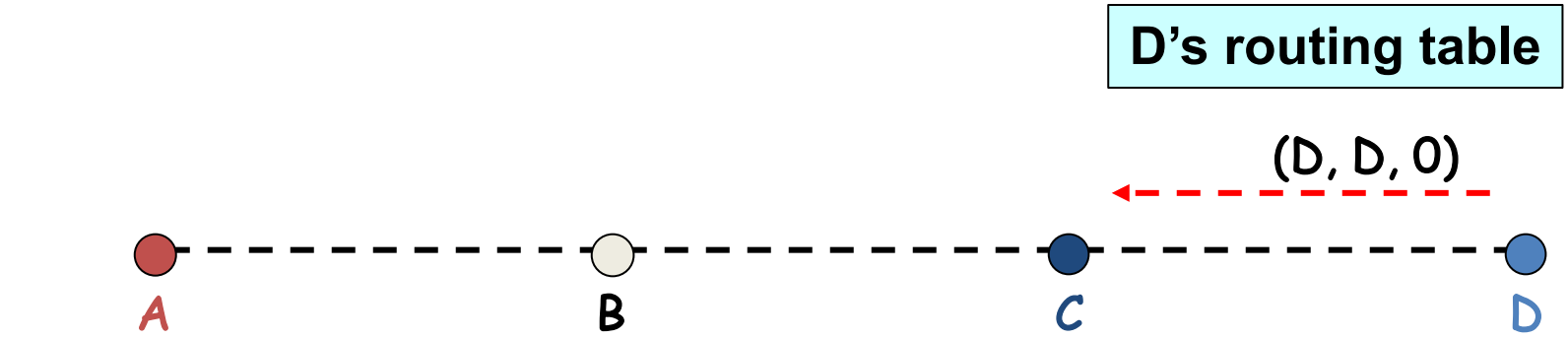
Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

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



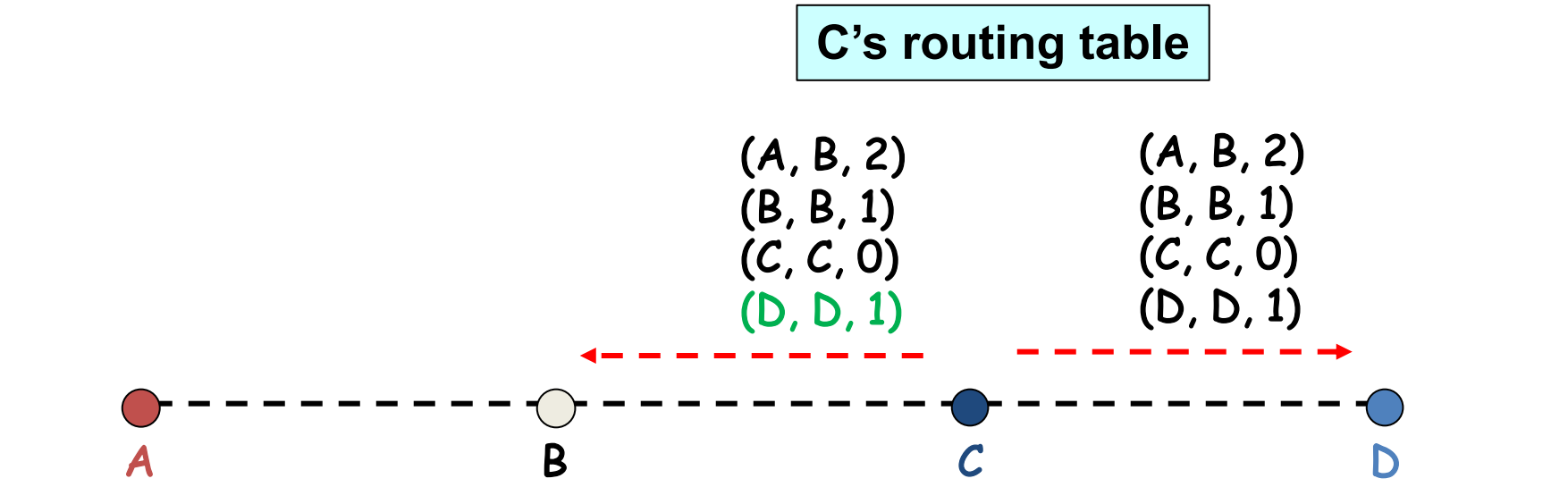
Dest.	Next	Metric
A	A	0
B	B	1
C	B	2

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

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

Distance Vector – New Node Join

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



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

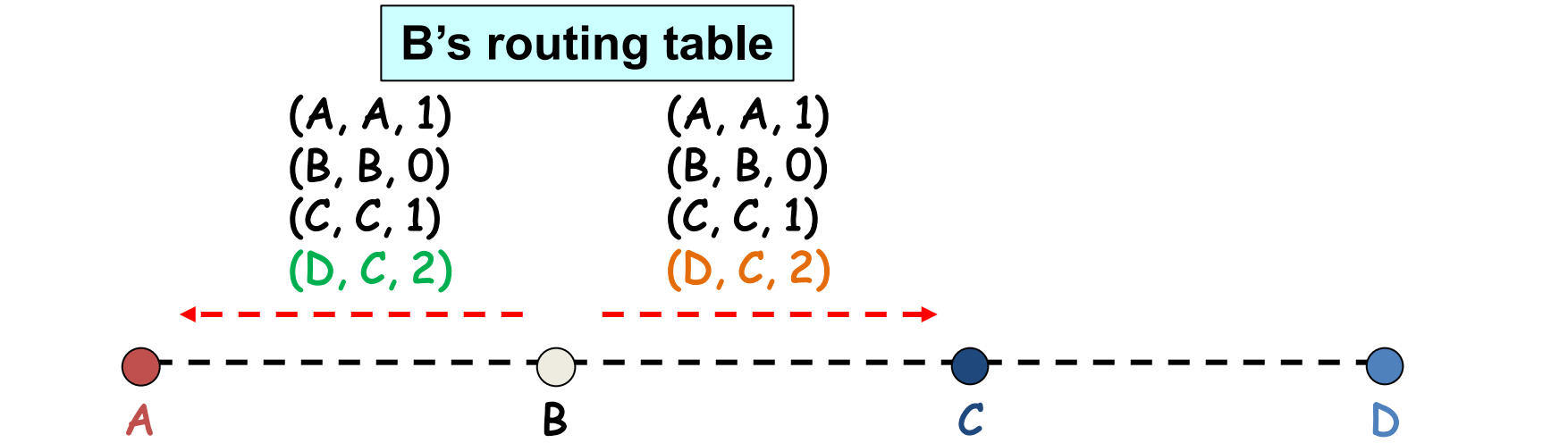
Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	C	2

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



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

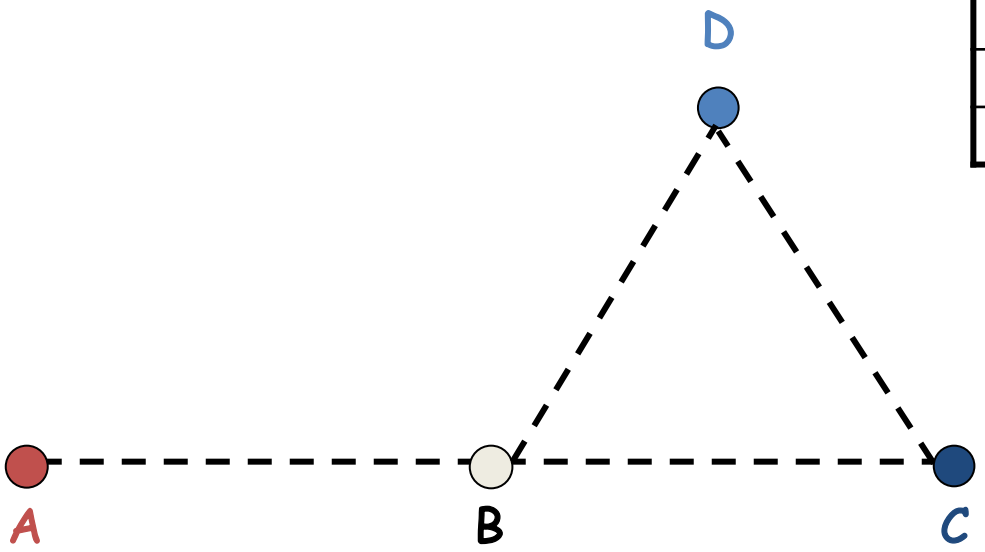
2. Destination Sequenced Distance-Vector Routing (DSDV)

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

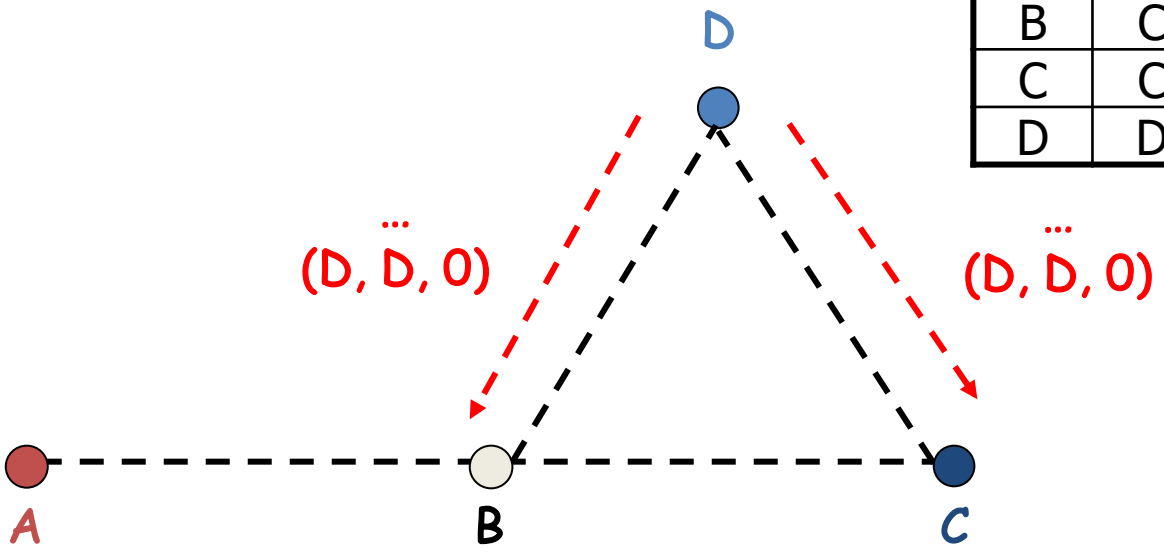
Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	C	2

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



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

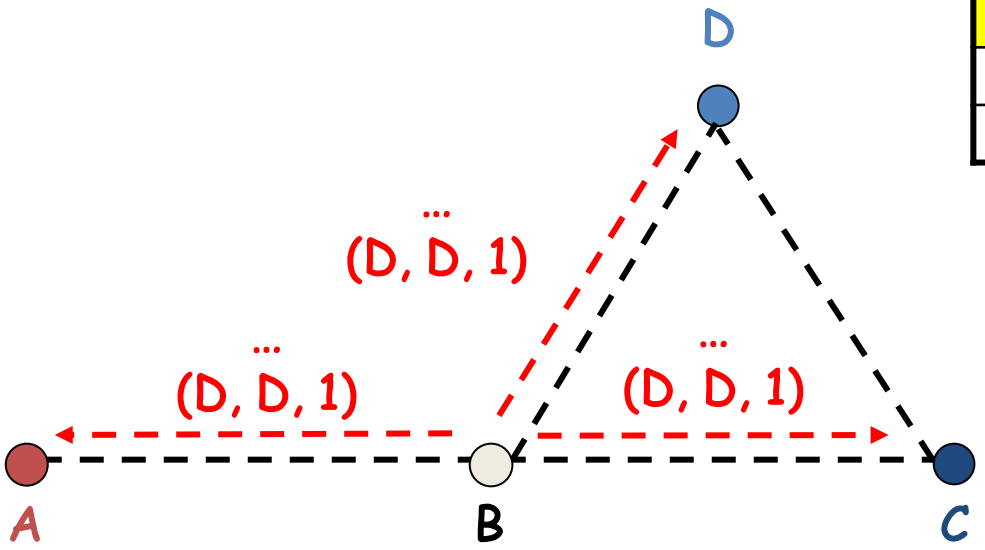
Dest.	Next	Metric
A	A	1
B	B	0
C	C	1
D	D	1

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



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

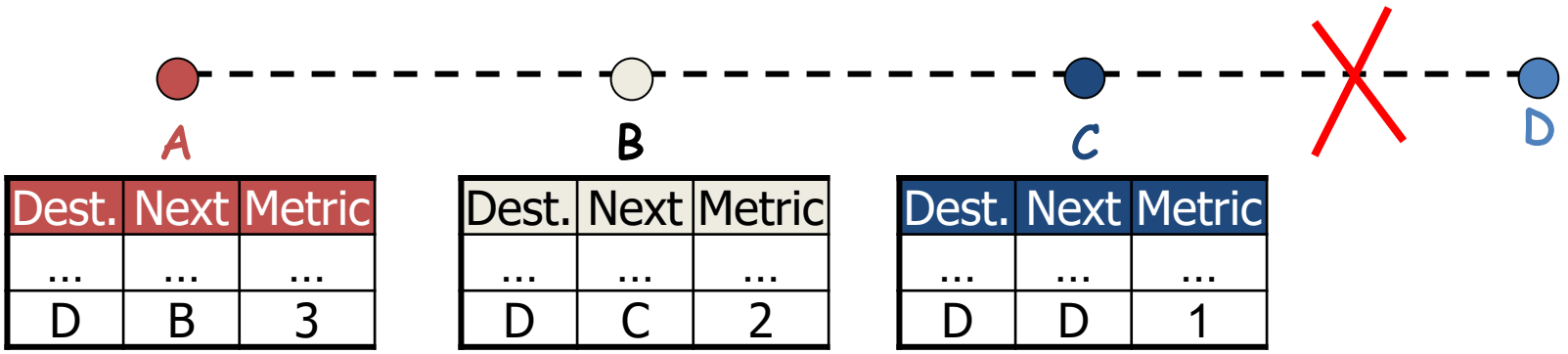
1. **Review Distance Vector Routing**
   - New node join
   - Route changes
   - **Broken link**

2. Destination Sequenced Distance-Vector Routing (DSDV)

3. Dynamic Source Routing (DSR)

Distance Vector – Broken Link

- Suppose link C ←→ D breaks



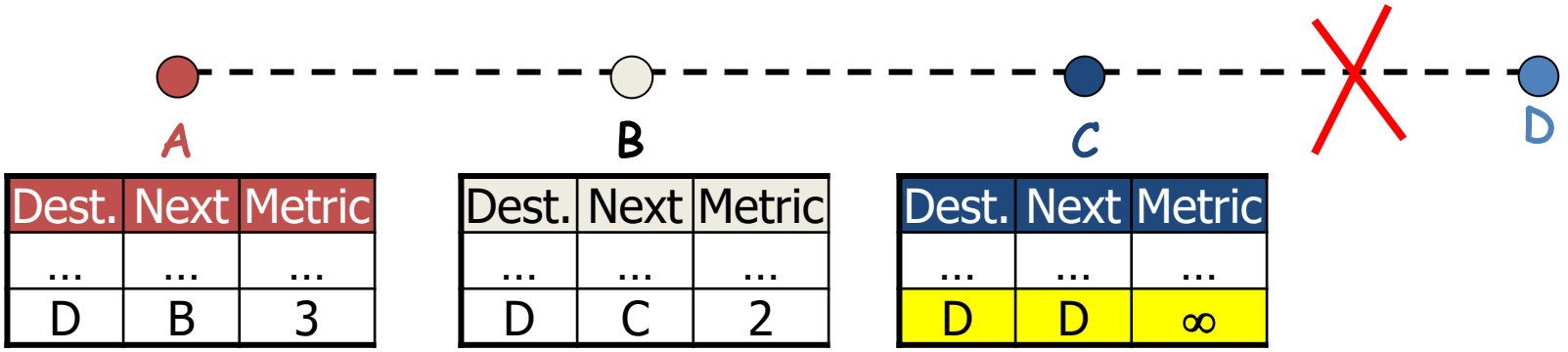
Dest.	Next	Metric
...	...	...
D	B	3

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

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

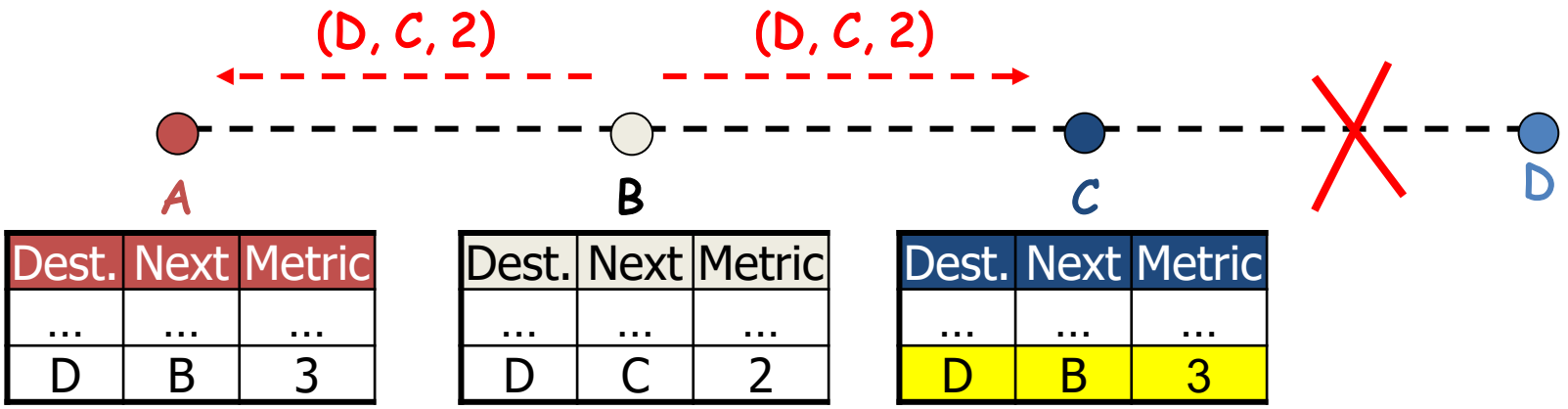
Distance Vector – Broken Link

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



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 < ∞)



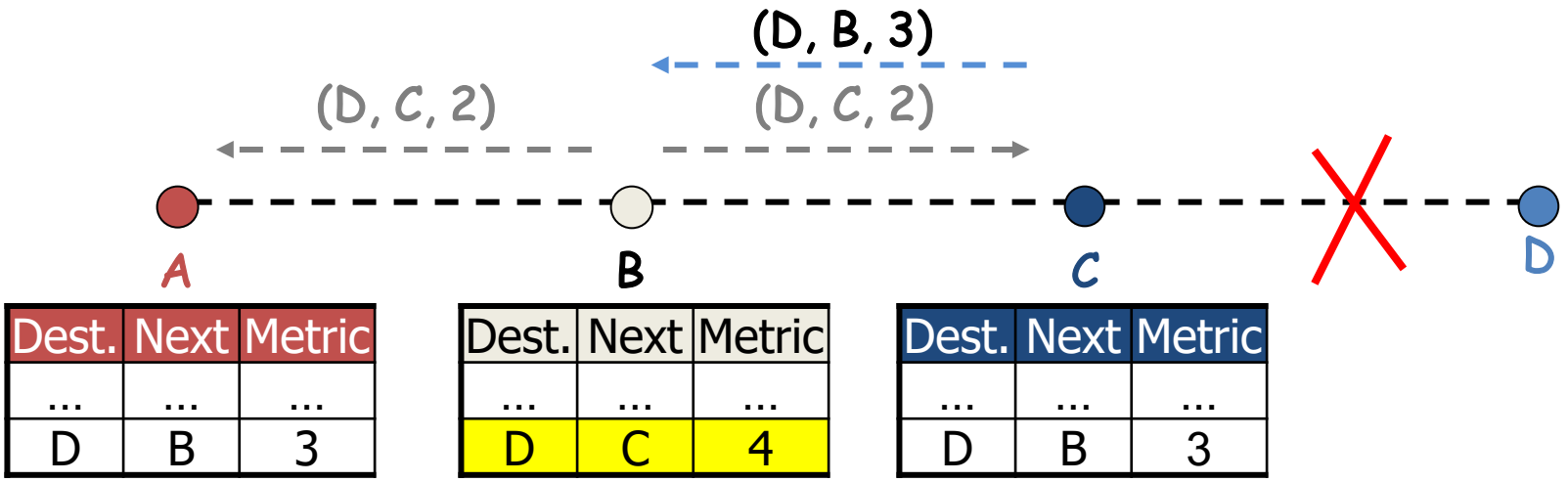
Dest.	Next	Metric
...	...	...
D	B	3

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

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*)



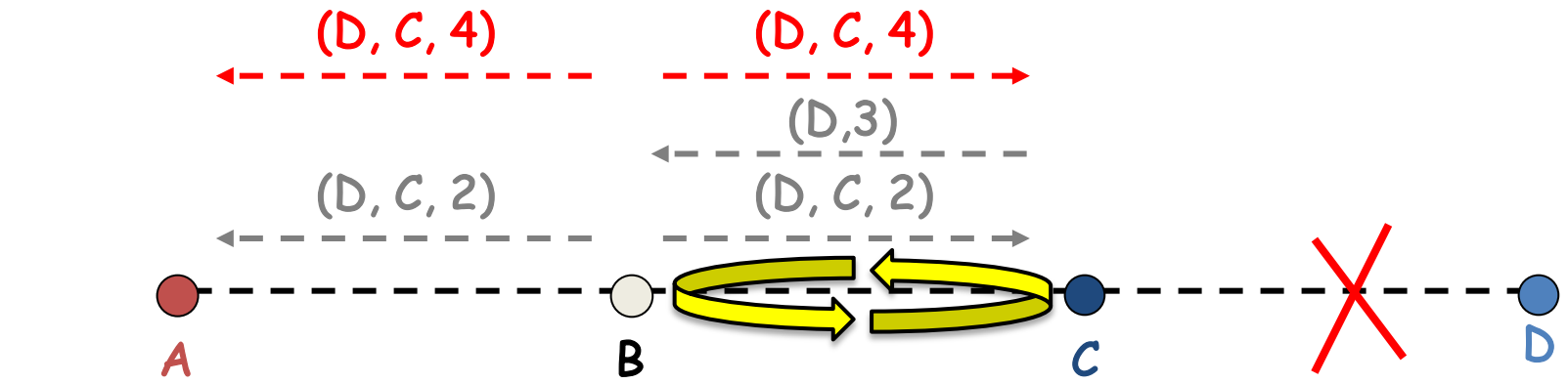
Dest.	Next	Metric
...	...	...
D	B	3

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

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

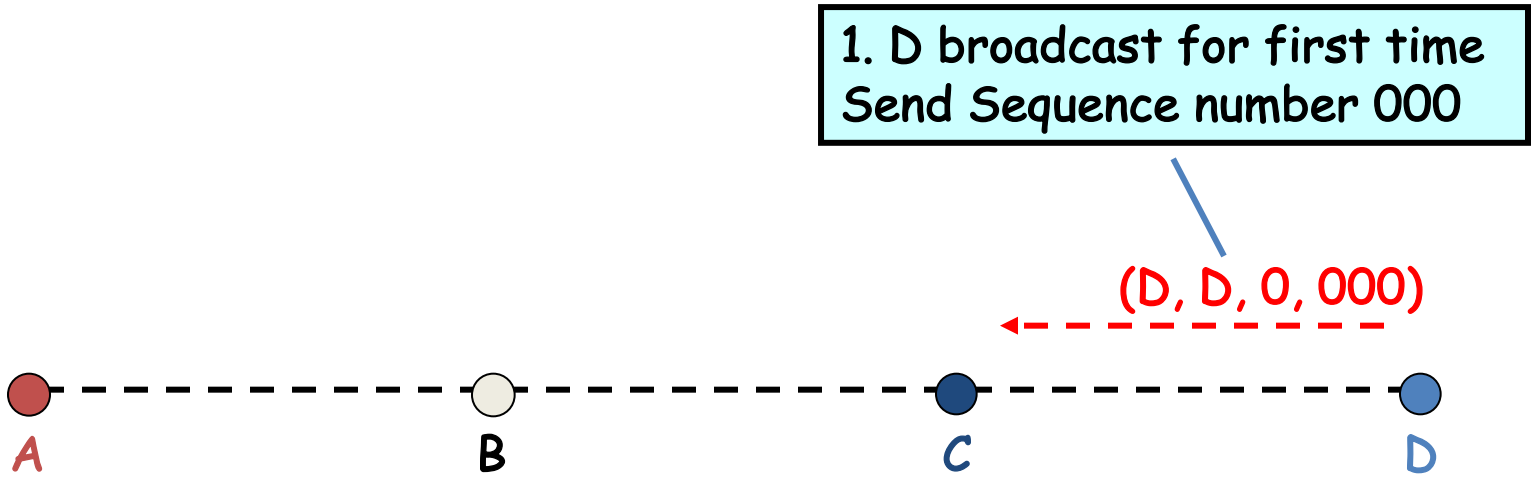
Rules to set sequence number:

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

- Node N thinks neighbor P is no longer directly reachable
  - Node N sets:
    - Seq(P) ← Seq(P) + 1
    - Metric(P) ← ∞

DSDV – New Node

- D joins the network
- D's broadcast first updates C's table w/ new entry for D

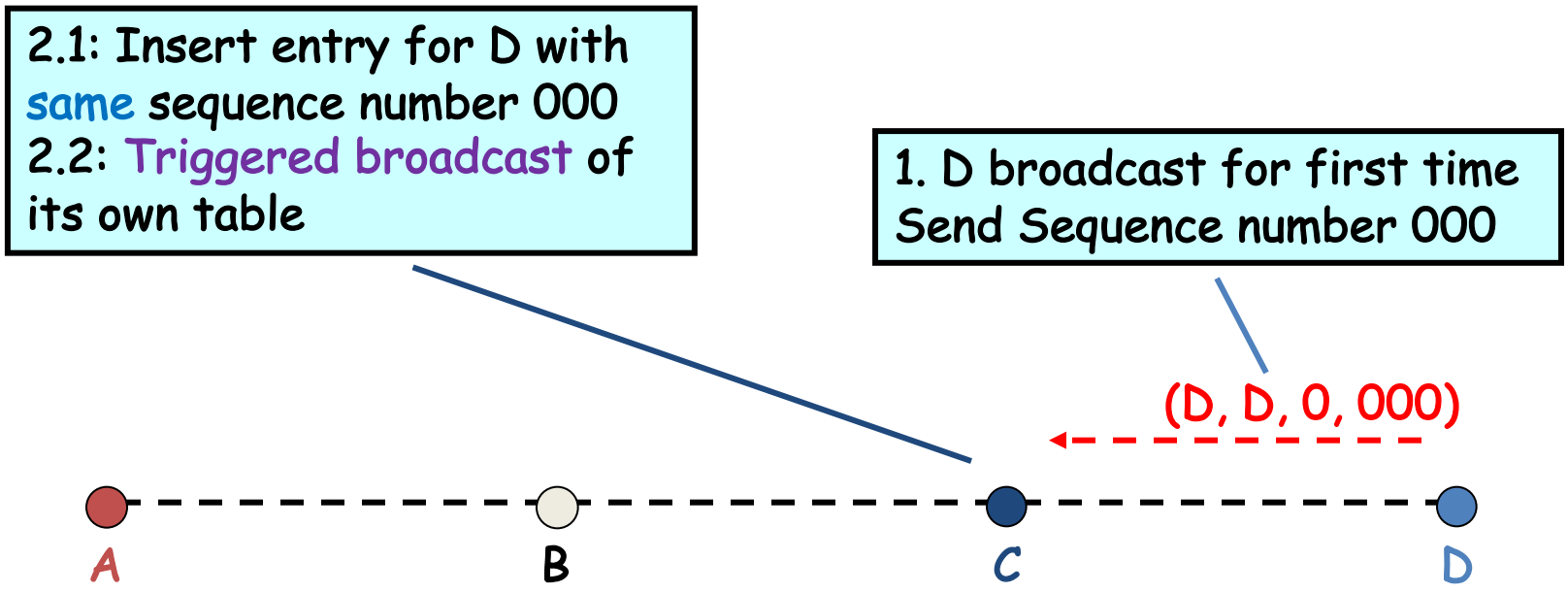


Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	104
C	B	2	590

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

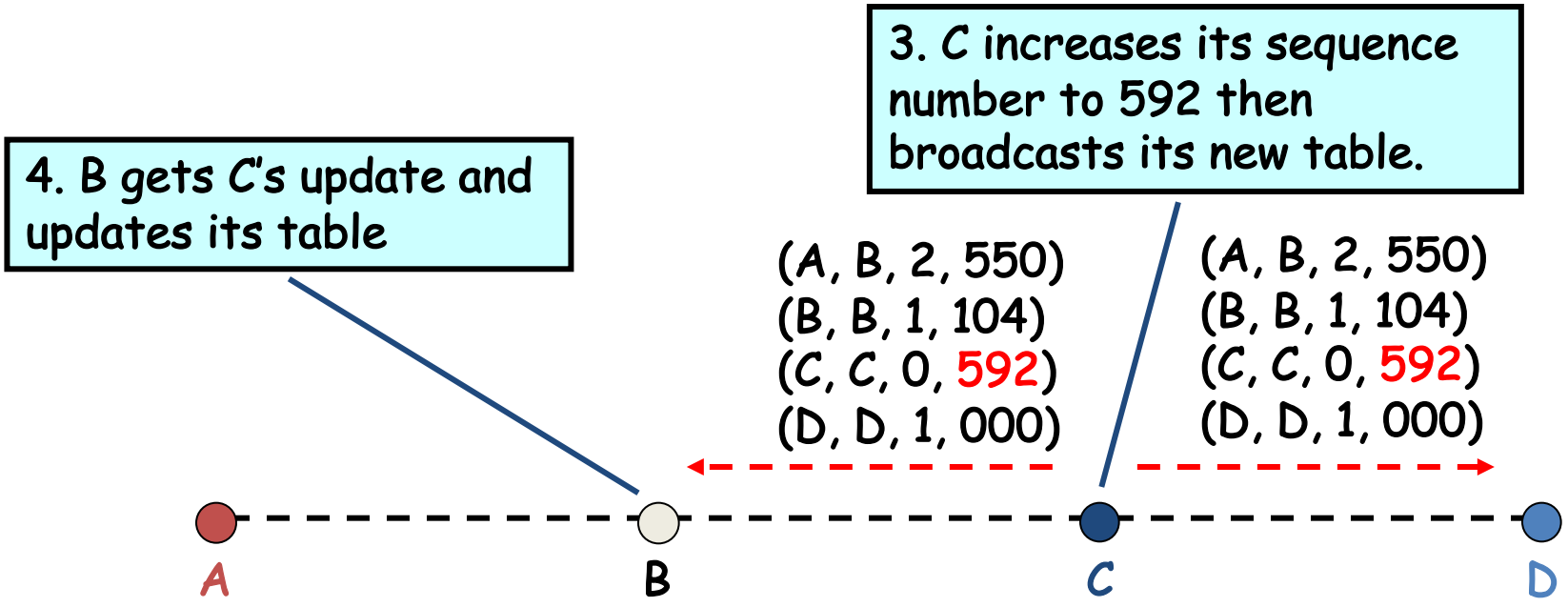


Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	104
C	B	2	590

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

DSDV – New Node



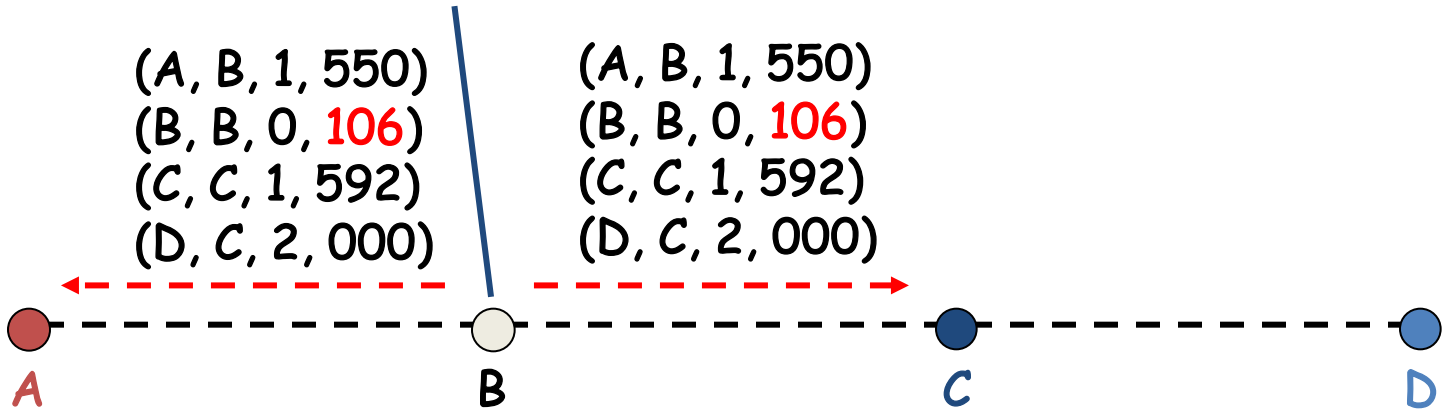
Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	104
C	B	2	590

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

DSDV – New Node

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



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

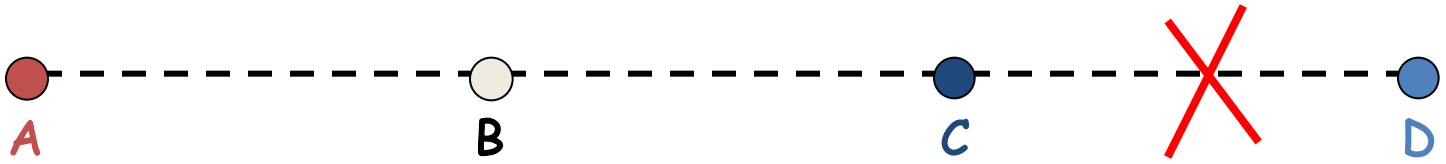
1. Review Distance Vector Routing

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



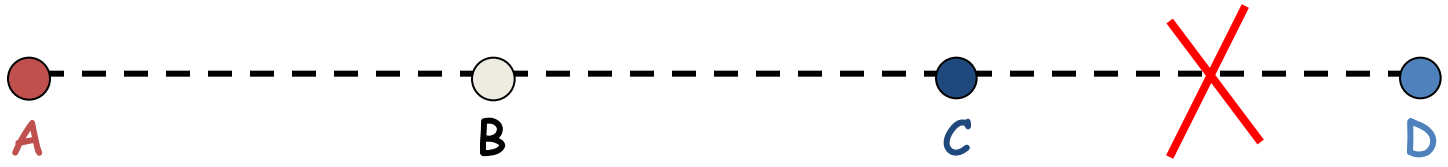
Dest.	Next	Metric	Seq.
A	A	0	550
B	B	1	106
C	B	2	592
D	B	3	000

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

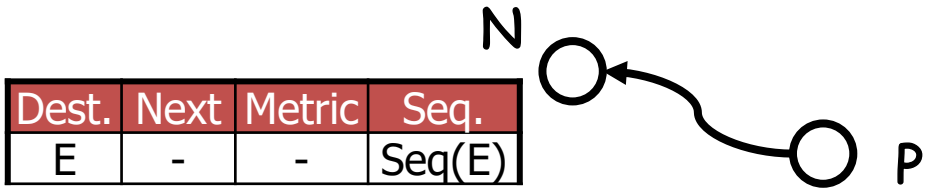
Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	106
C	C	1	592
D	C	2	000

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

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)

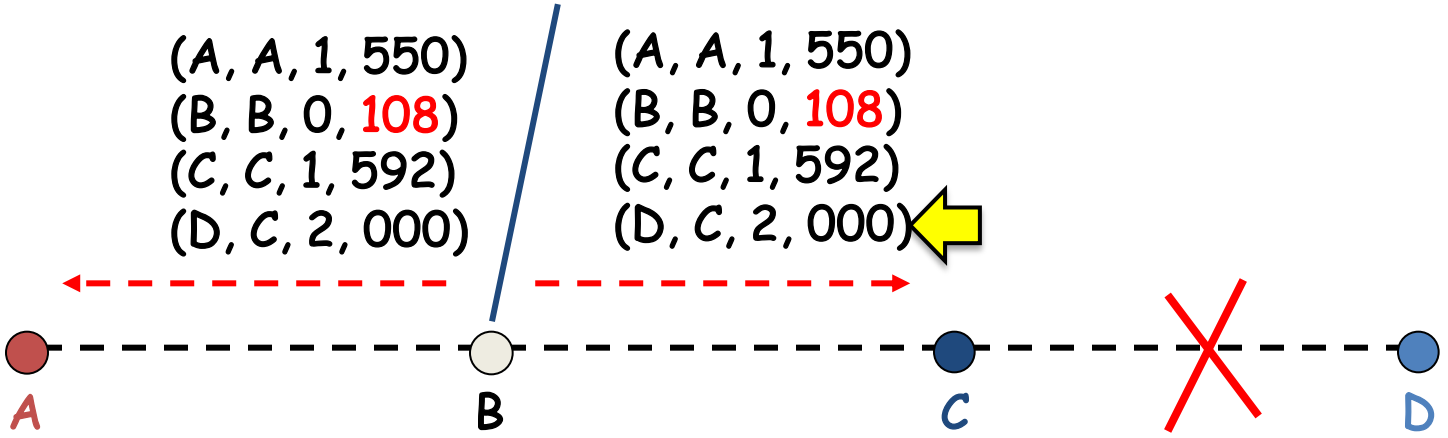
  - Update routing table entry for **node E when**:
    - **Seq(E) in P's advertisement > Seq(E) in N's table**

DSDV – Broken Link

- B next broadcasts its routing table

- No effect on C's entry for D

  (because 000 isn't greater than 001)
- No loop → no count to infinity



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	C	2	000

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

Today

1. Review Distance Vector Routing

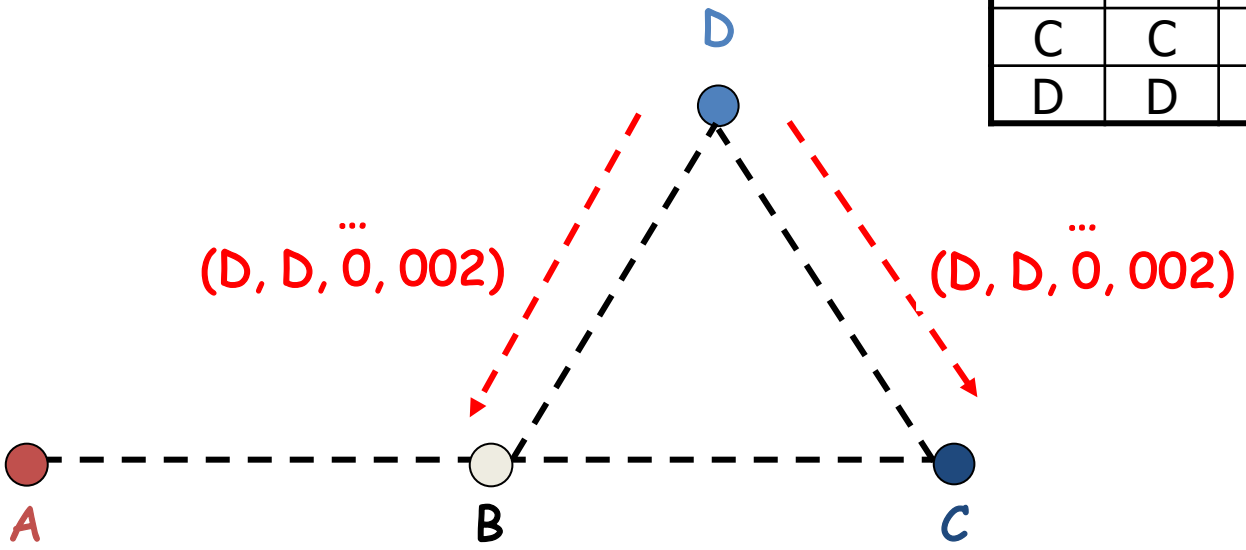
2. **Destination Sequenced Distance-Vector Routing (DSDV)**
   - New node join
   - Broken link
   - **Route change**

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



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

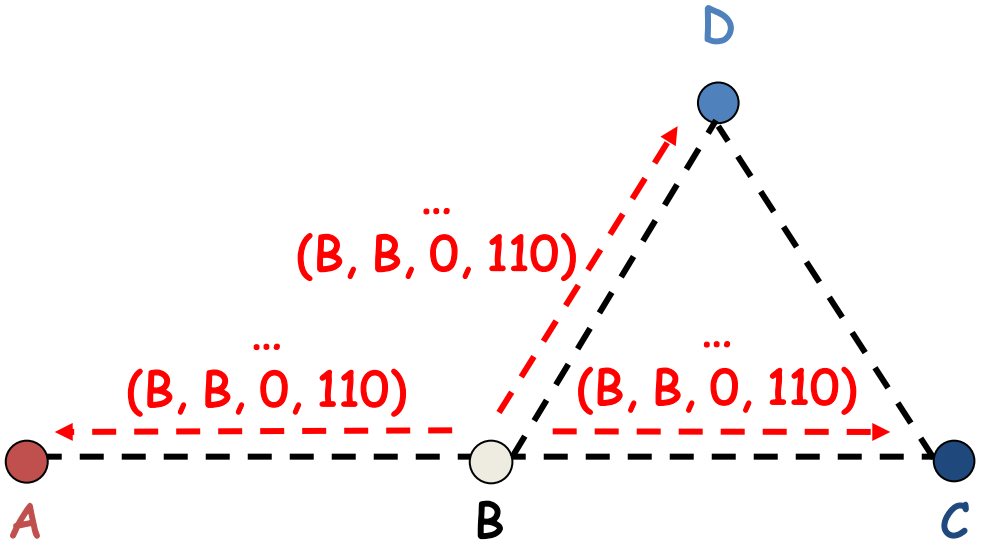
Dest.	Next	Metric	Seq.
A	A	1	550
B	B	0	108
C	C	1	592
D	D	1	002

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



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

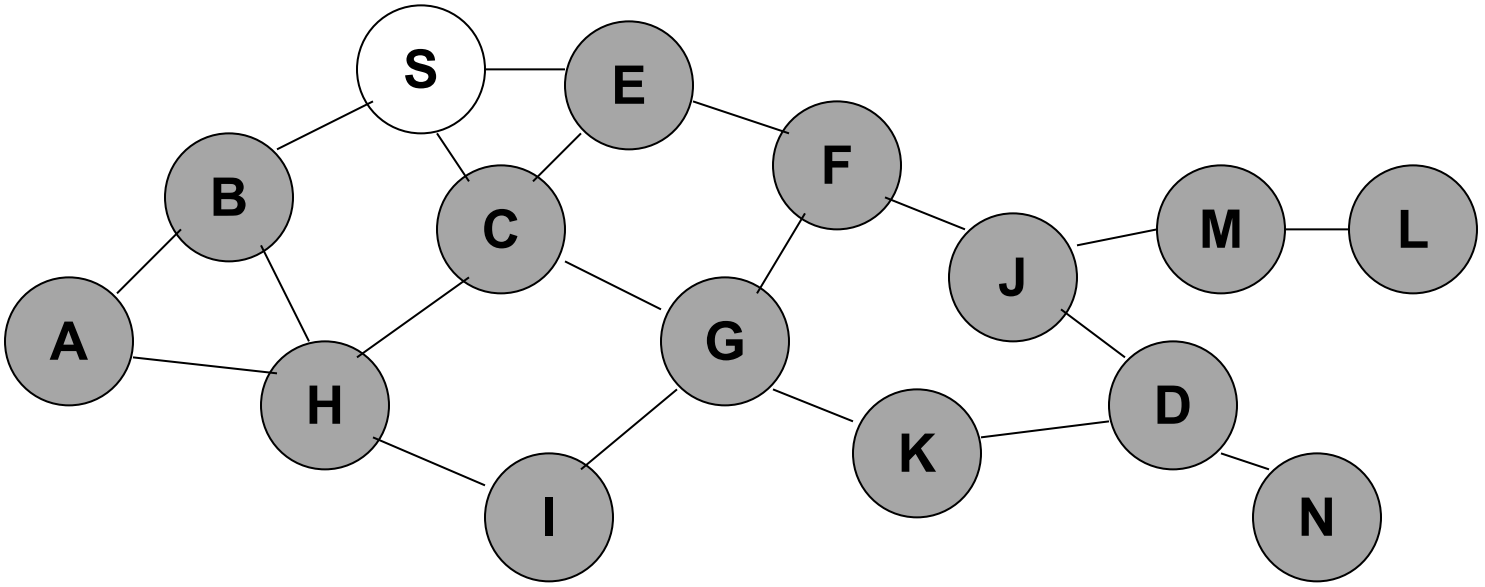
Today

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

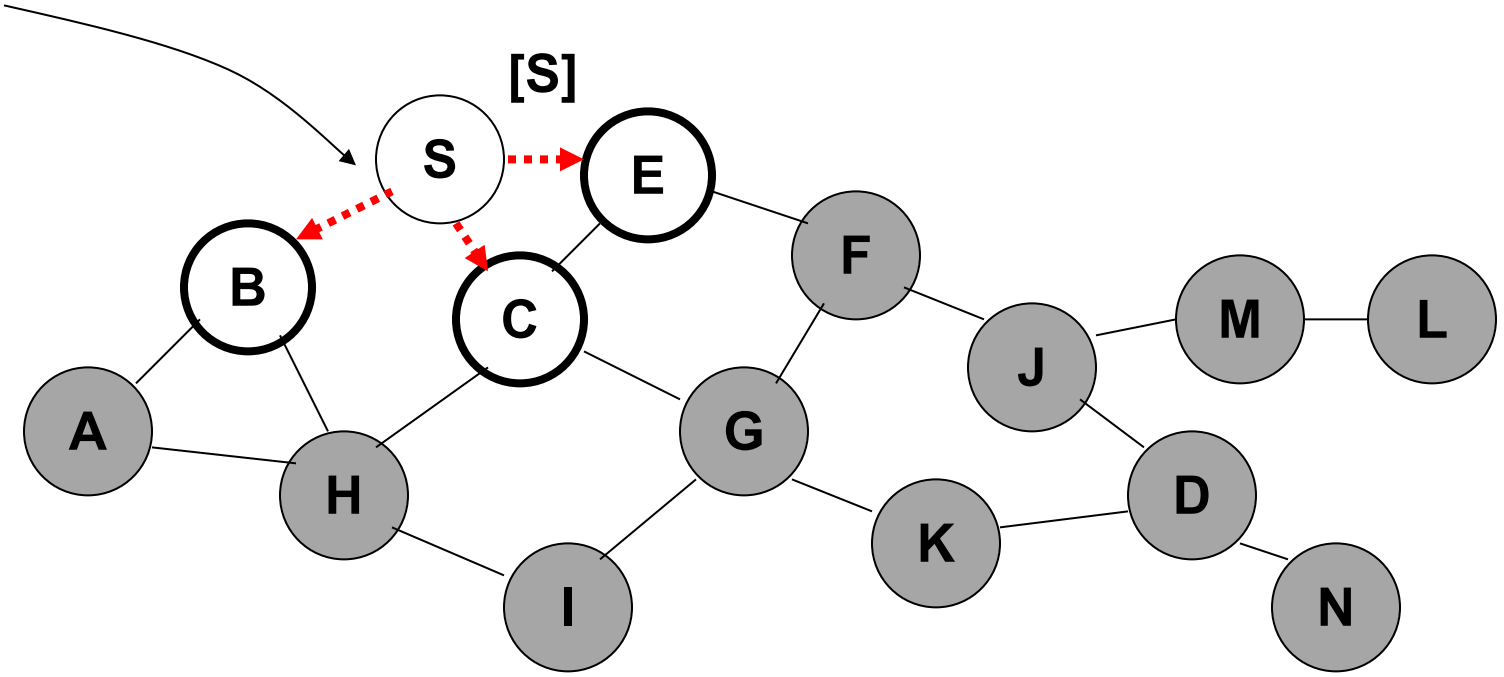
Route Discovery in DSR



Represents a node that has received RREQ for D from S

Route Discovery in DSR

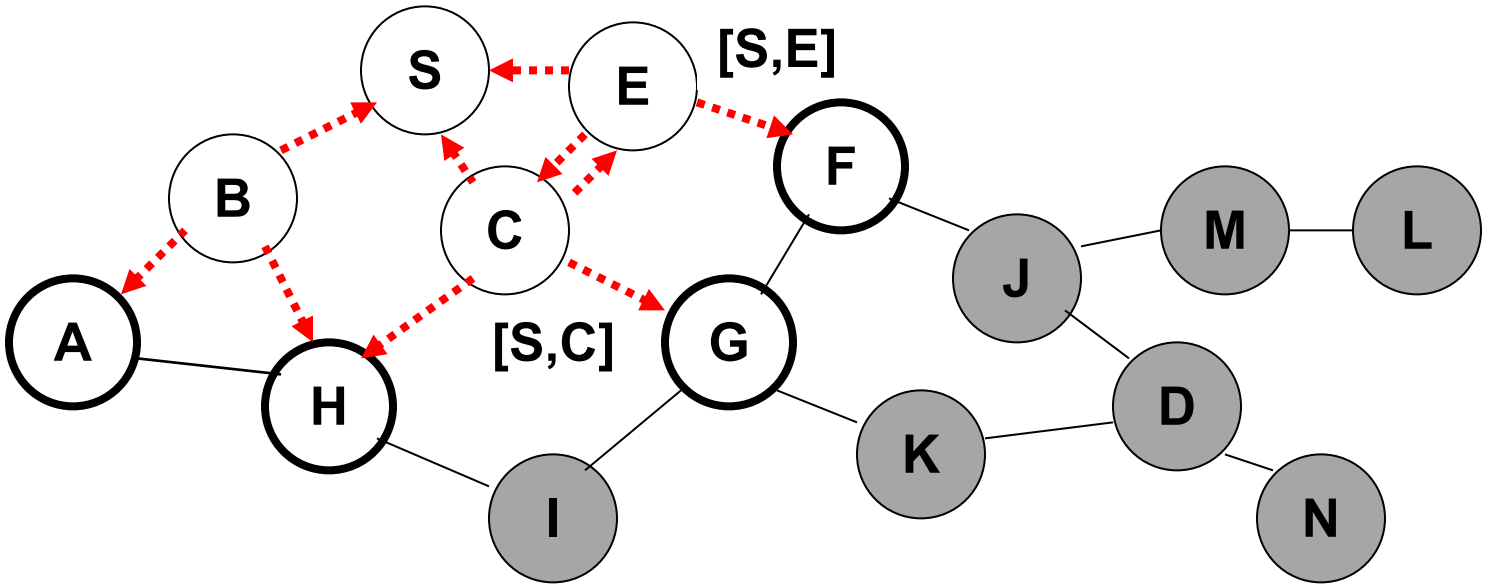
Broadcast transmission



Represents transmission of RREQ

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

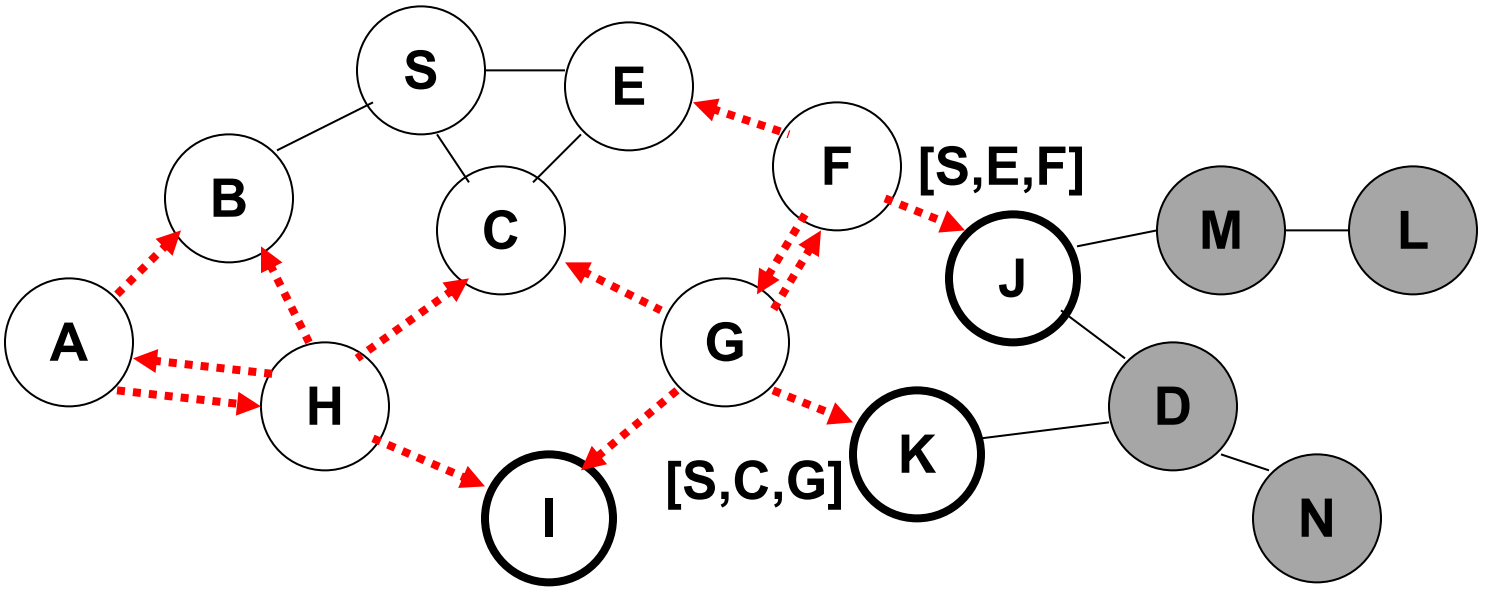
Route Discovery in DSR



Represents transmission of RREQ

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

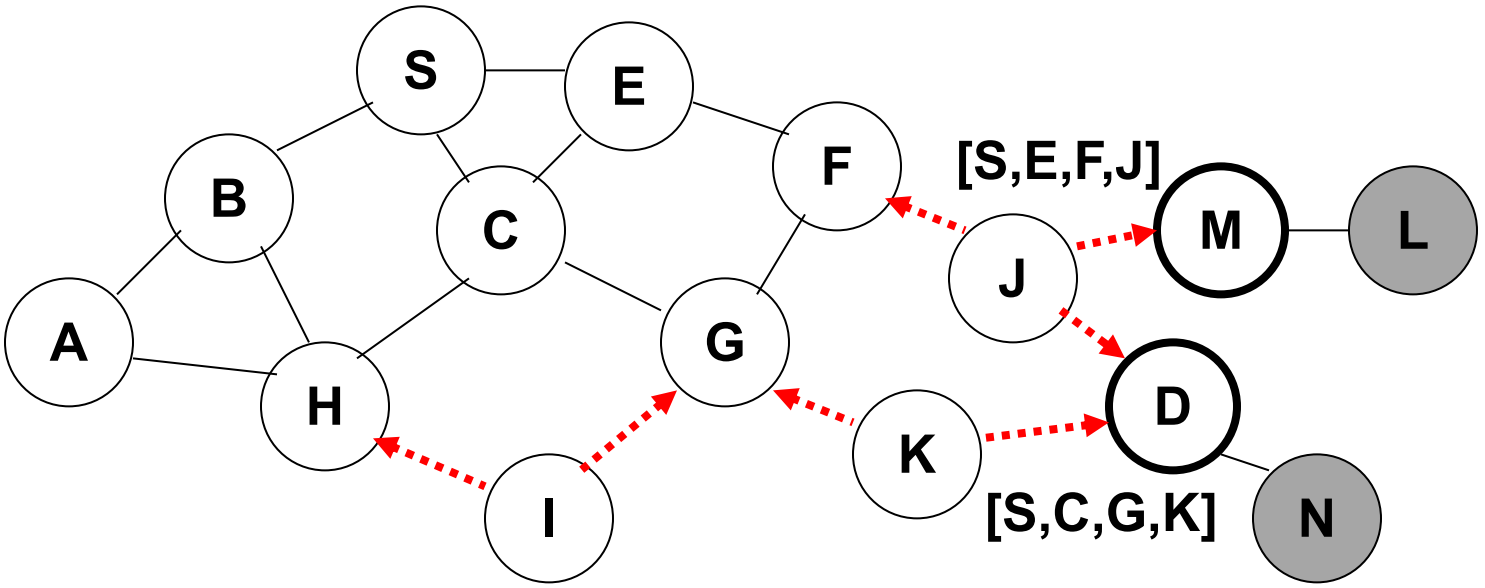
Route Discovery in DSR



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

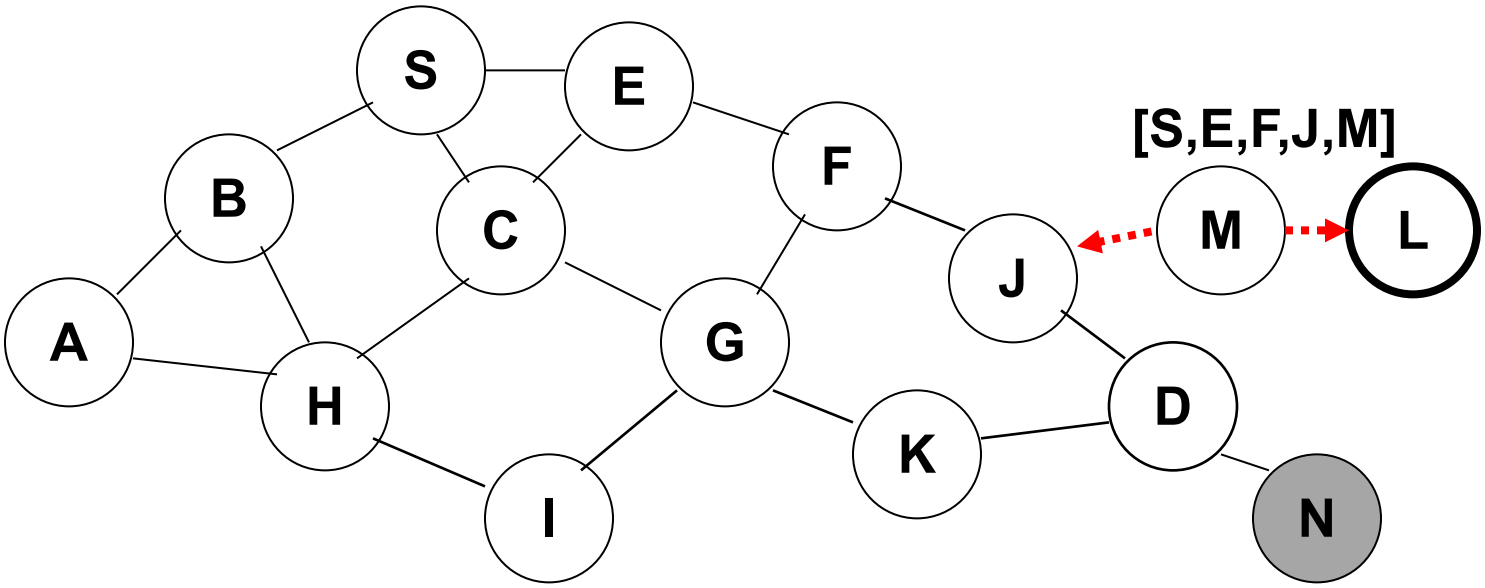
Route Discovery in DSR



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

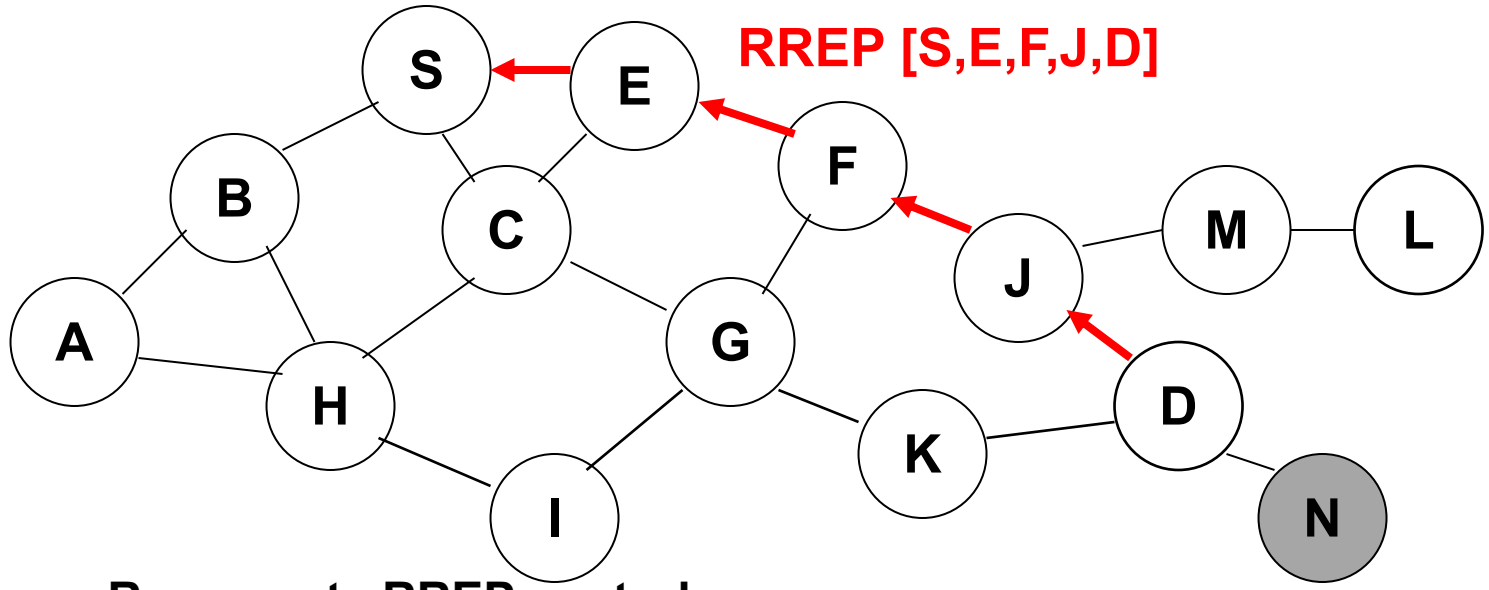


Represents transmission of RREQ

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

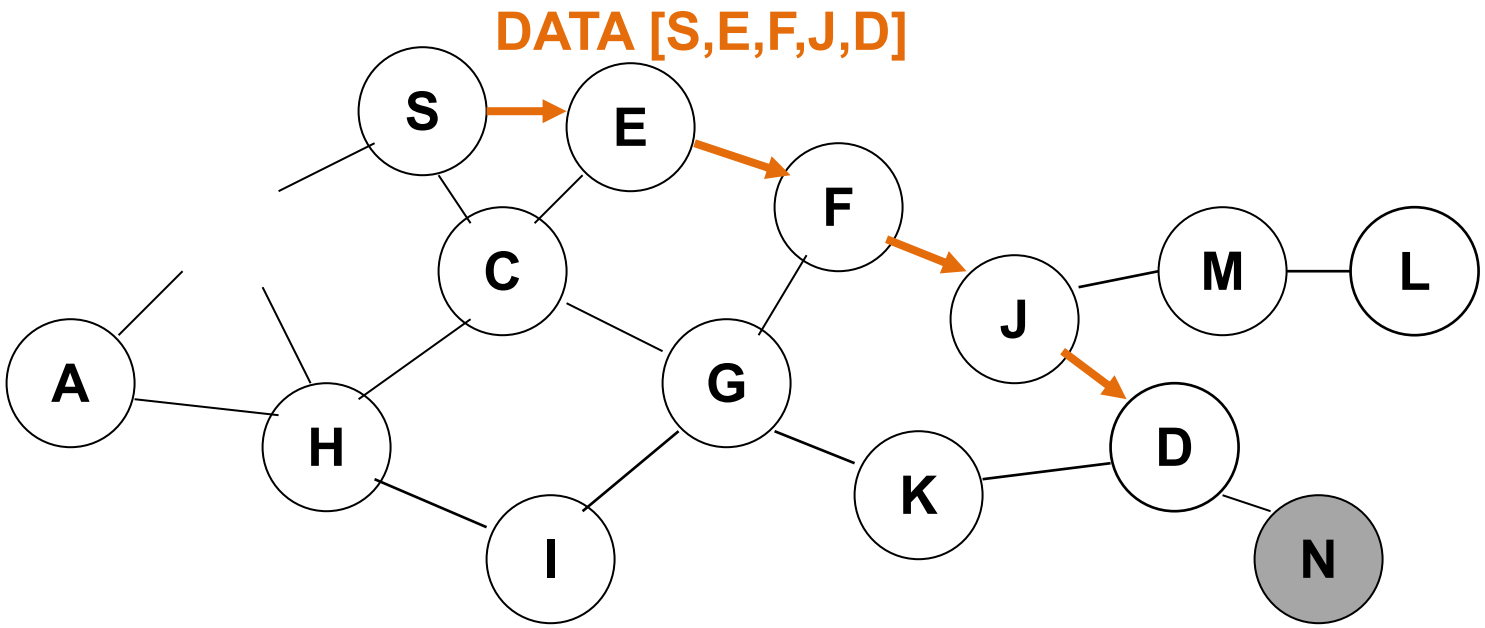
Route Reply in DSR

- 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



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



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