ROUTING PROTOCOLS

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Fall 2012

ELC 659/ELC724

Routing

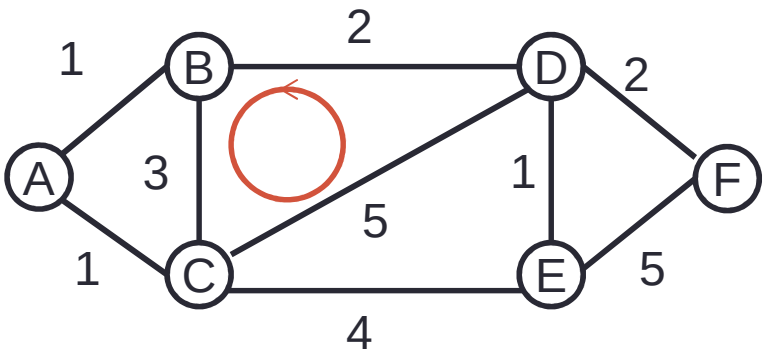
- Network-wide process the determine the end to end paths that packets take from a source to a destination
  - Analogies:
    - Travel from Cairo to Houston City (No direct flight)
    - Sending a postcard (has only sender and receiver addresses)
- Routing Protocol:
  - The algorithm that adaptively computes these paths (routing tables)
    - Each packet has a field to indicate the distention ID (e.g. address, or prefix)
- Manual route configuration is unrealistic
  - Error-prone (human factor), slow, non-adaptive, ……

Aspect of Routing

- Measurement
  - Determines the cost of links (distance, delay, energy, …)
- Protocol
  - How to distribute information (e.g., distance)
- Algorithm
  - How to calculate the route (e.g., shortest path, least cost, min energy)

Routing Requirements

- Given:
  - Network Graph: G = (V, E)
  - Each edge e in E has a cost
- Required:
  - Fast lookups (i.e., small tables)
  - Minimal control messages
  - Robust (avoid loops, oscillations)
  - Use optimal paths (based on a target cost function)



Basic Routing Approaches

- Link State
  - Computes shortest distance path using **global and complete** knowledge about the network
- Distance Vector
  - Computes shortest paths in an **iterative and distributed** way based only on the knowledge of the distance to **immediate** nodes

Link State Routing

- Each node broadcast link state packets to all nodes in the network (flooding)

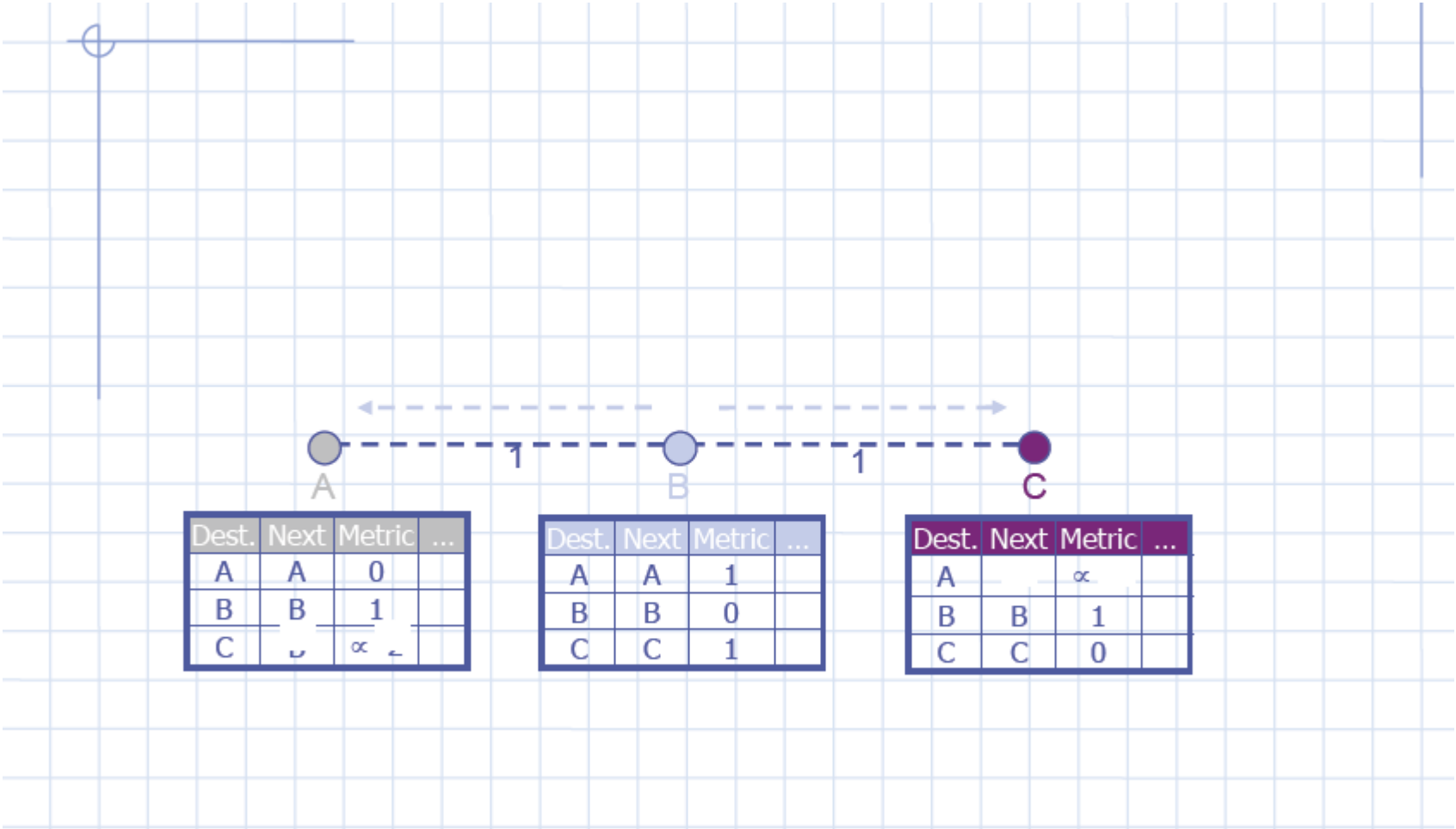
Node	Neighbor	Cost

- Each node collects **all** these packets
  - Hence, each node knows the entire topology
- Each node **locally** computes the shortest path itself
  - Dijkestra's Algorithm
    - Has a set P (permanent) of nodes which shortest path is known (have distance D_a^x)
    - Add set T (temporary) that contains nodes directly reachable (1-hop) by P
    - Pick closest node(s) that minimize min ($d_{ij} + D_a^x$) for all i in P and j in T and add it to P
    - Repeat until P contains all nodes

Distance Vector Routing (Bellman-Ford)

- Initialize distance vectors (DV)
- Exchange DV's with nearest neighbors **ONLY**
- Update DV
- Go to step 2 unless convergence is reached

Distance Vector Routing



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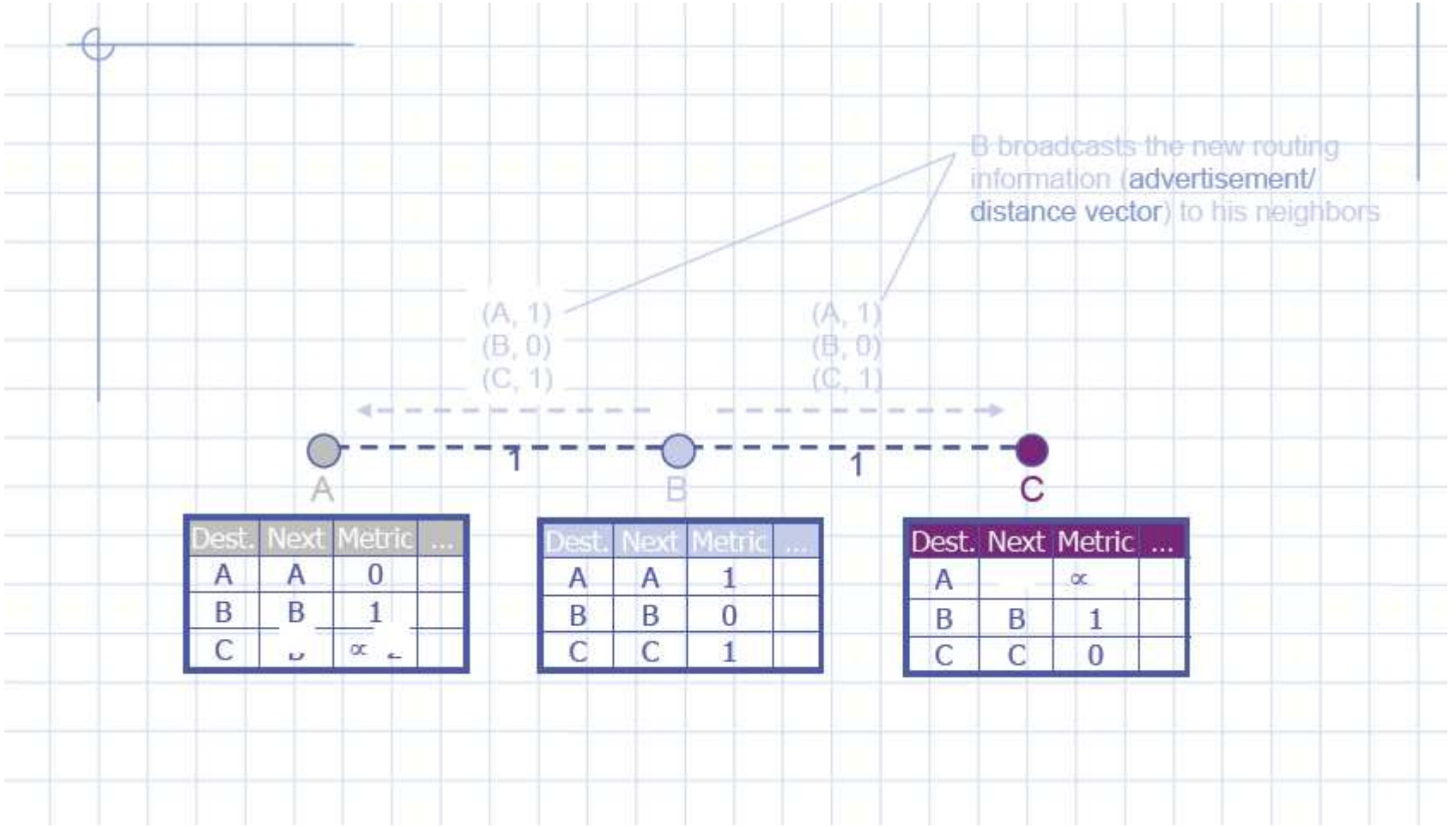

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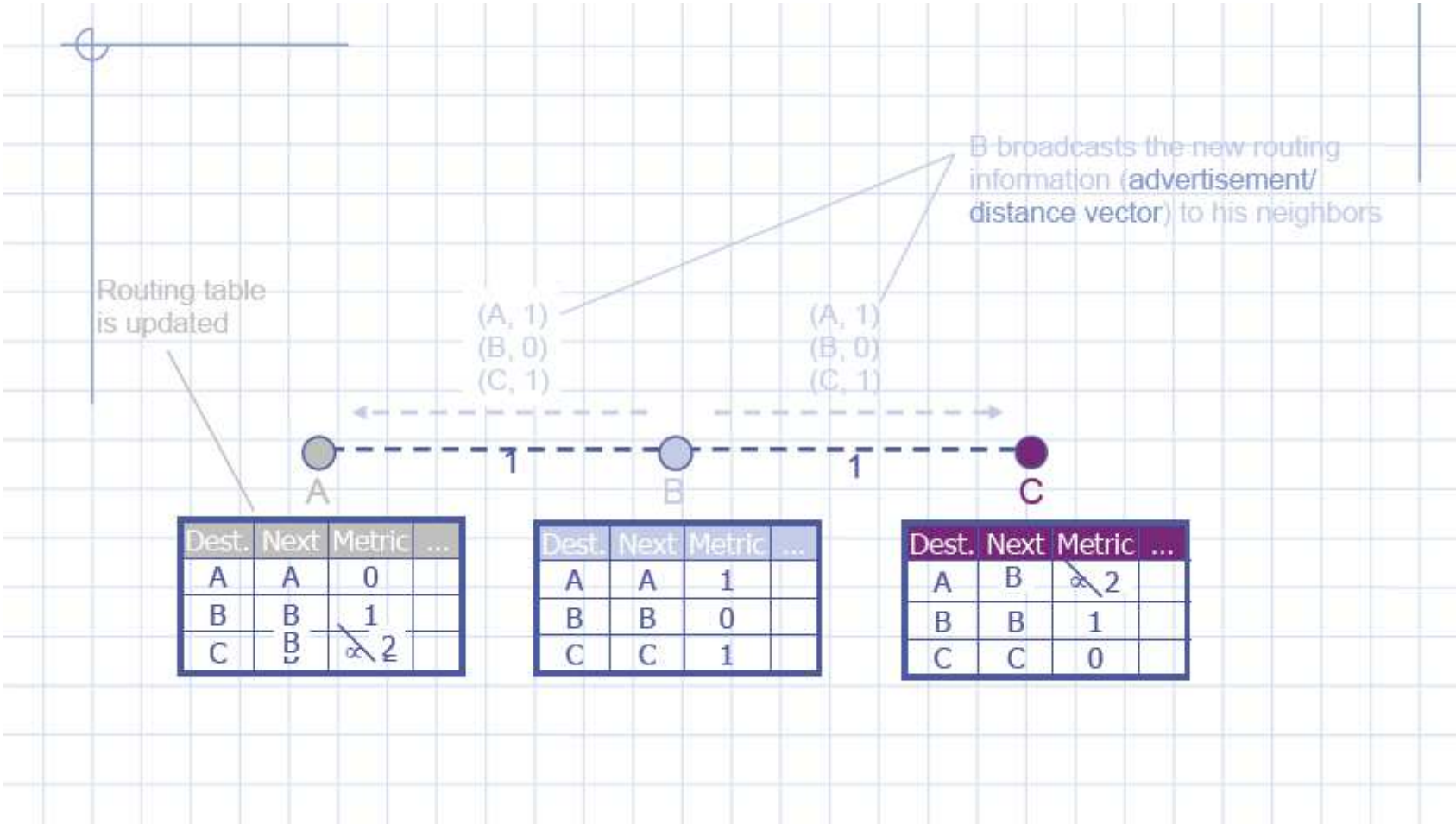

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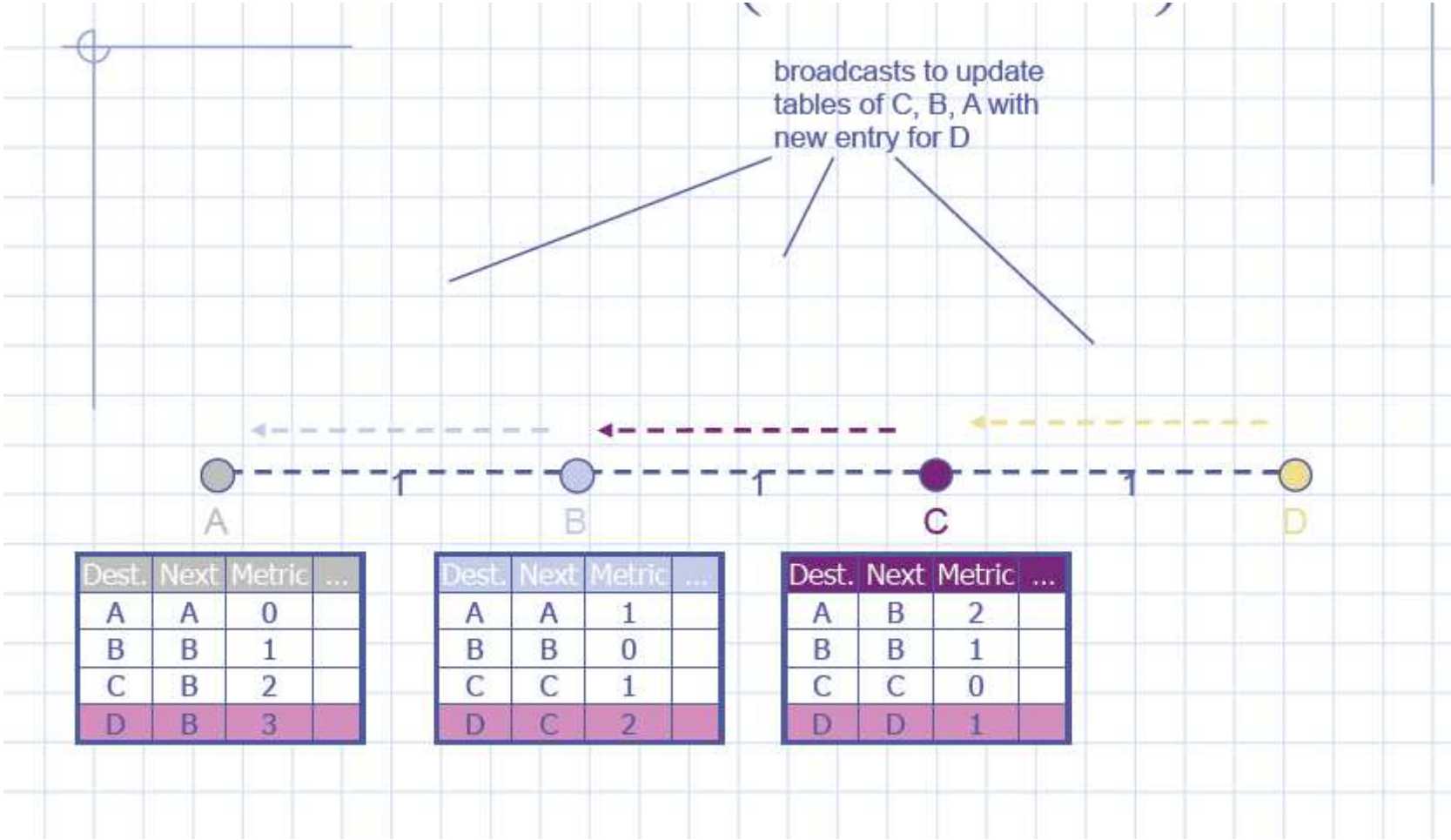
Distance Vector Routing (New Node)



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	

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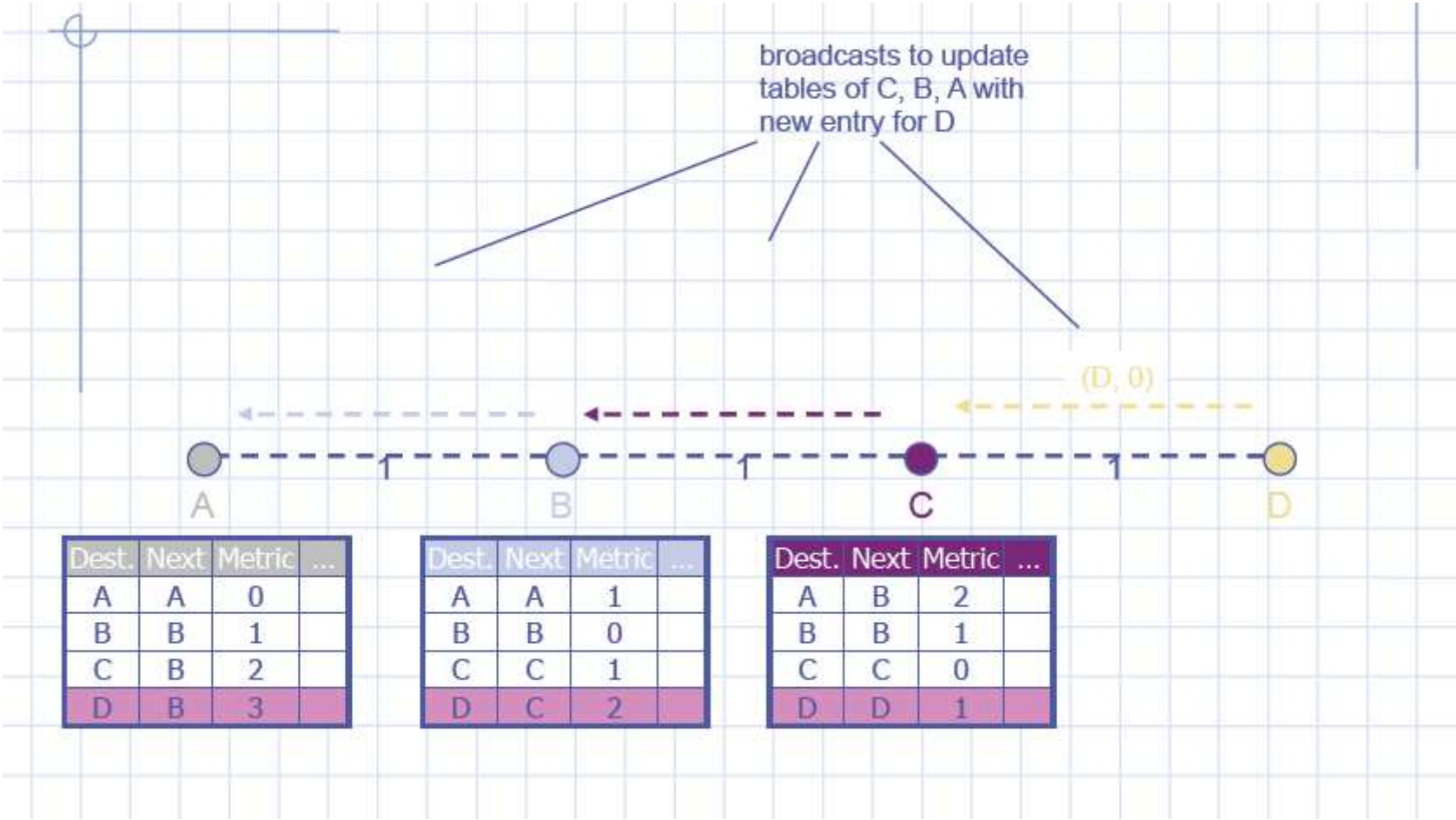

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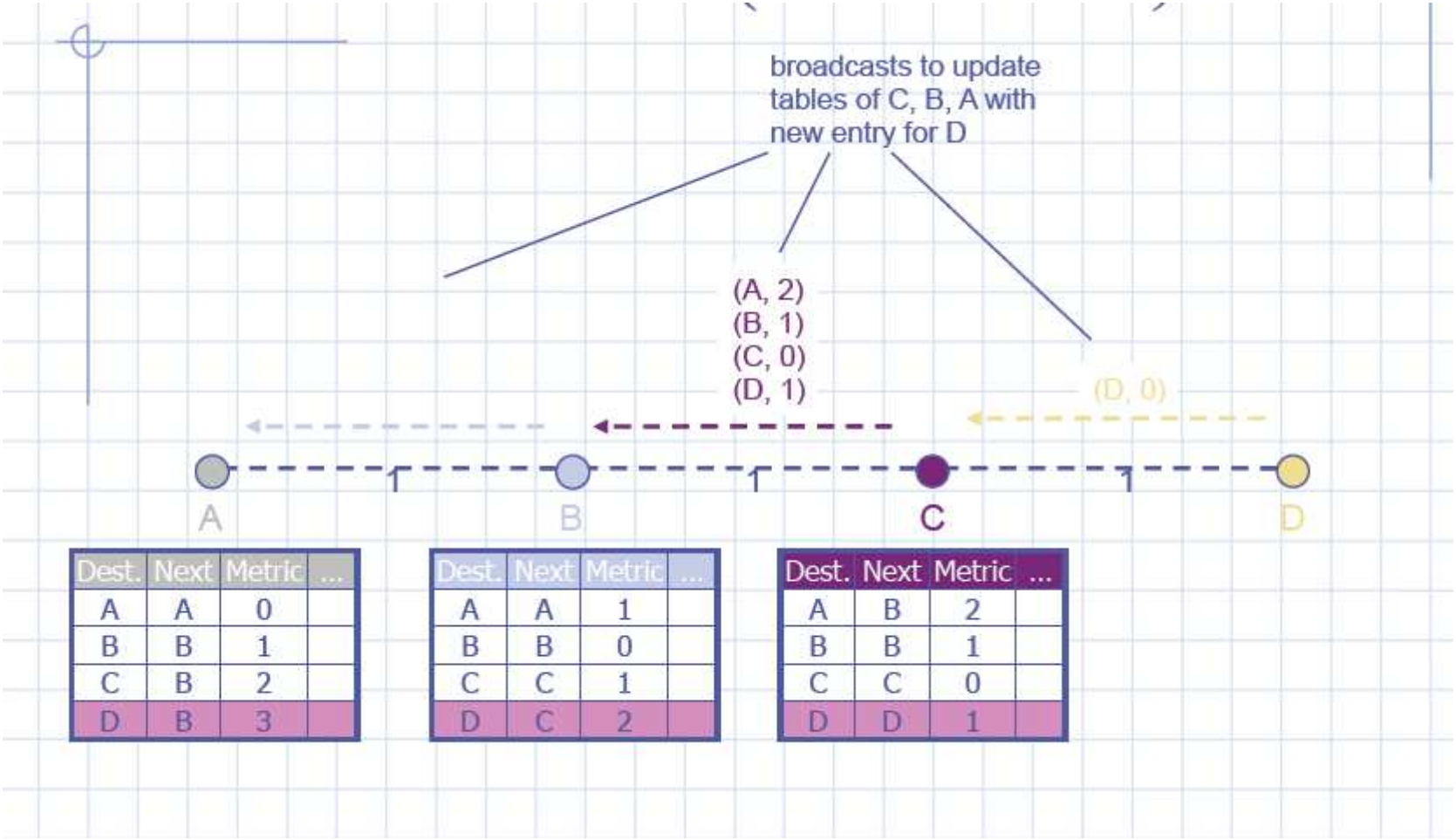

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Dest.	Next	Metric	...
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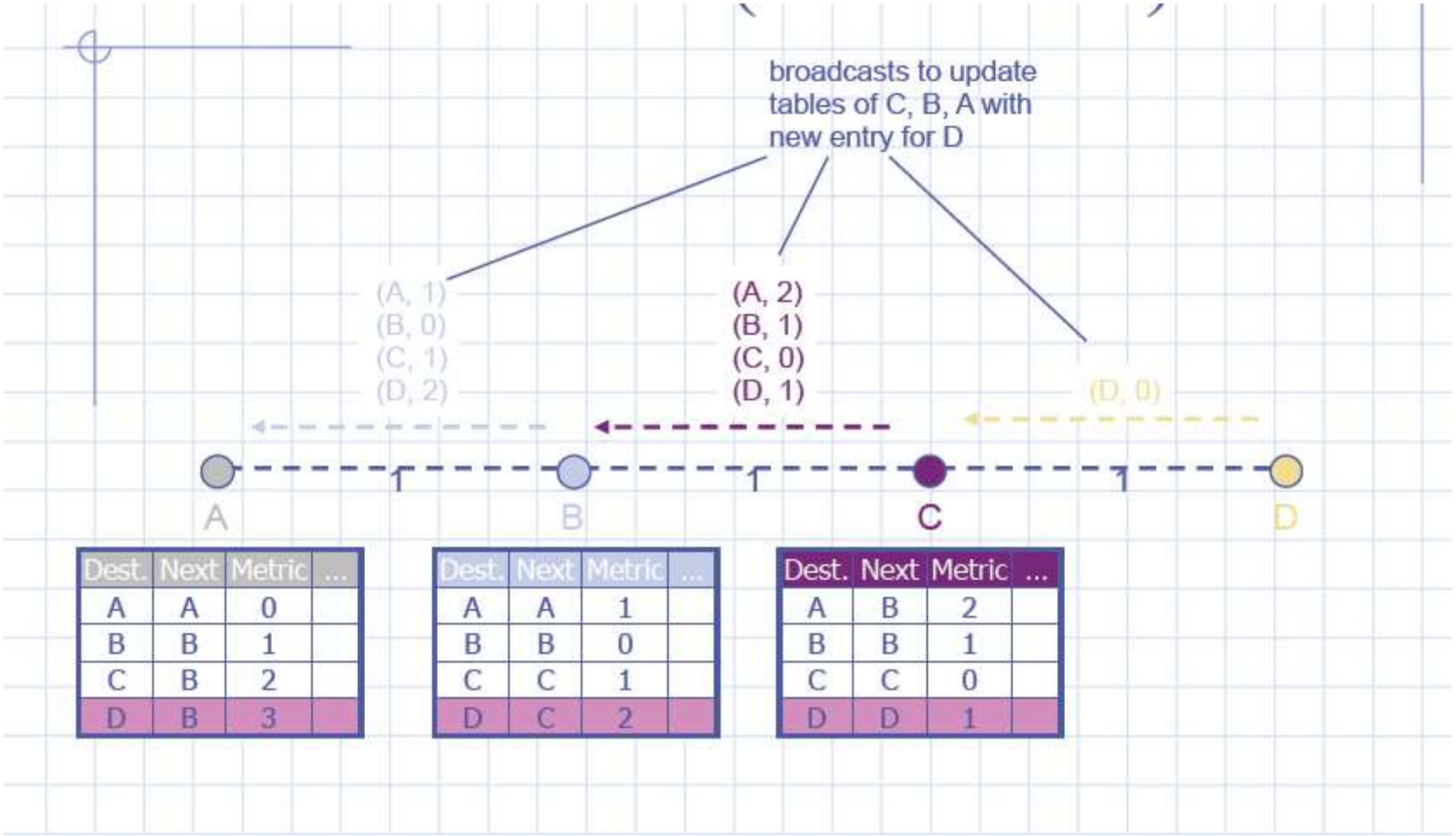

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B	B	0	
C	C	1	
D	C	2	

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

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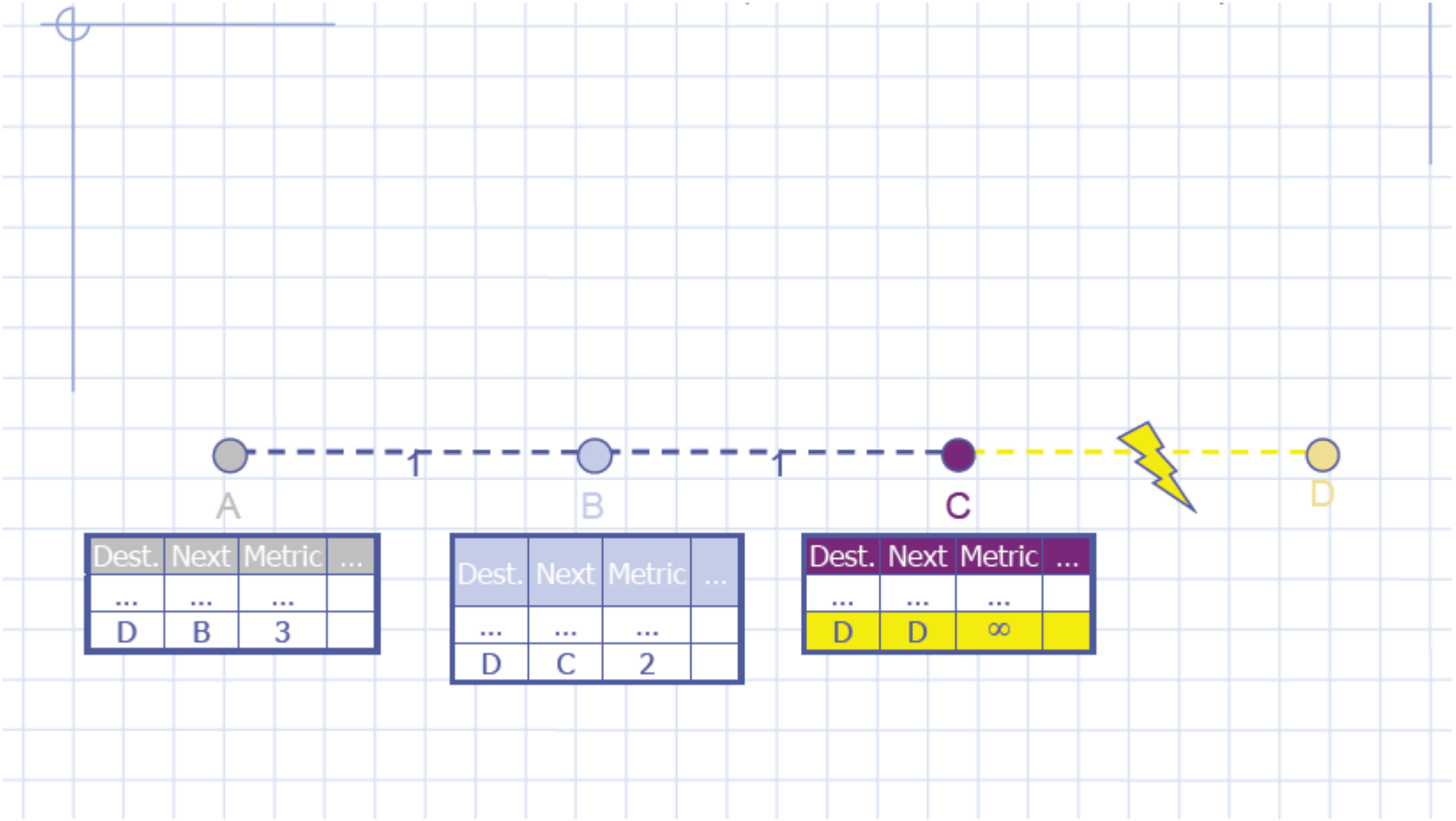
Distance Vector Routing (Broken Link)



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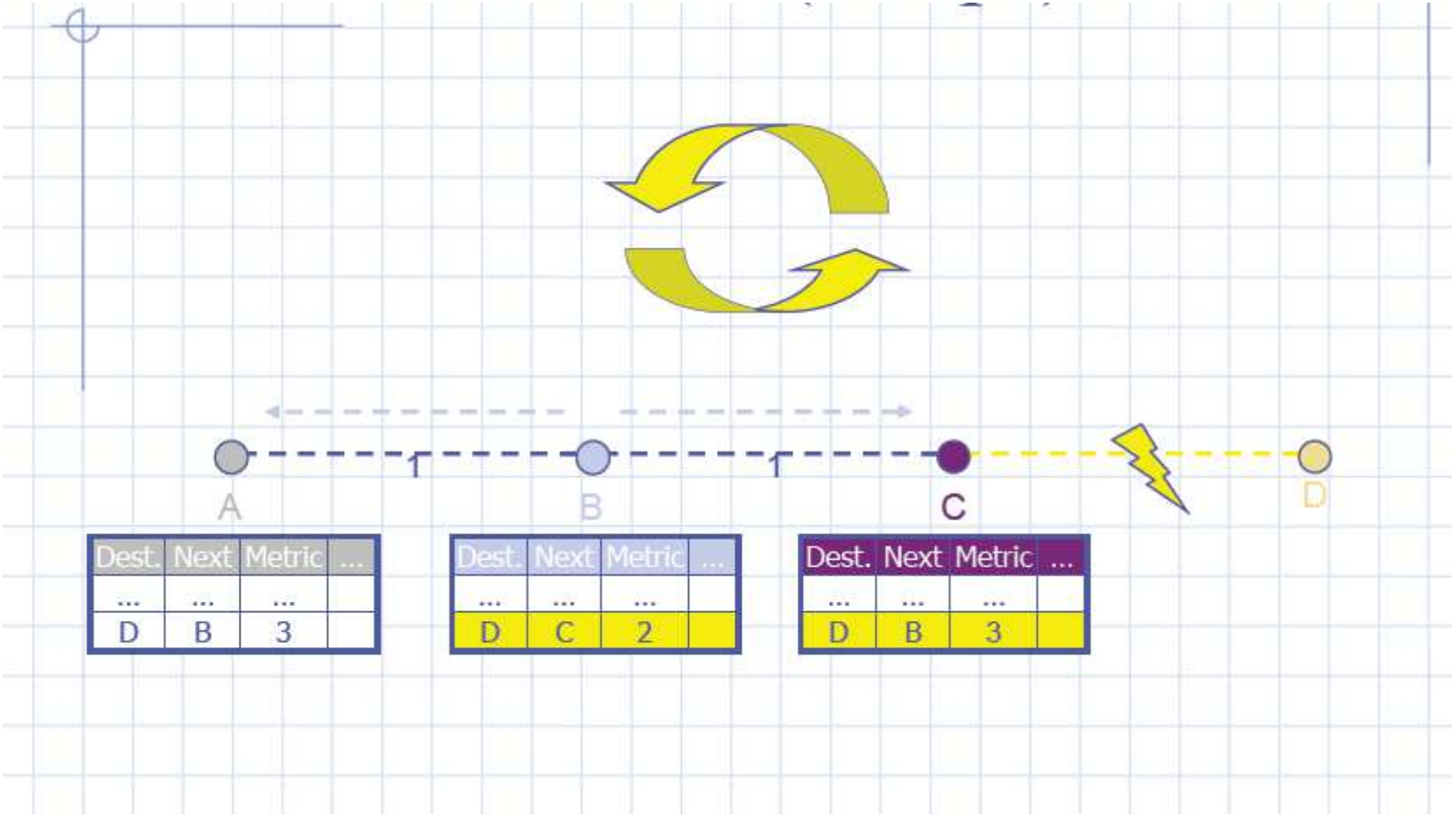
Distance Vector Routing (Loops)



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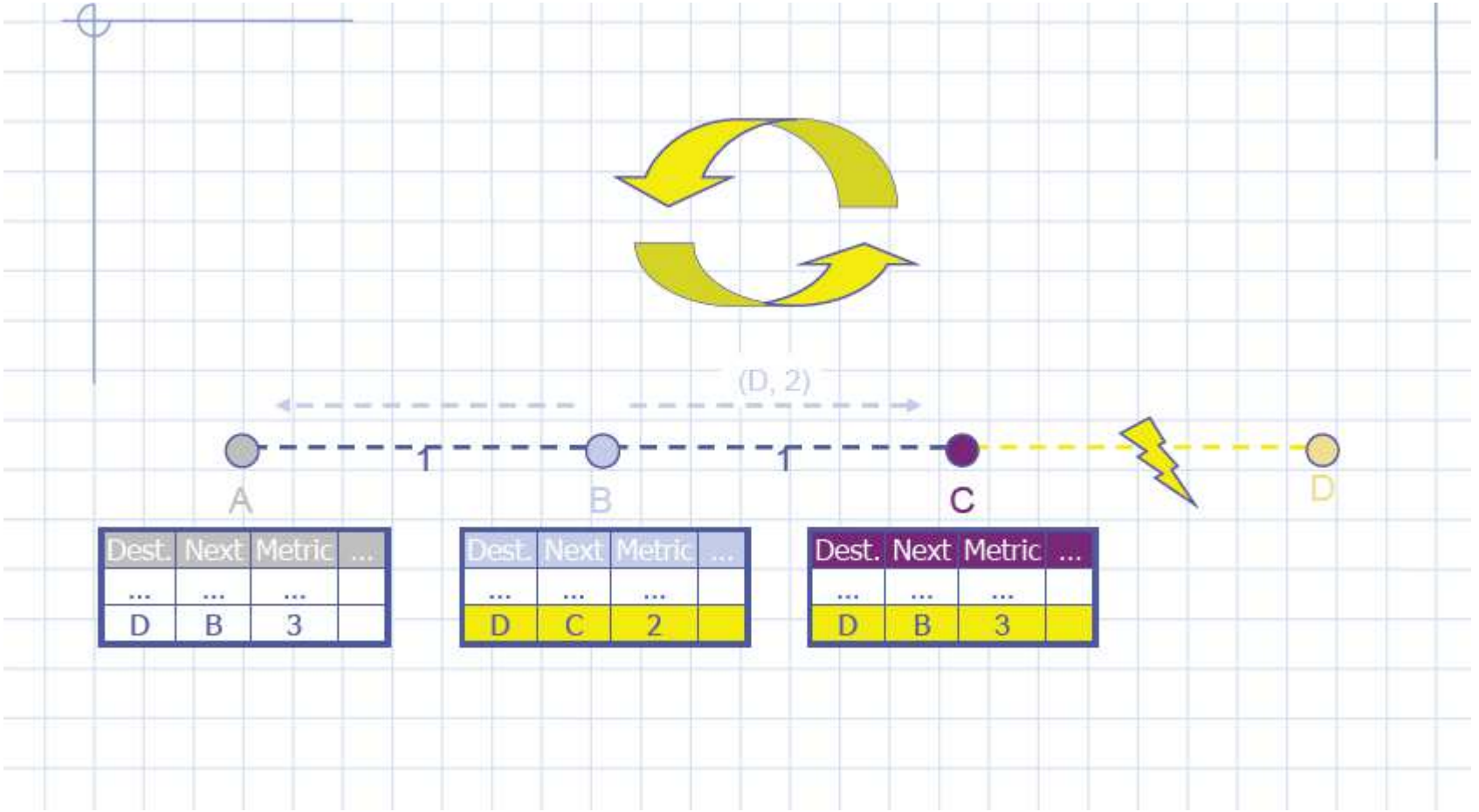

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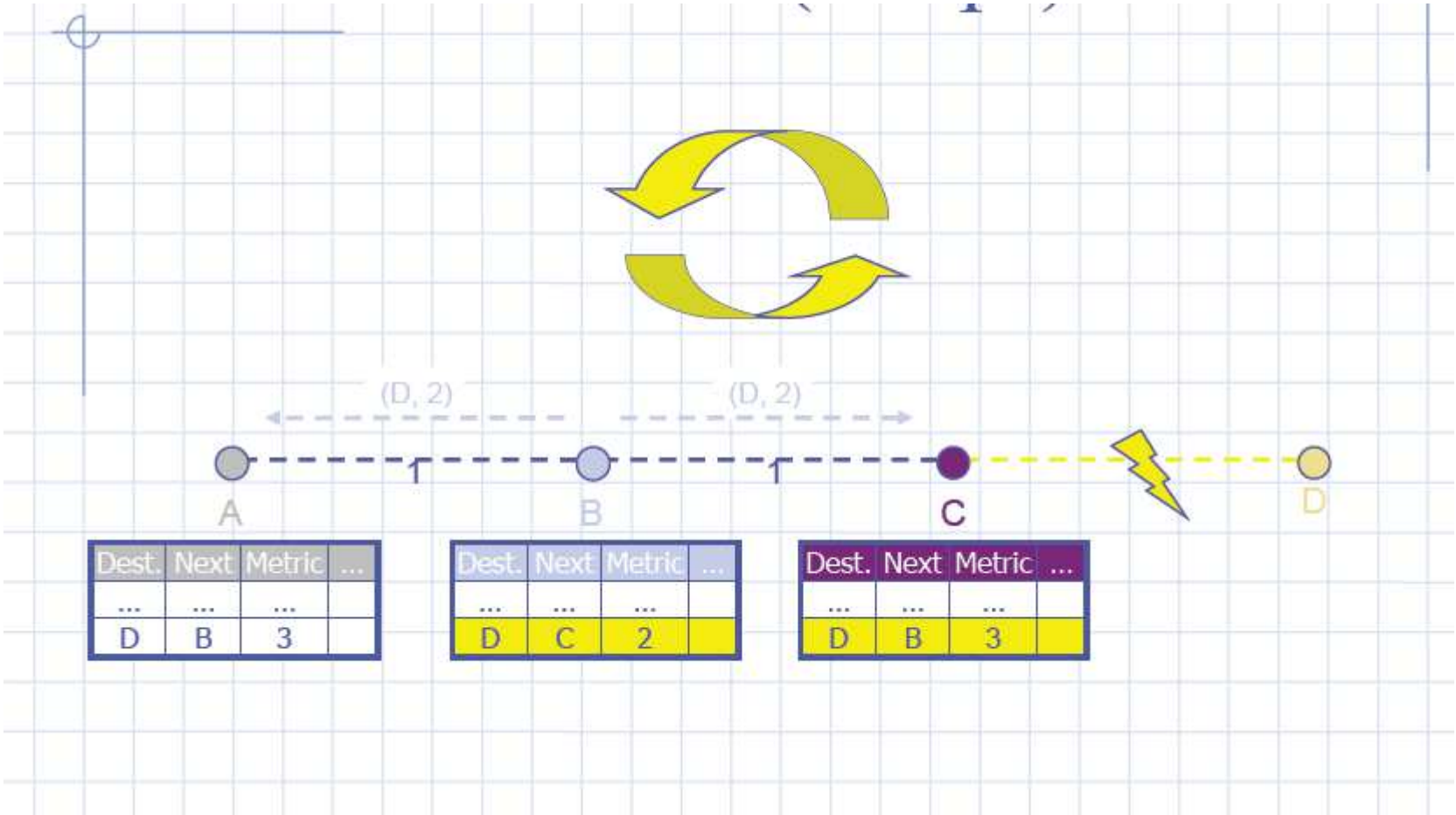

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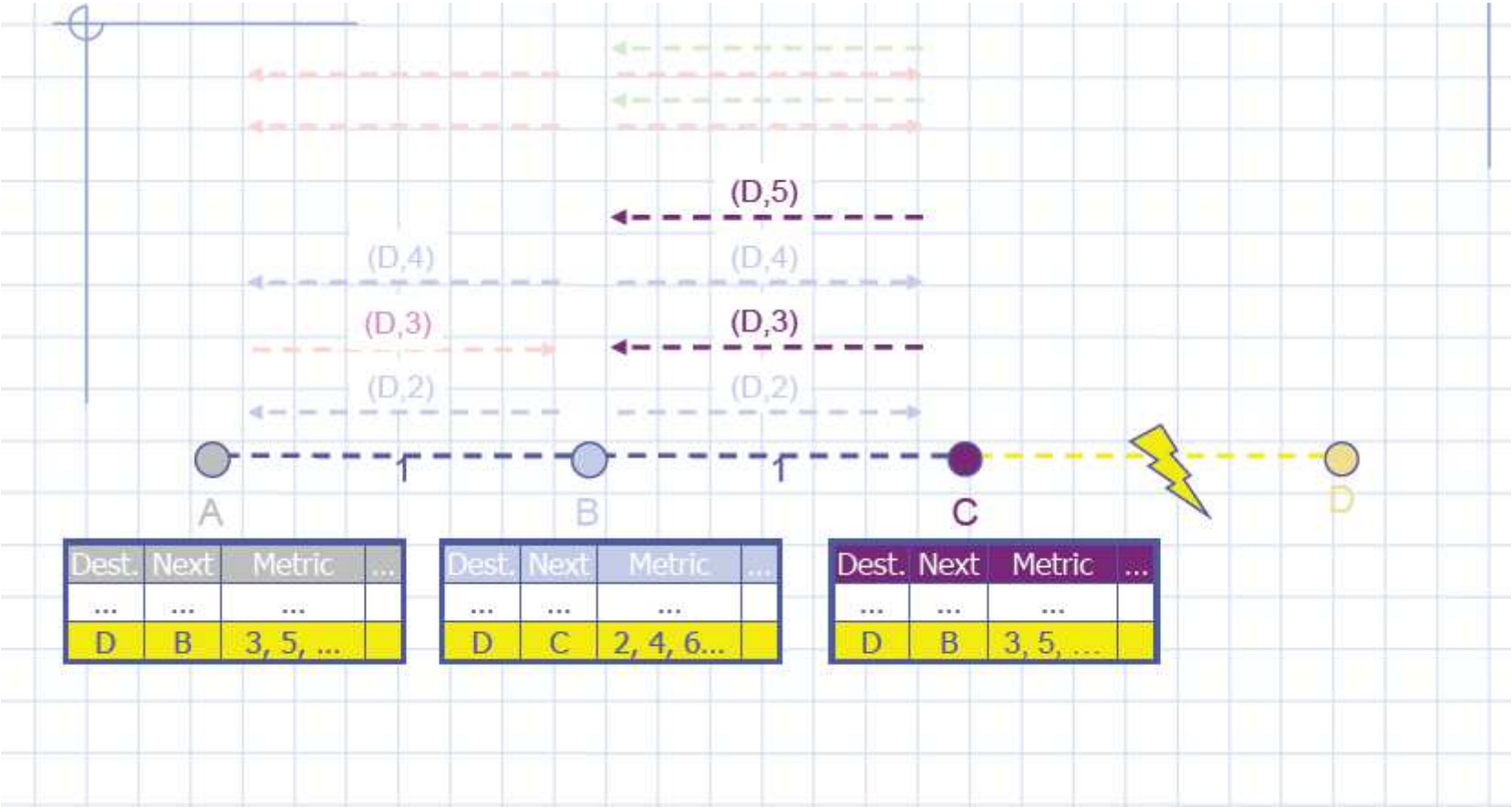
Distance Vector Routing (Count to infinity)



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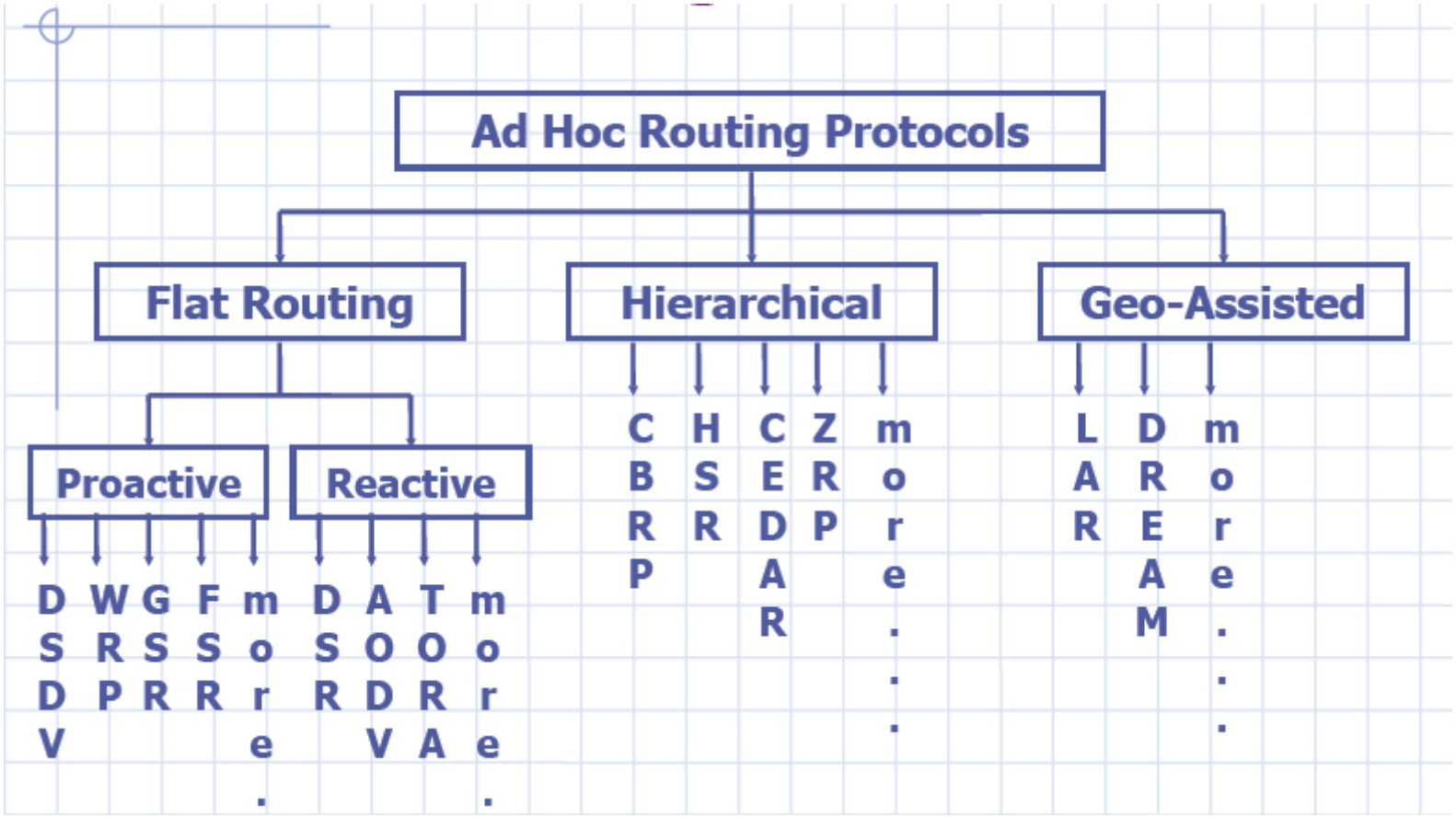
MANET Challenges

- Lack of a centralized entity
- Network topology changes frequently and unpredictably
- Routing and Mobility Management
- Channel access/Bandwidth availability
- Hidden/Exposed station problem
- Asymmetrical links
- Power limitation

MANET Routing Protocols

- **Proactive Protocols**
  - Table driven
  - Continuously evaluate routes
  - Low latency in route discovery
  - Large capacity to keep network information current
  - A lot of routing information may never be used!
- **Reactive Protocols**
  - On Demand
  - Route discovery by some global search
  - Bottleneck due to latency of route discovery
  - May not be appropriate for realtime communication
  - Scalability

MANET Routing Protocols



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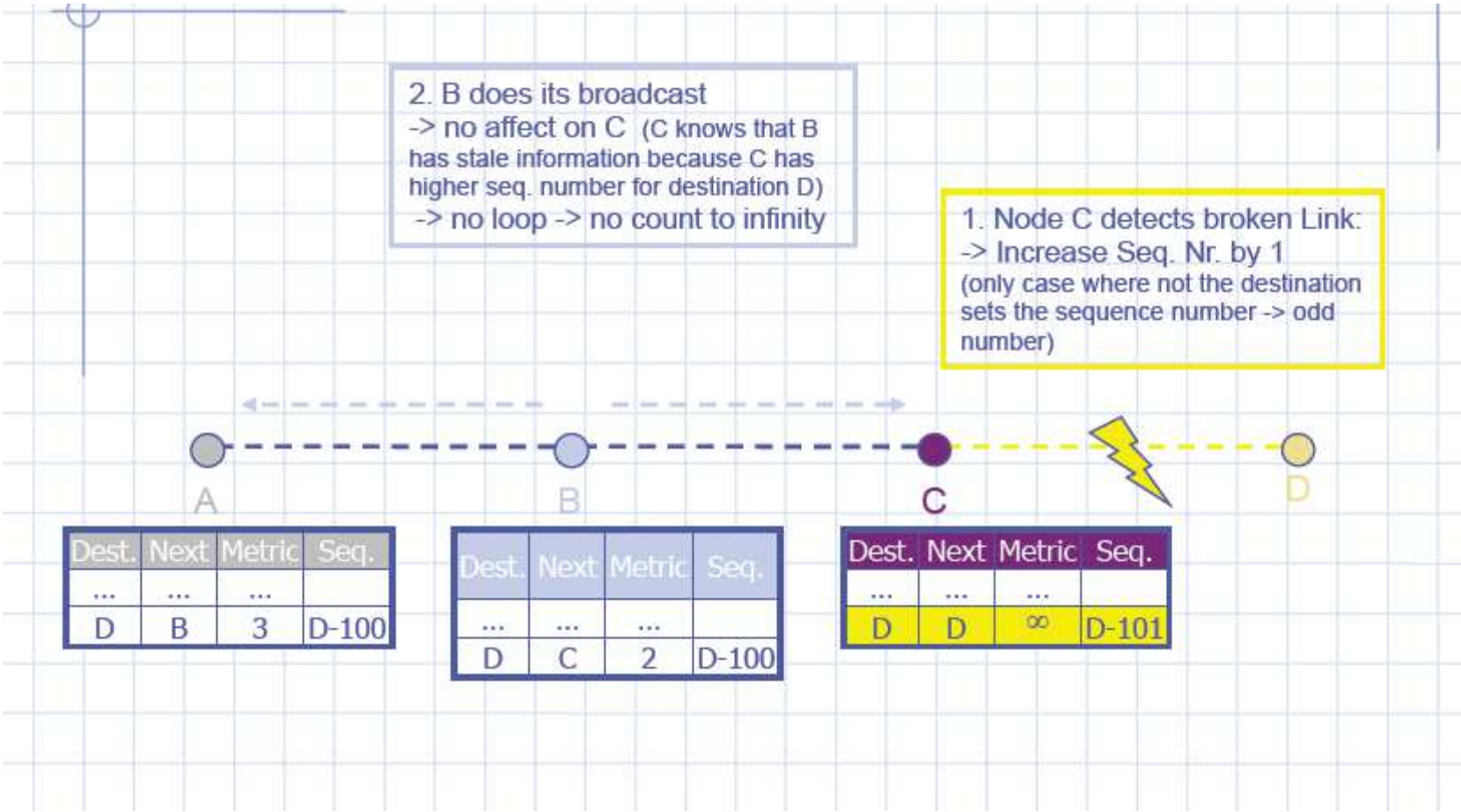
Destination Sequence Distance Vector Routing

- Keep the simplicity of Distance Vector
- Guarantee Loop Free
  - New Table Entry for Destination Sequence Number
- Allow fast reaction to topology changes
  - Make immediate route advertisement on significant changes in routing table
  - but wait with advertising of unstable routes (damping fluctuations)

DSDV

- Advertise to each neighbor own routing information
  - Destination Address
  - Metric = Number of Hops to Destination
  - Destination Sequence Number
  - Other info
- Rules to set sequence number information
  - On each advertisement, the node increases own destination sequence number by 2 (use only even numbers)
  - If a node is no more reachable (timeout) increase sequence number of this node by 1 (odd sequence number) and set metric = ∞.

DSDV (no loops, no count to infinity)



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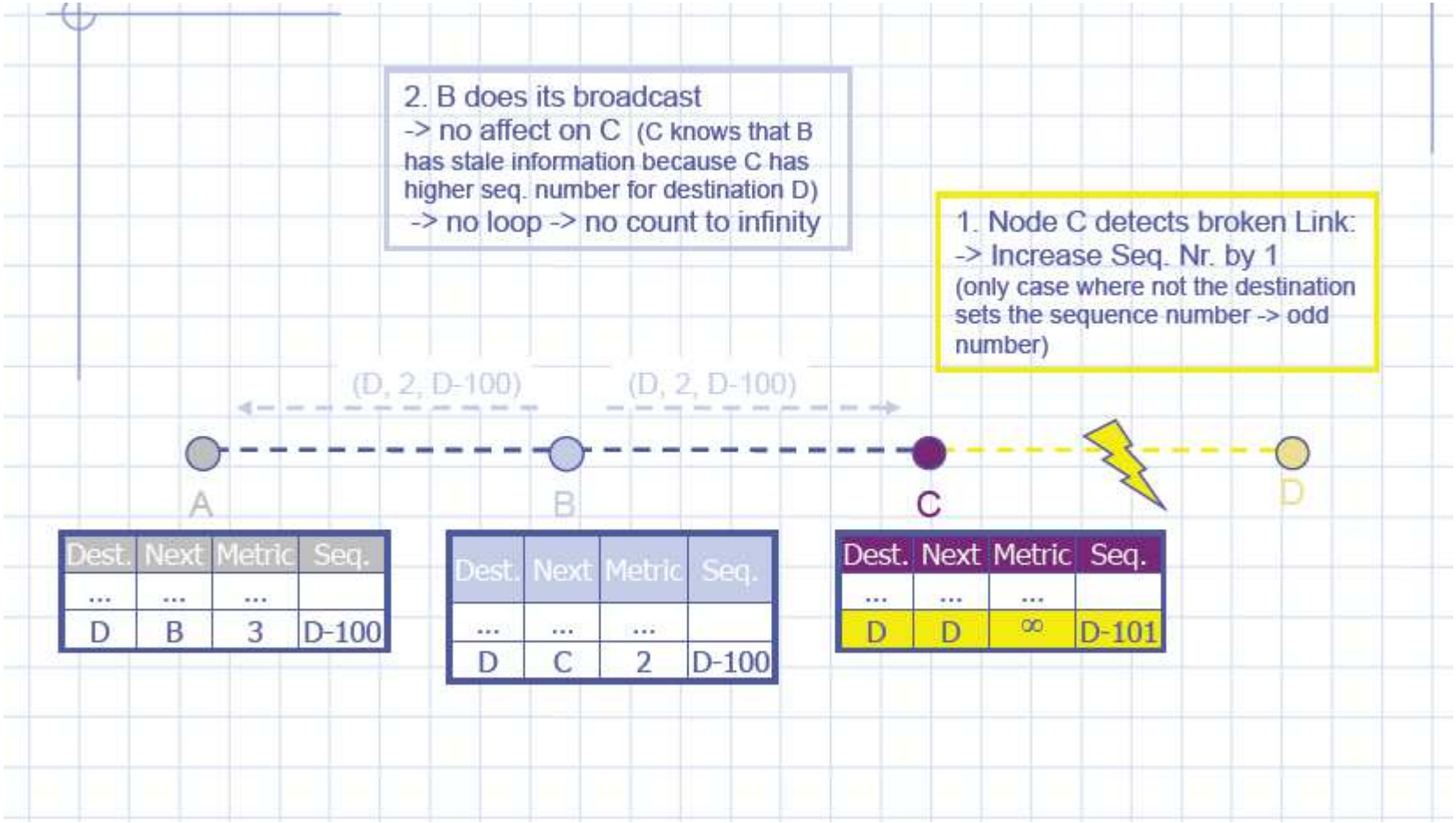

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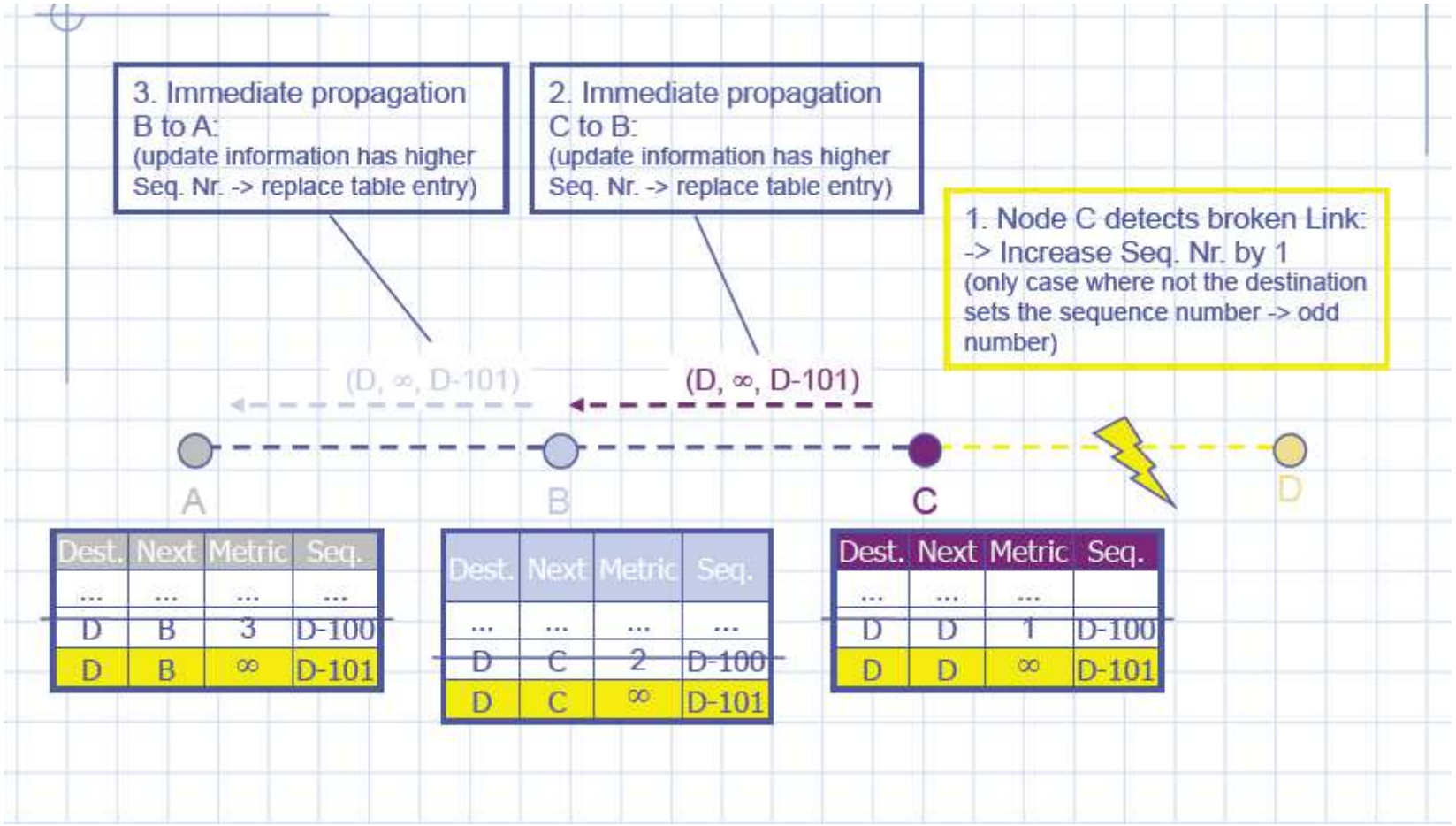

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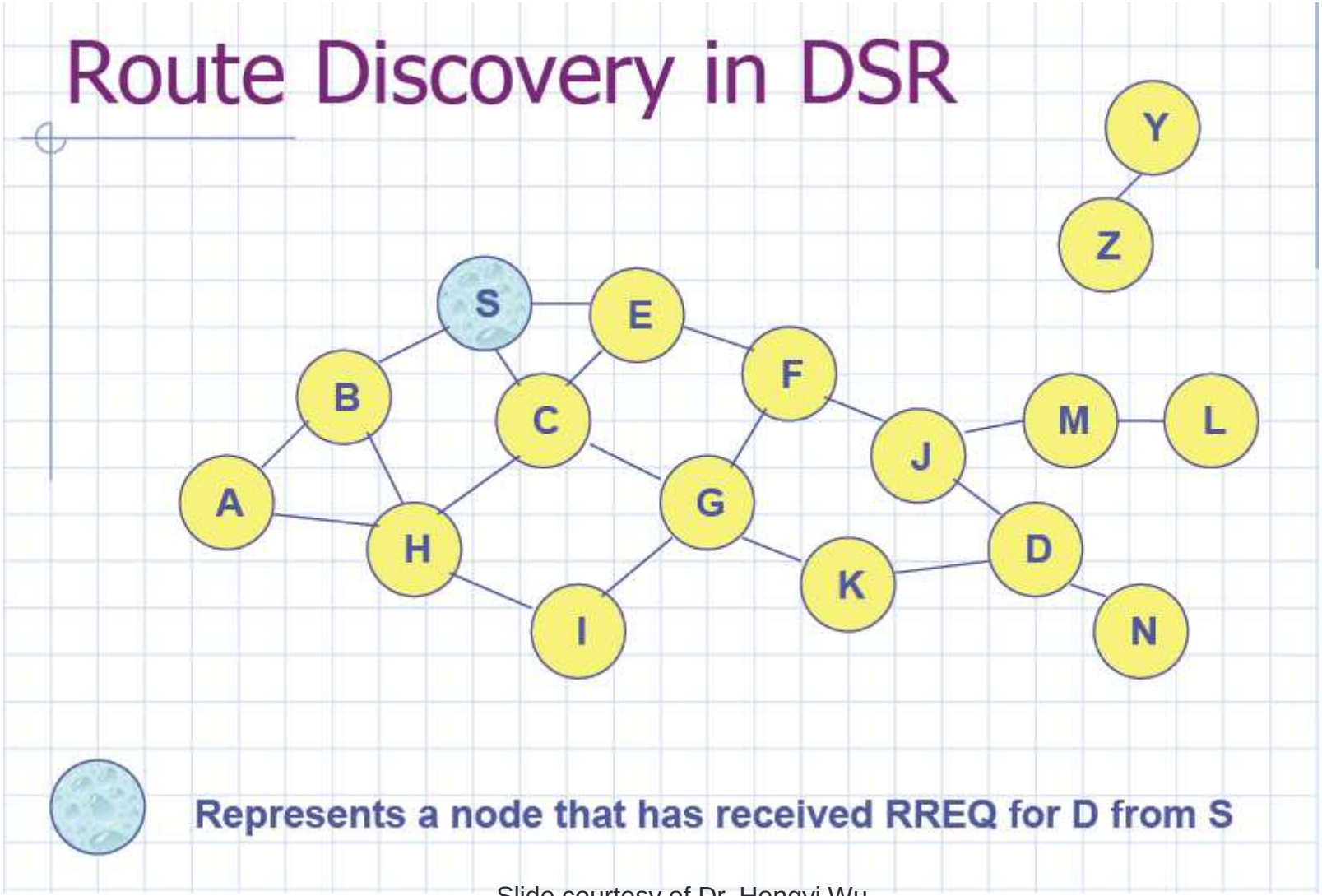
Dynamic Source Routing (DSR)

- The nodes don't maintain routing table
- When node S wants to send a packet to node D, but does not know a route to D, node S initiates a route discovery
- Source node S floods Route Request (RREQ)
  - Sender Address
  - Receiver Address
  - Request id, determined by sender
  - Each intermediate node appends own identifier when forwarding RREQ

Dynamic Source Routing (DSR)



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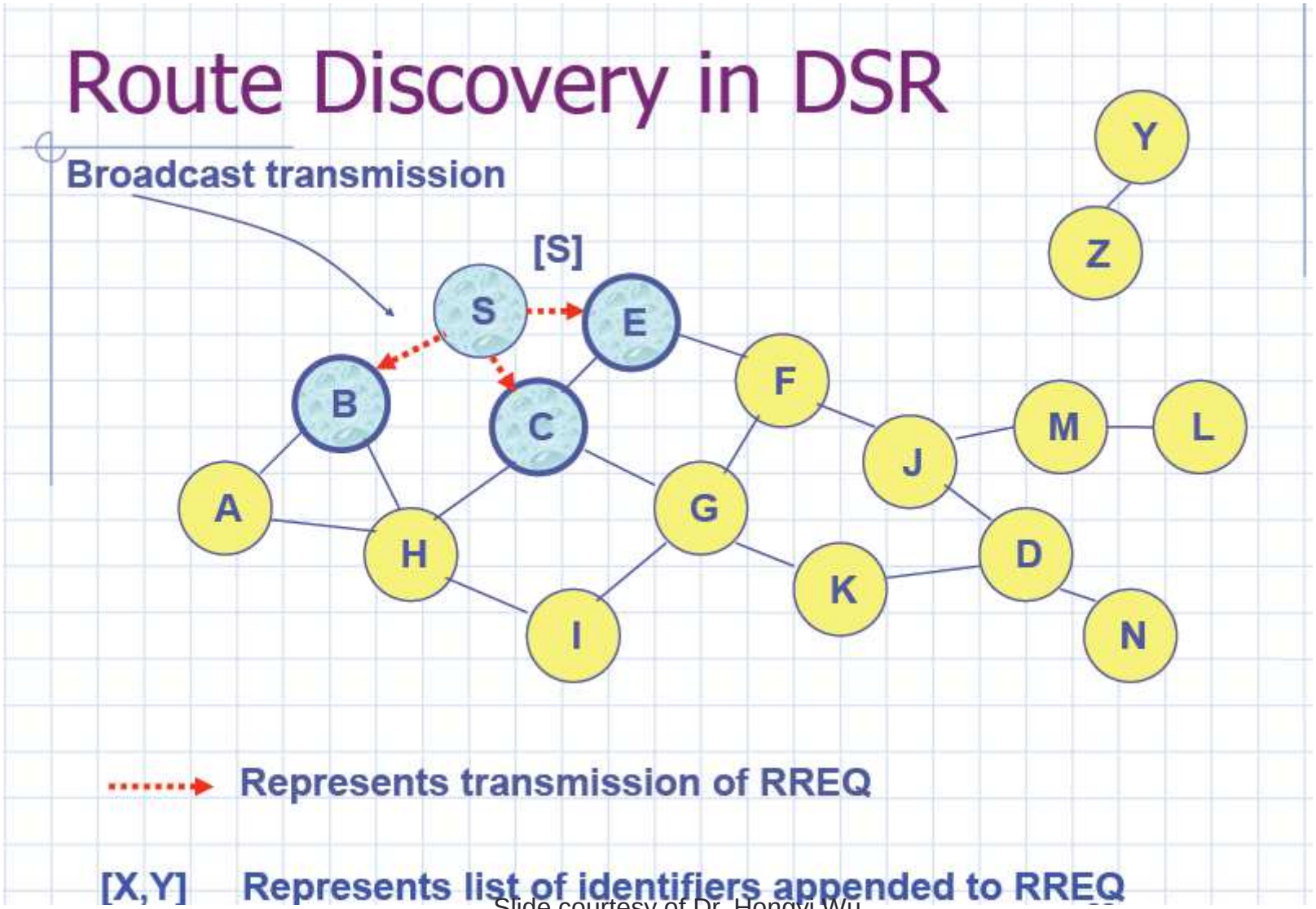

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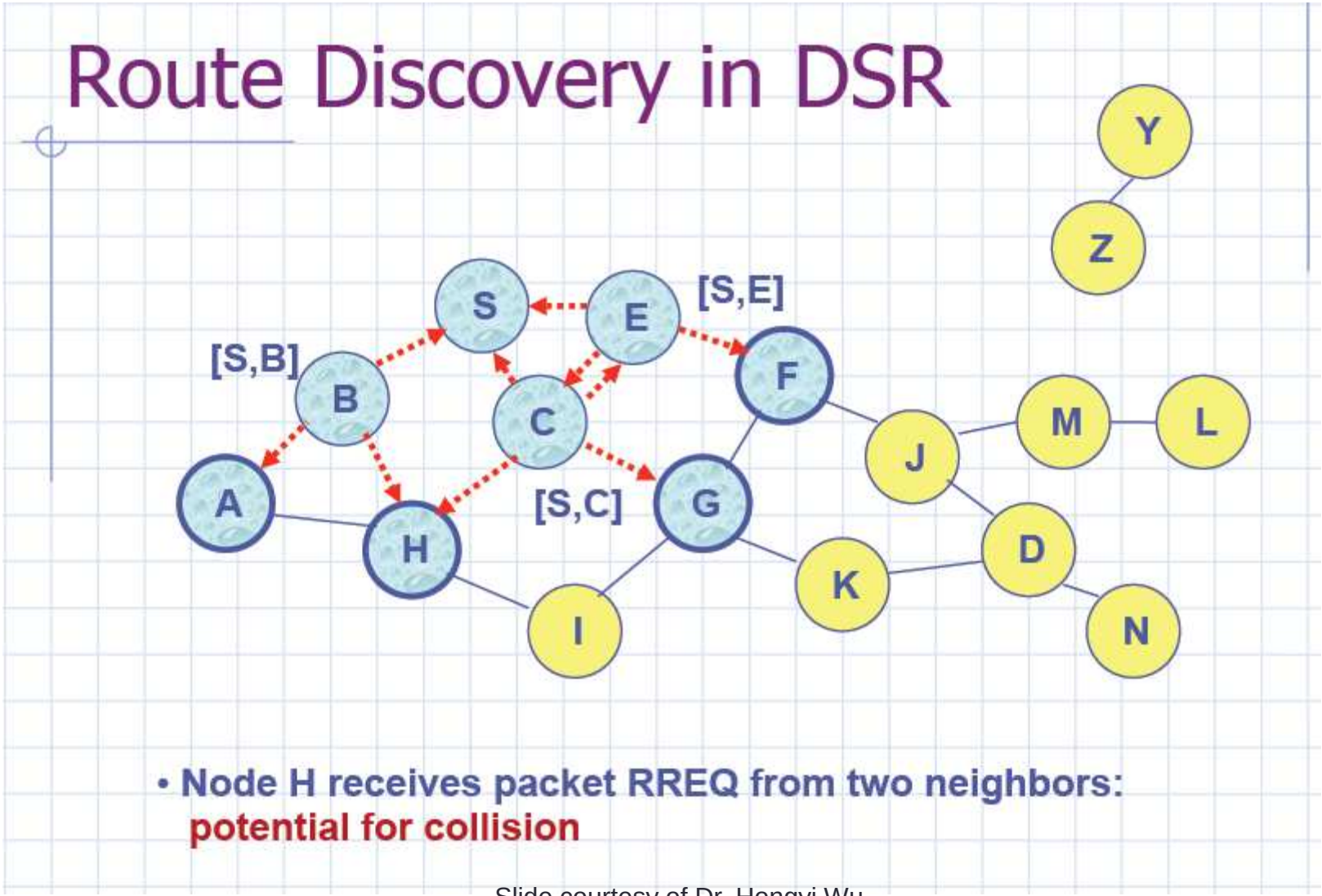

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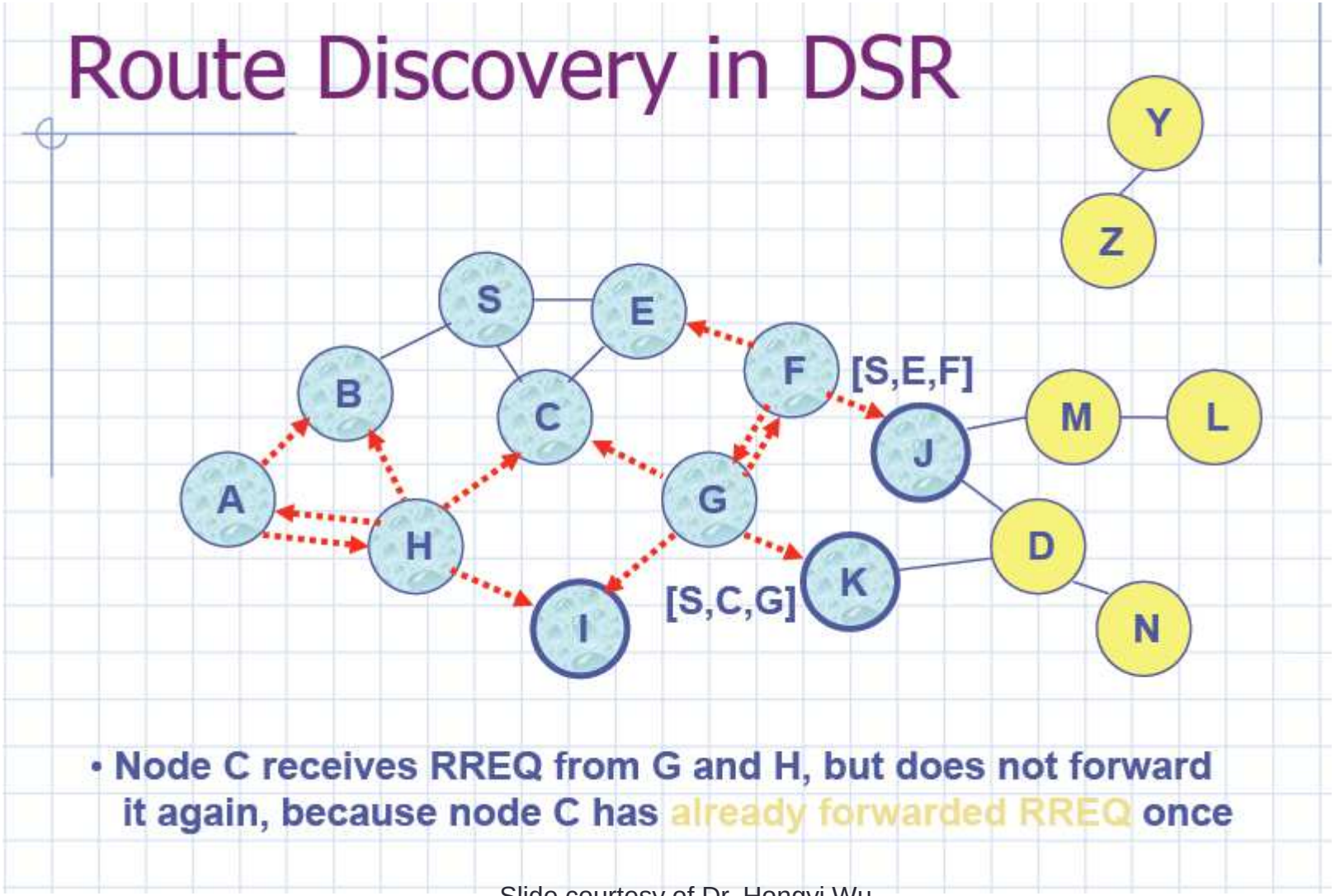

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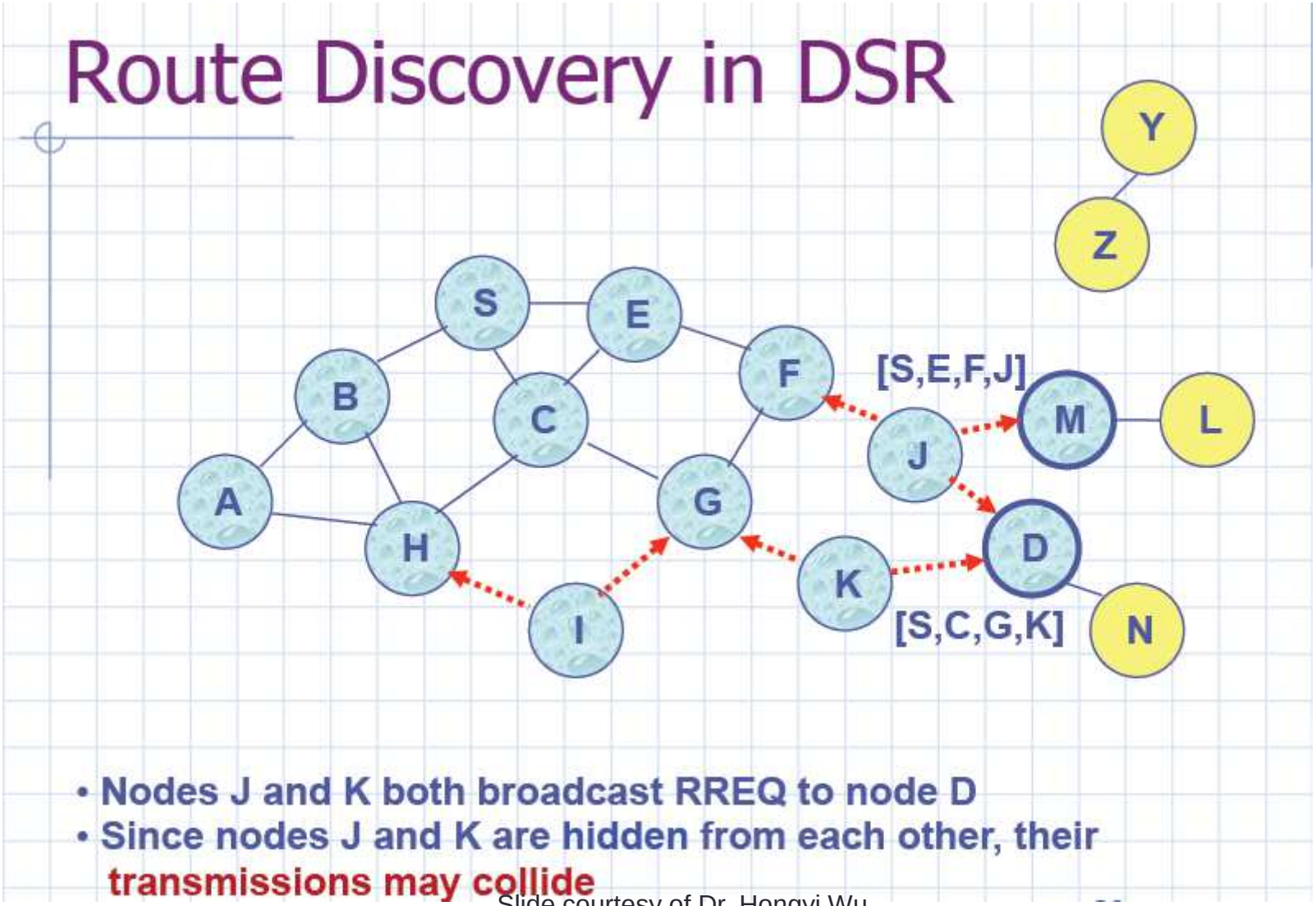

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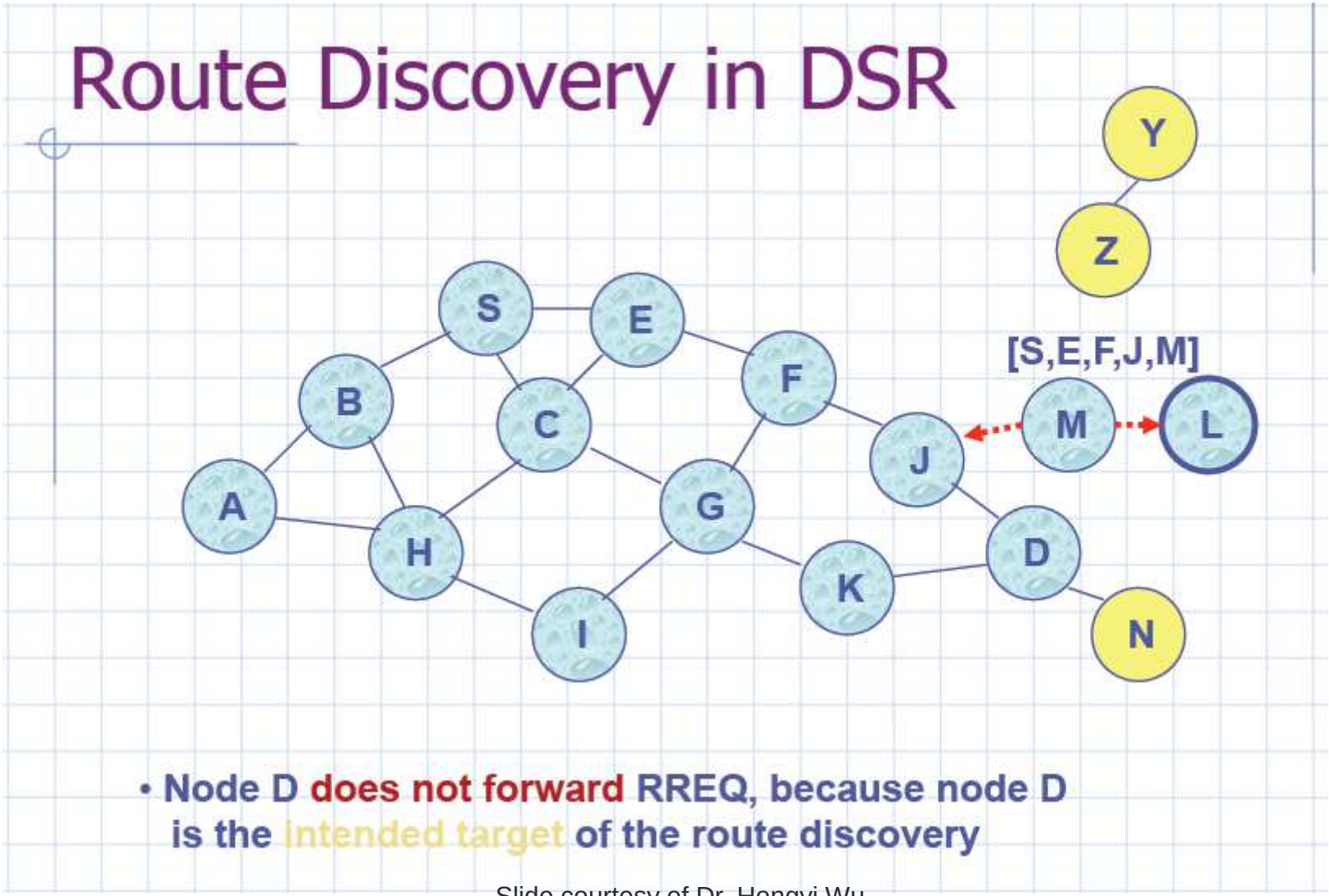

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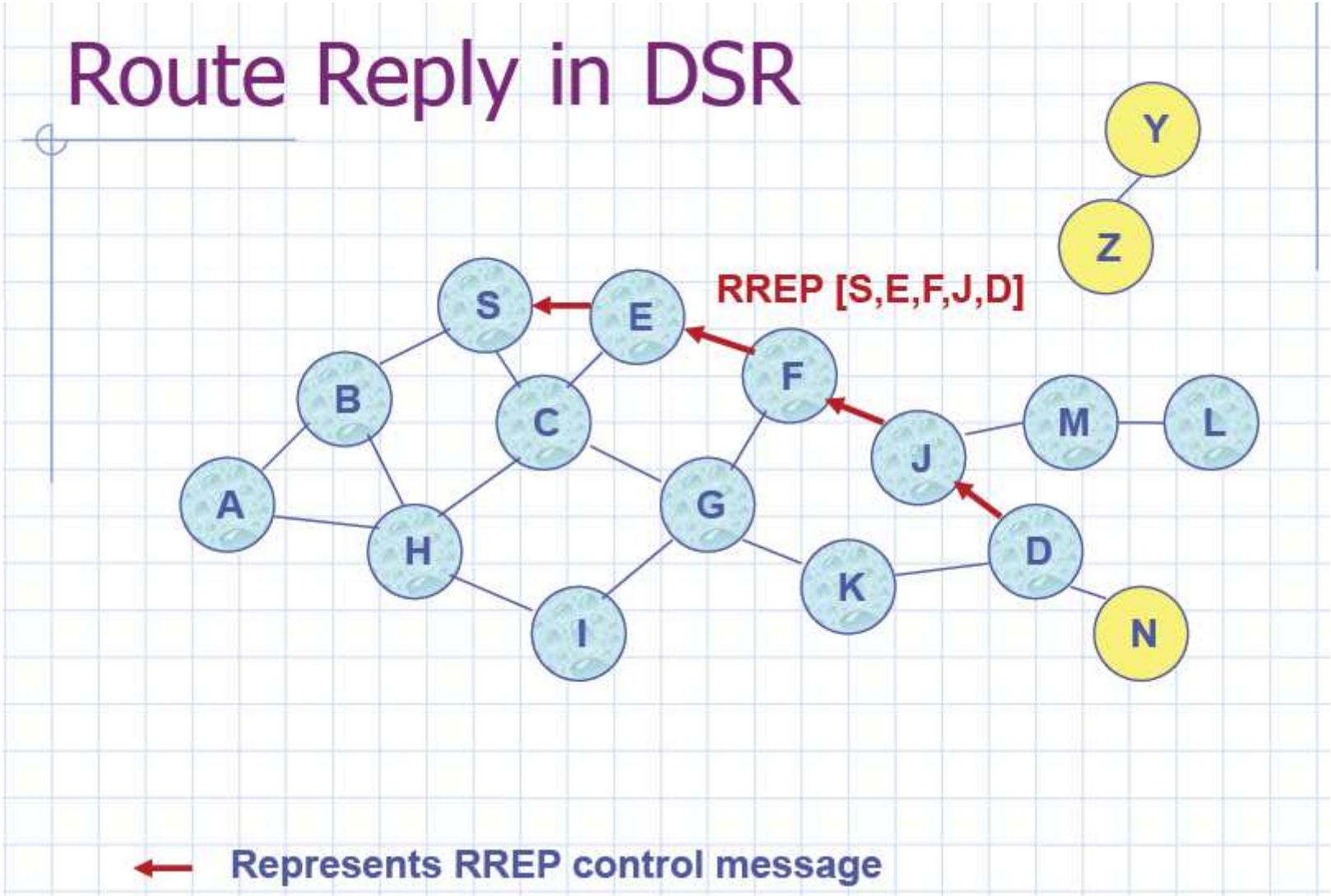

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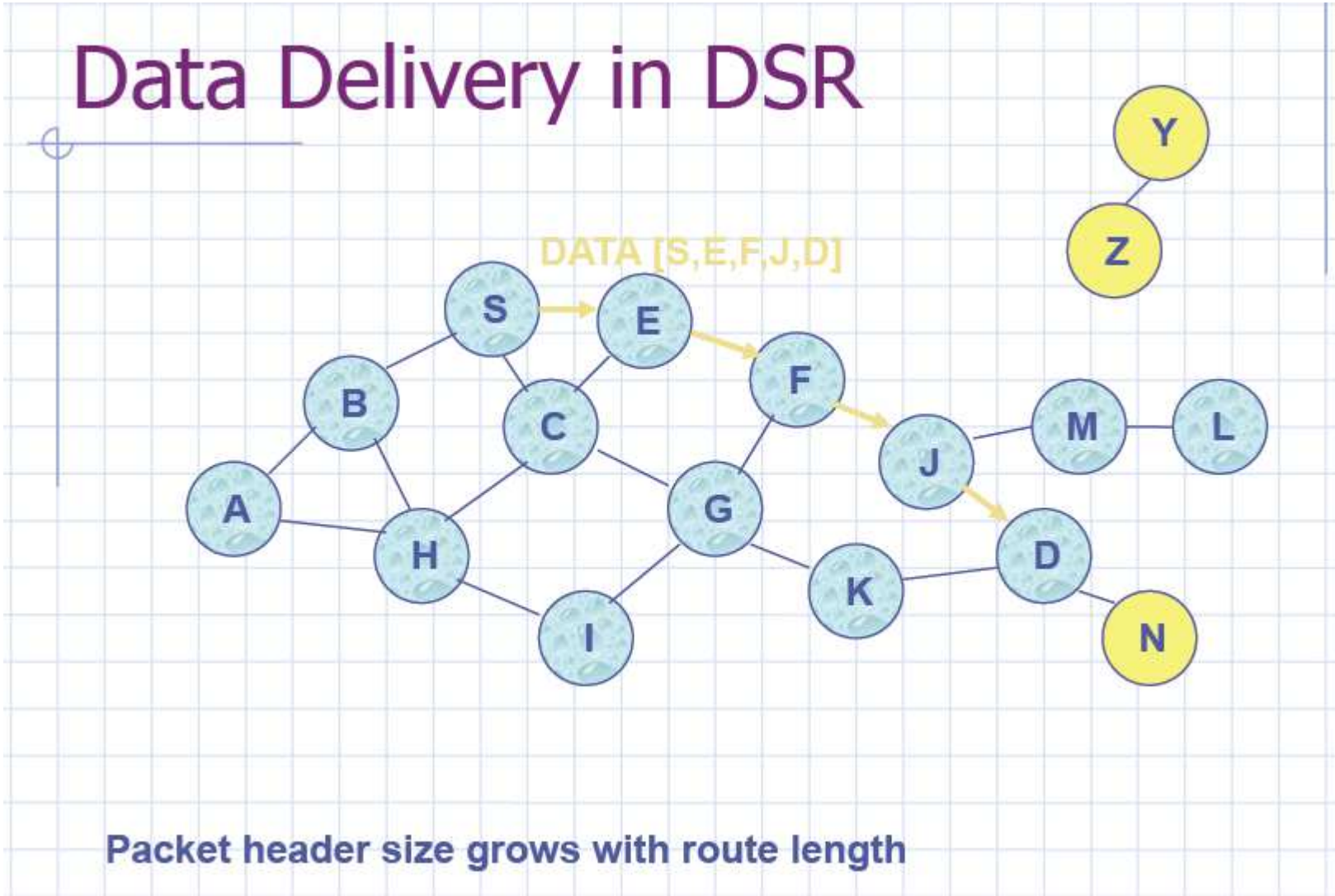

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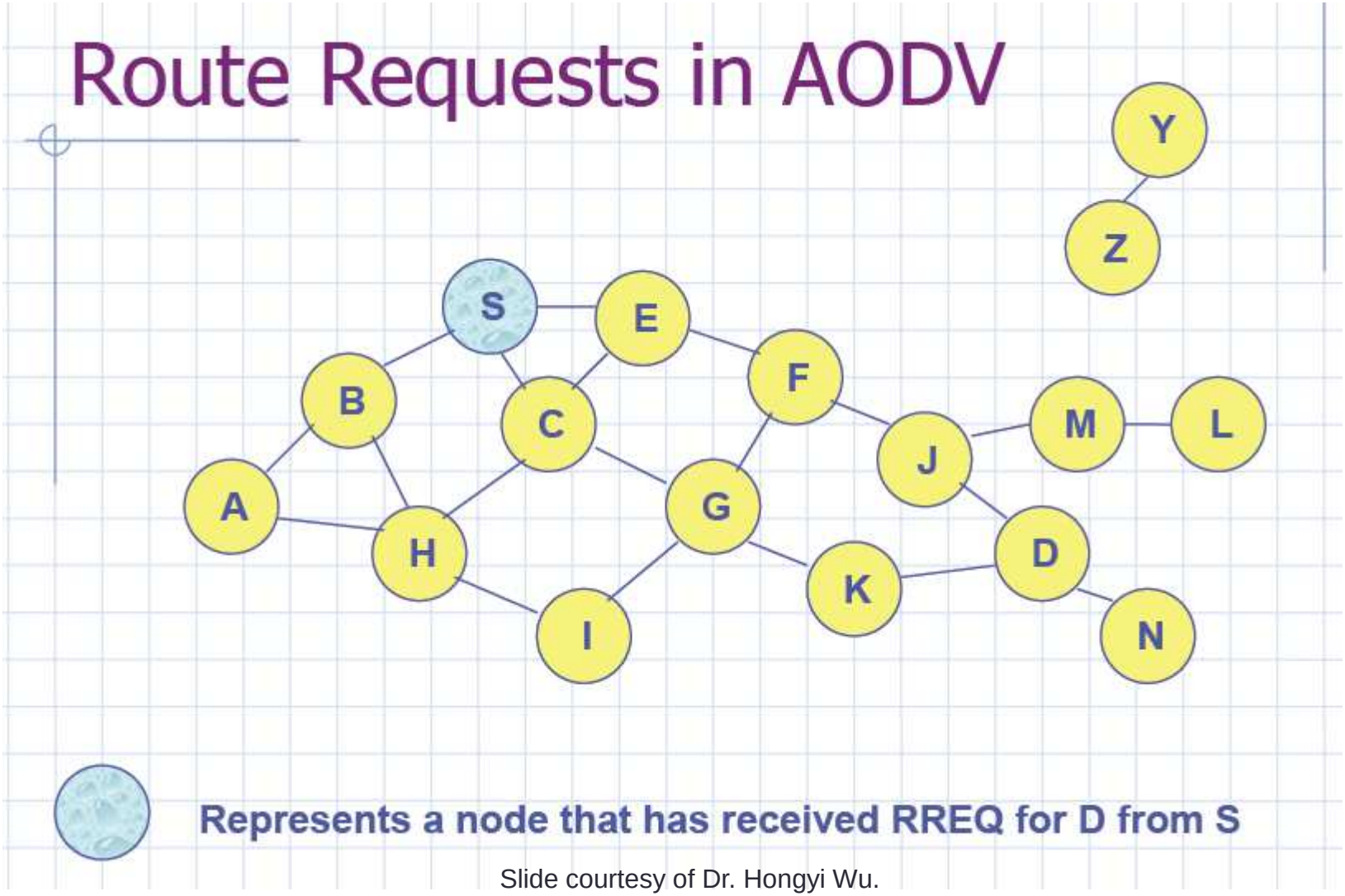
Ad hoc On-demand Distance Vector (AODV)



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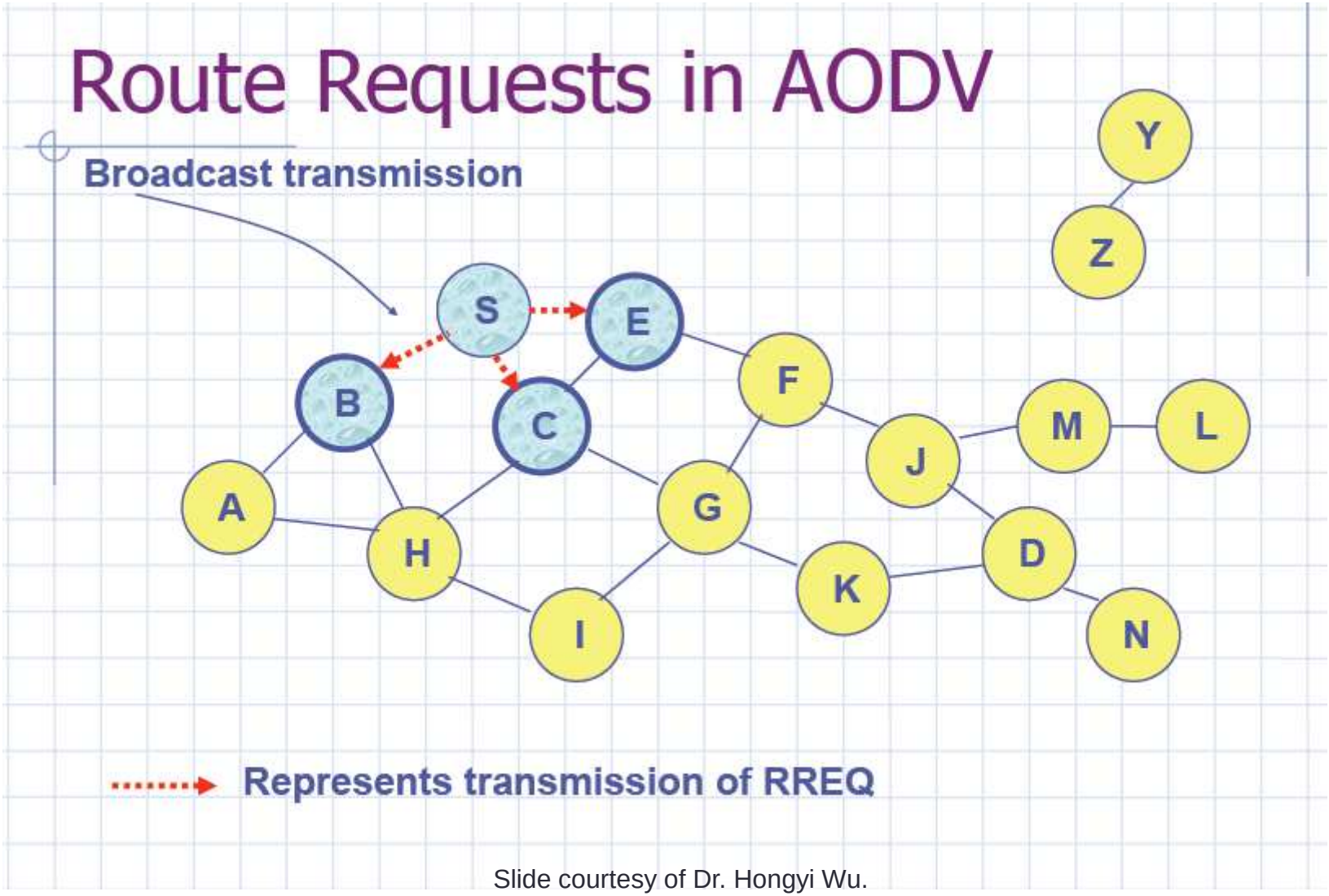

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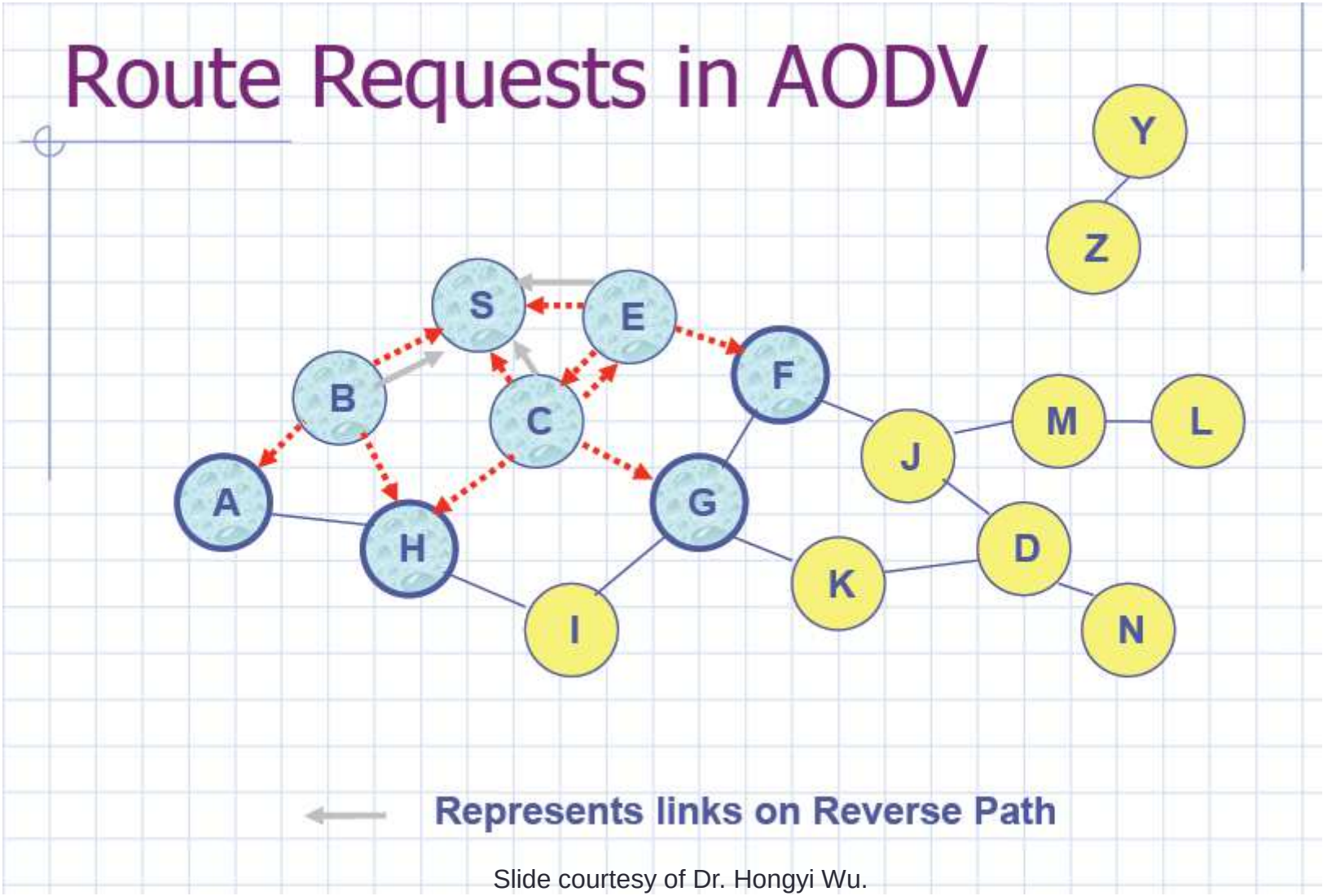

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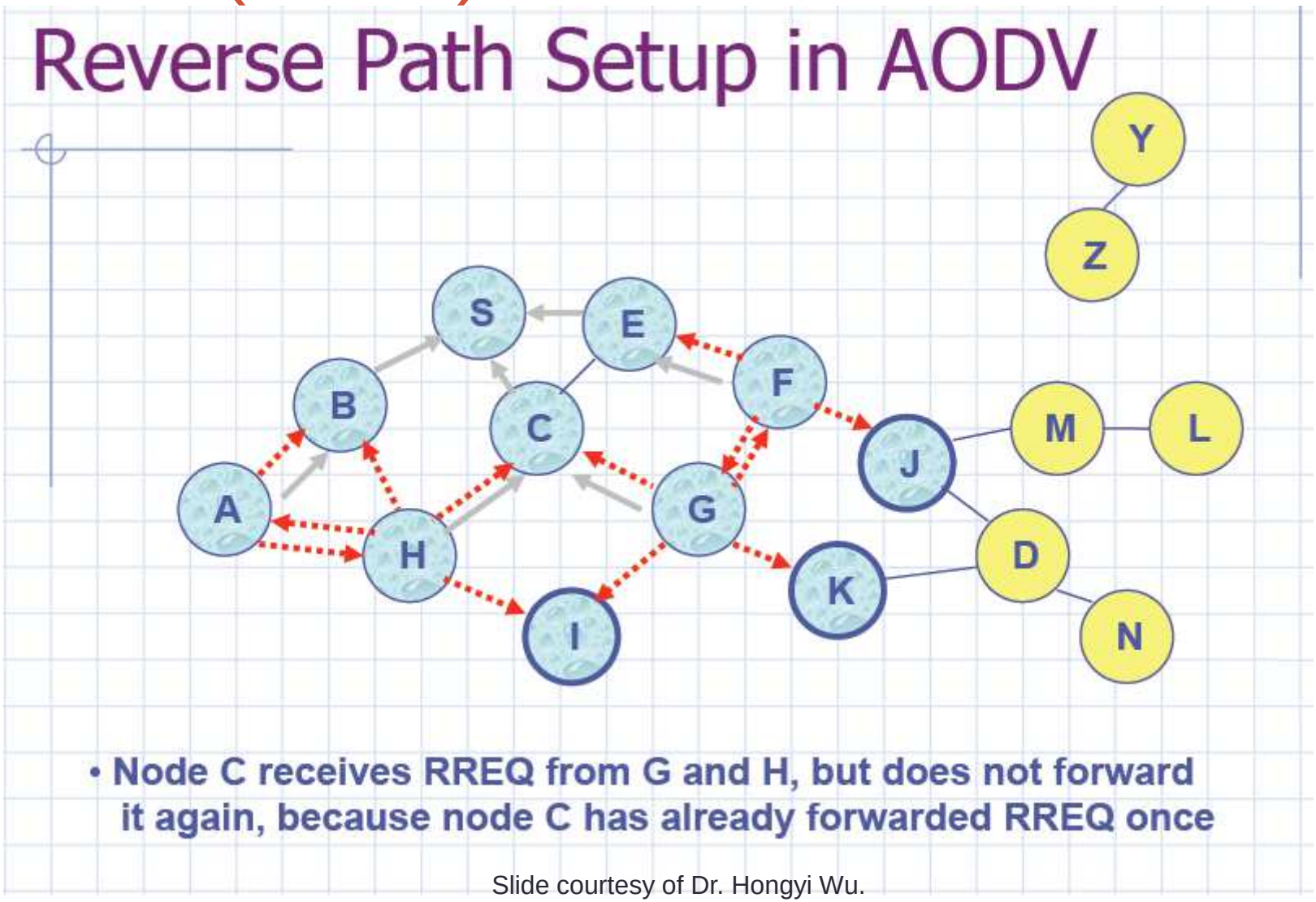

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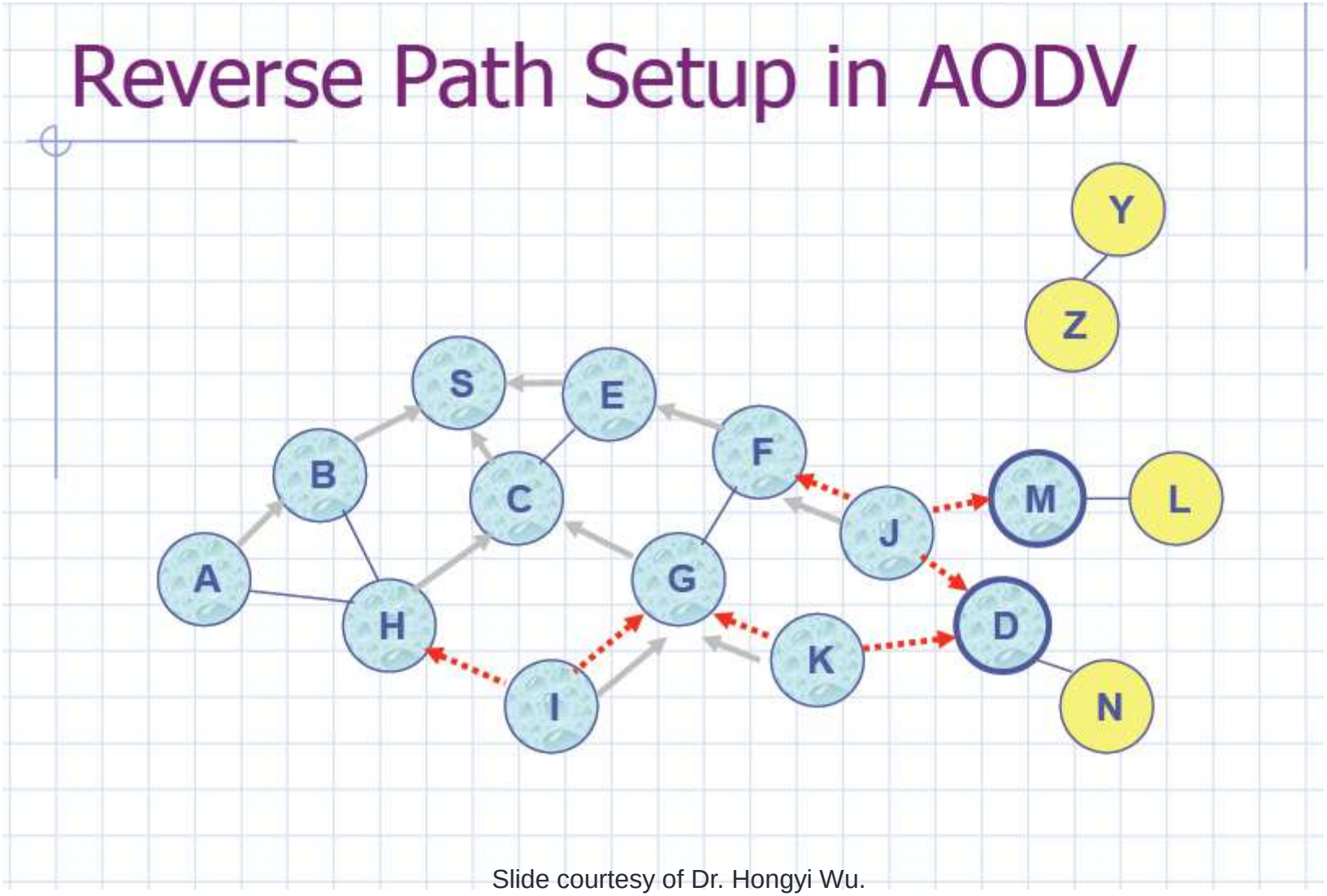

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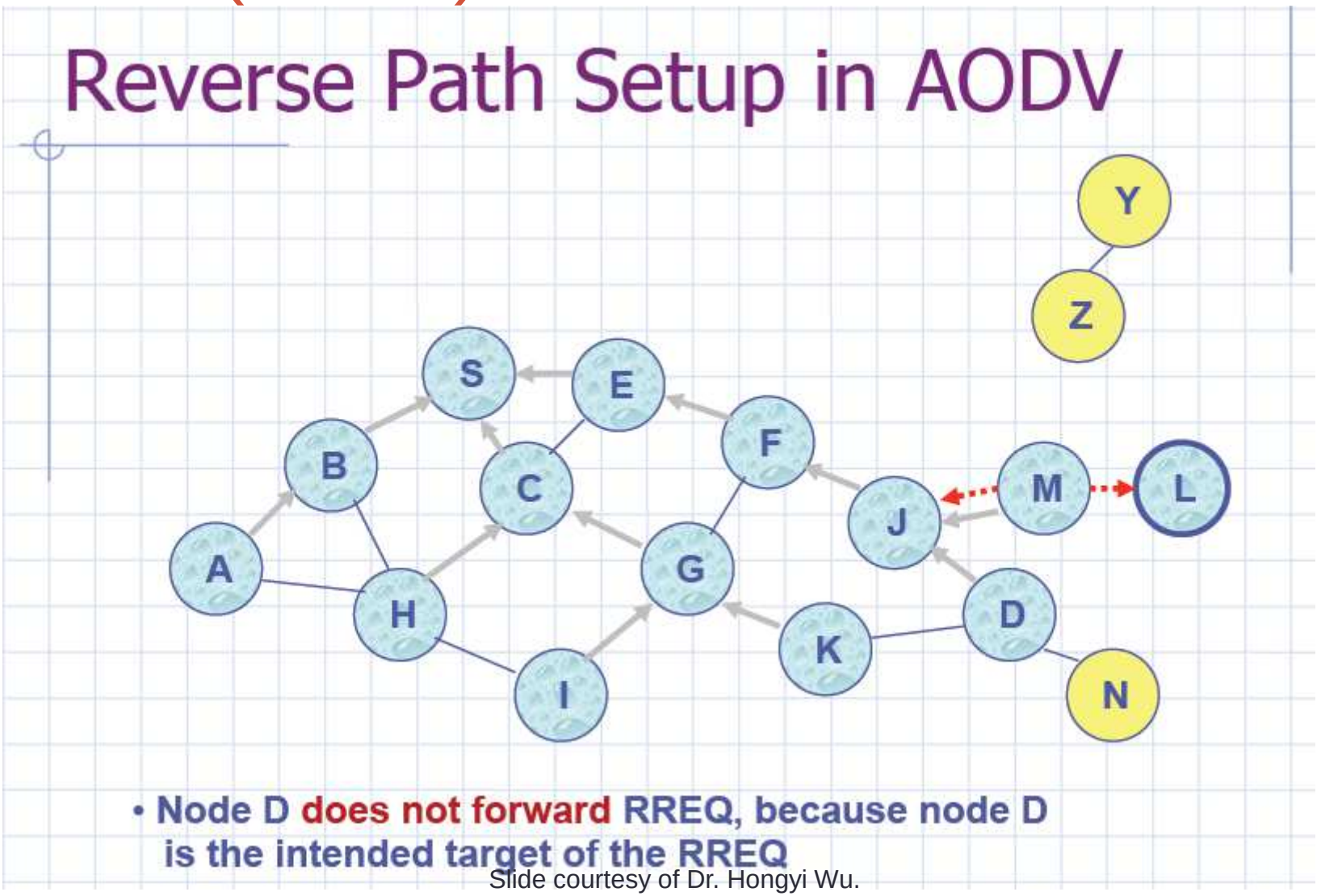

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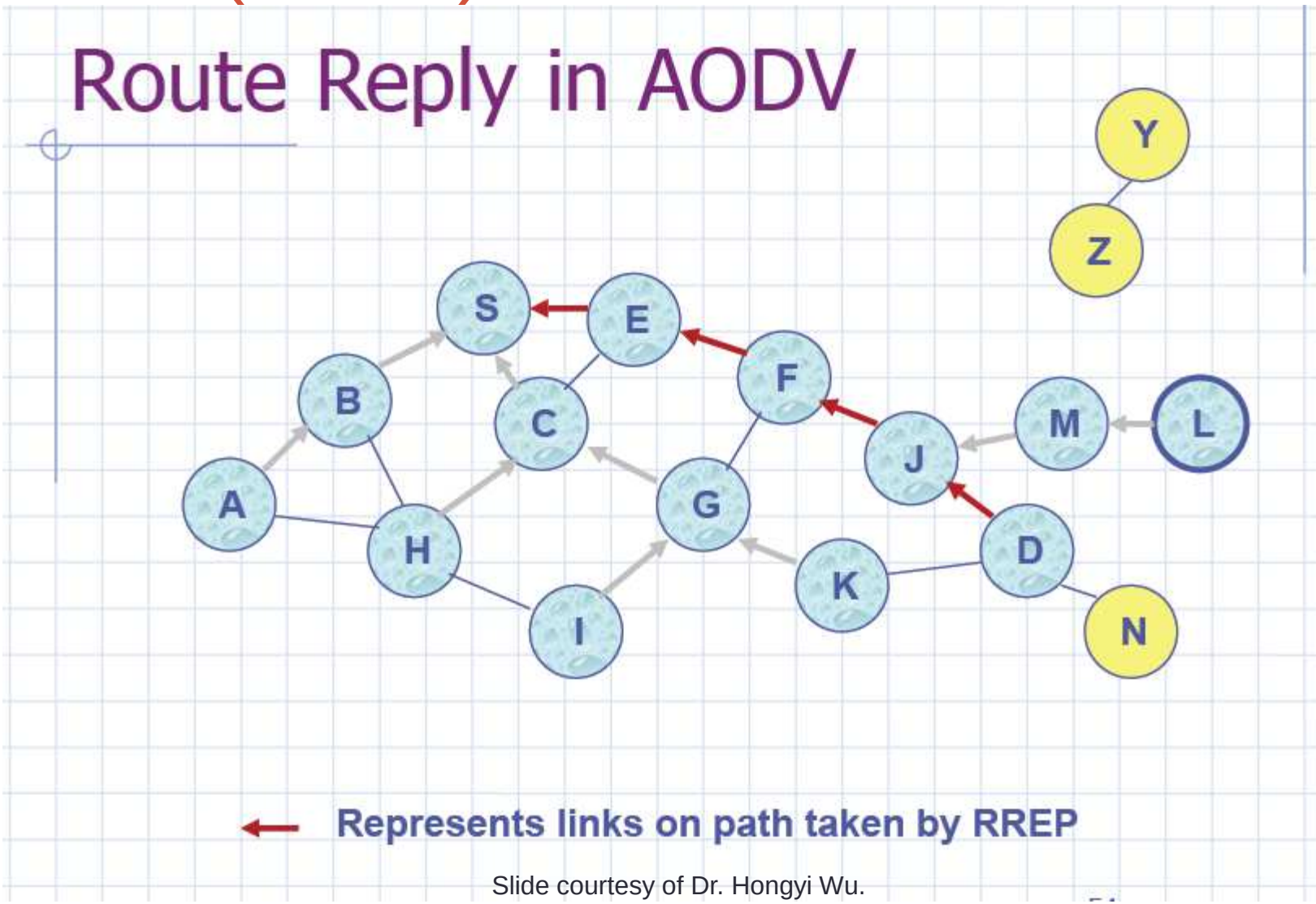

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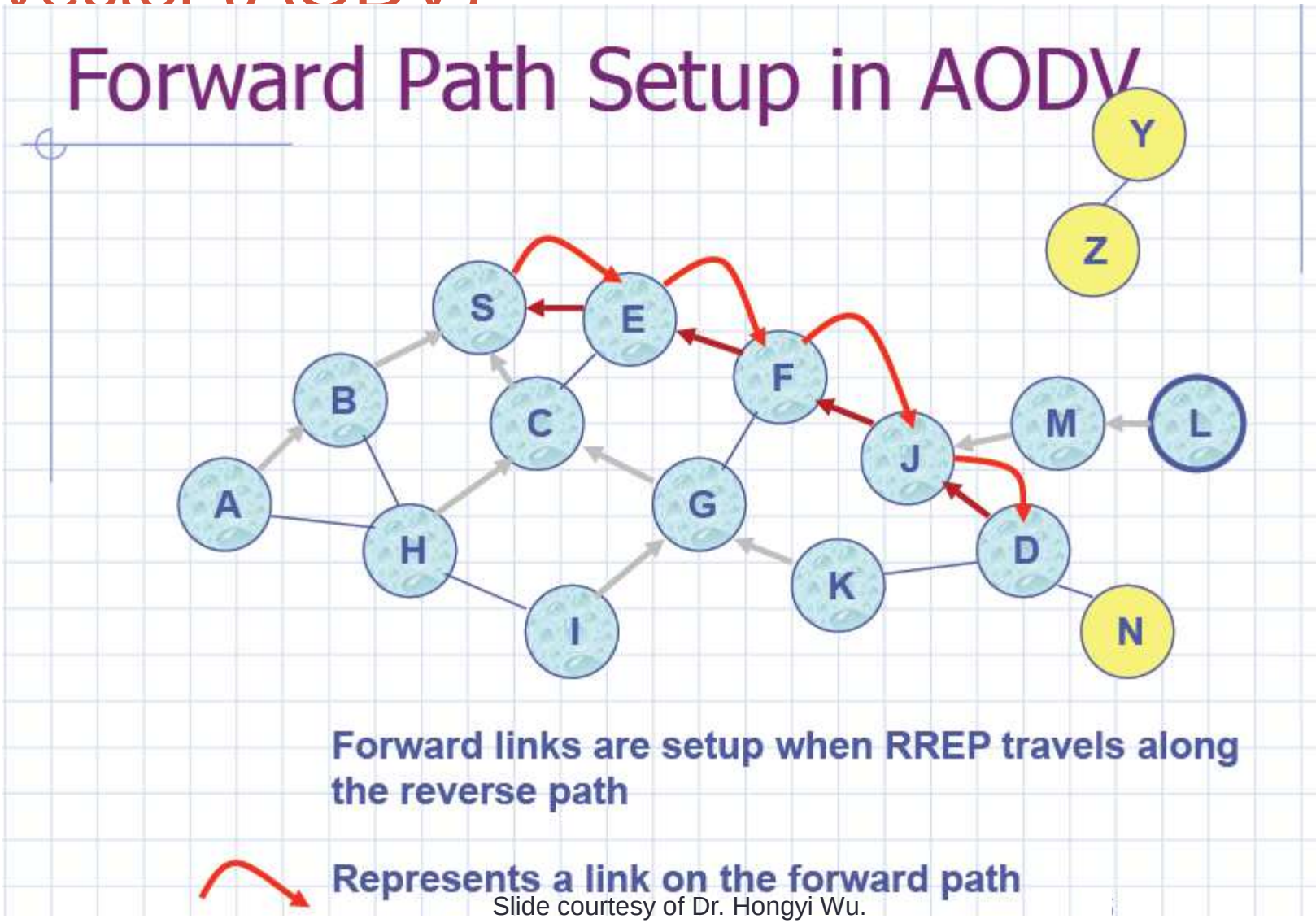

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