Mobility and MANET
Intelligent Transportation Systems

Rolland Vida

MANET routing

- **Proactive routing**
  - The routing table is continuously maintained
    - No matter if there is traffic or not
  - Relatively stable networks
  - DSDV – based on the Bellman-Ford algorithm
- **On demand, reactive routing**
  - Builds a route only if needed, if a packet has to be sent to the destination
  - The routes are temporary, are dismantled if not used
  - AODV
- Hybrid protocols
  - Combining the previous two
- Position-based protocols
  - Makes use of geographical position information for routing

Constraints

- Delay
  - Proactive protocols provide lower delay, as routes are prepared in advance, and always up to date, ready to use
  - Reactive protocols provide large delay, as the route from A to B has to be found, when needed
- Overhead
  - Proactive protocols have a large overhead, too much signaling traffic to build and maintain the routes, even if no real data to send
  - Reactive protocols have lower overhead, useless routes are not maintained
- Each application will choose the best protocol
  - Low mobility -> Proactive protocols
  - High mobility -> Reactive protocols

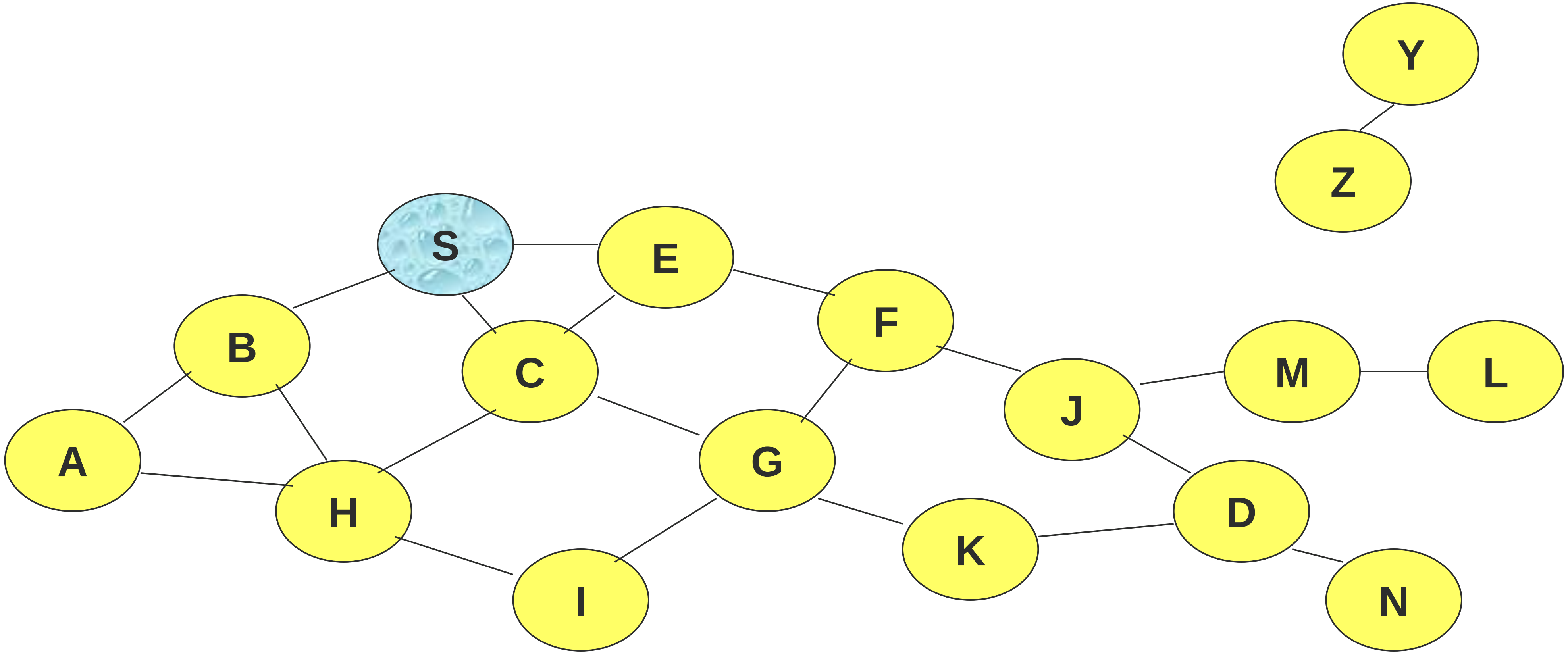
Ad Hoc On-Demand Distance Vector Routing (AODV)

- Reactive protocol
  - Maintains a routing table in each node, no need to store the route in the packet header
  - The route is built and maintained only if it is „active”

AODV

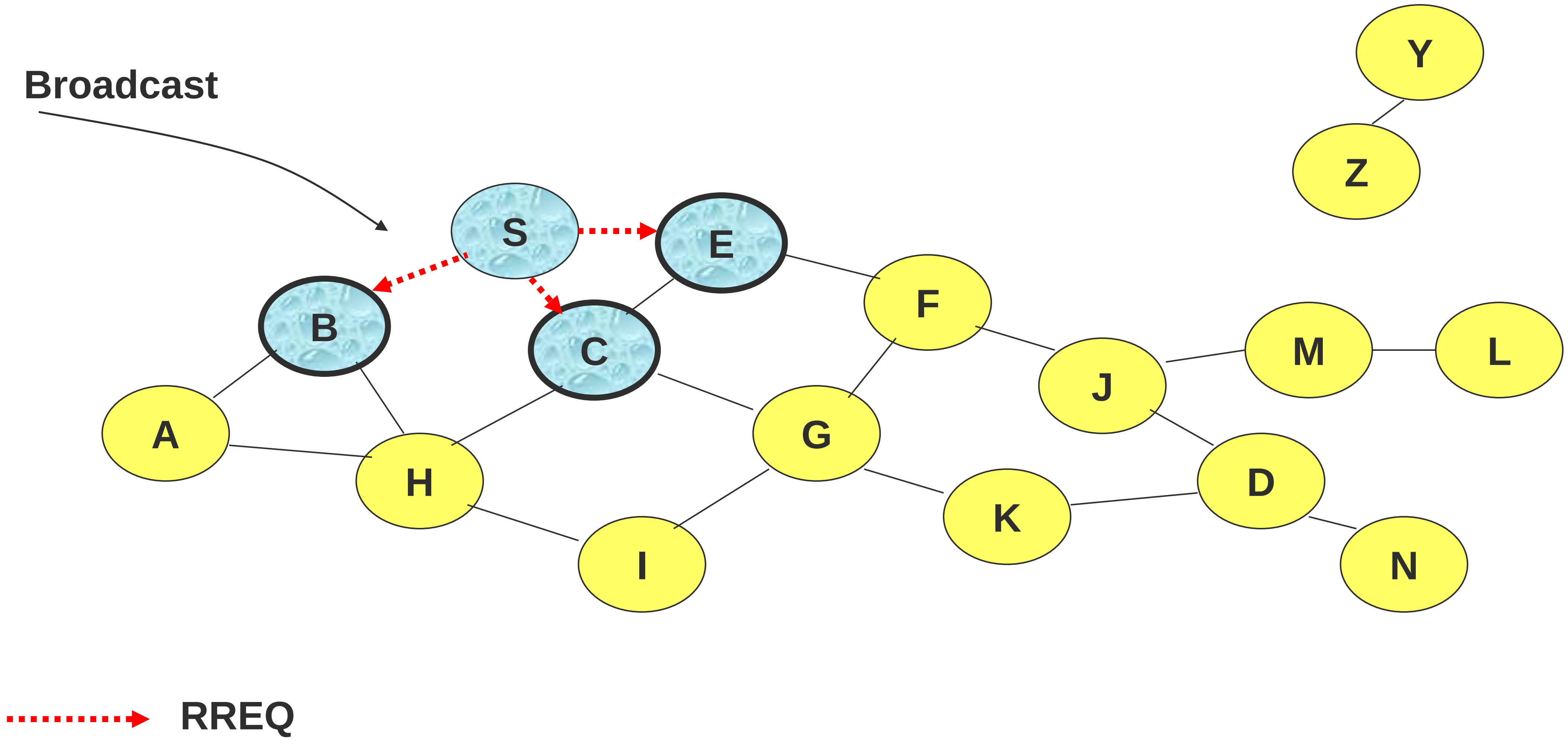
- To discover the route, the source broadcasts a **Route Request (RREQ) message**
- Those who receive it, rebroadcast it
- When a node rebroadcasts a Route Request message, it stores a **reverse path pointer** towards the node from where the request came
  - AODV symmetric (bi-directional) links
  - A small timer ensures that these records time out after a while
- If the RREQ arrives to the destination D, a **Route Reply (RREP)** message is sent back
- It will propagate along the path built from the reverse path pointers

Route Request - AODV

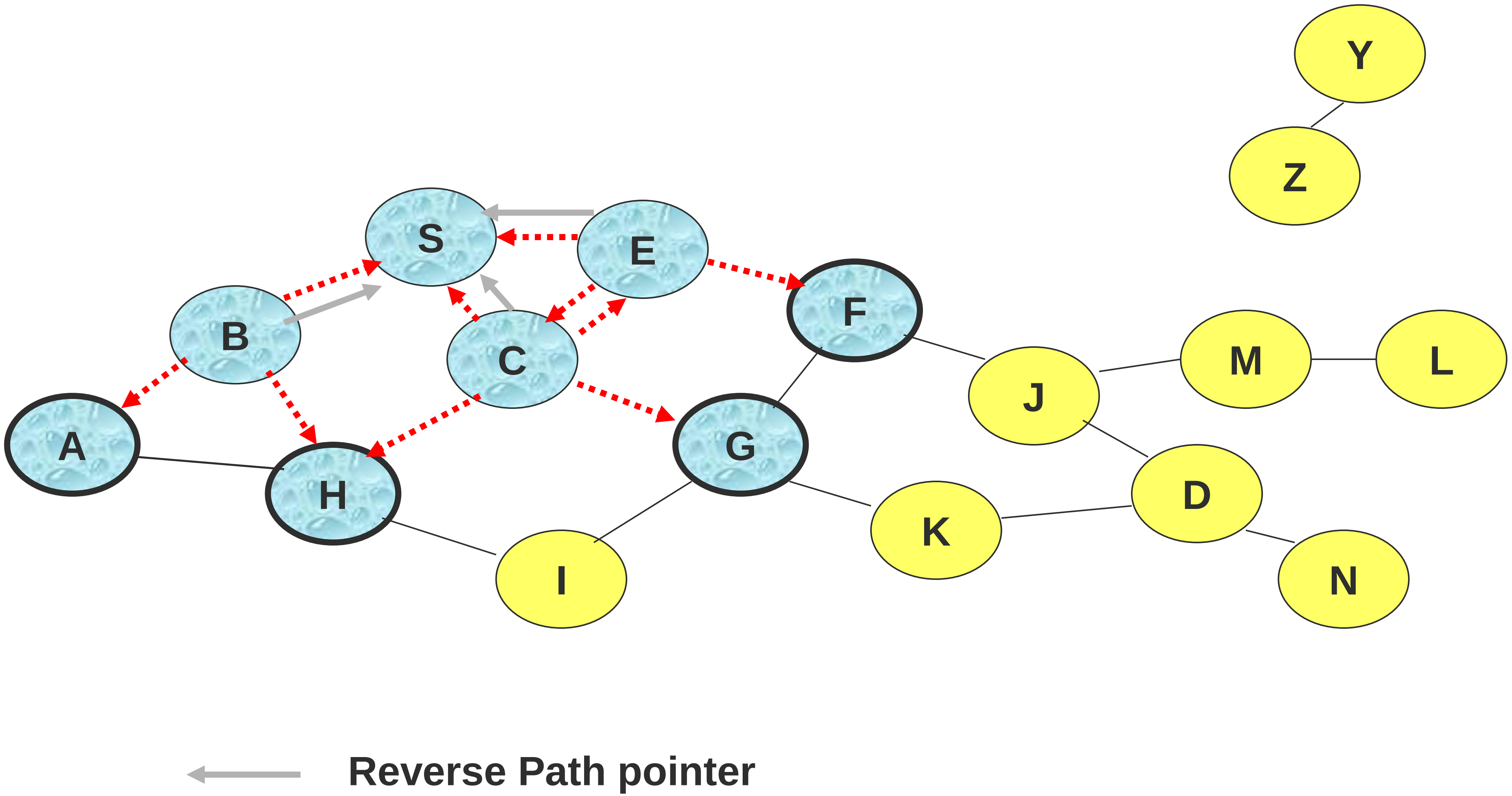


Node that already received a RREQ for D initiated by S

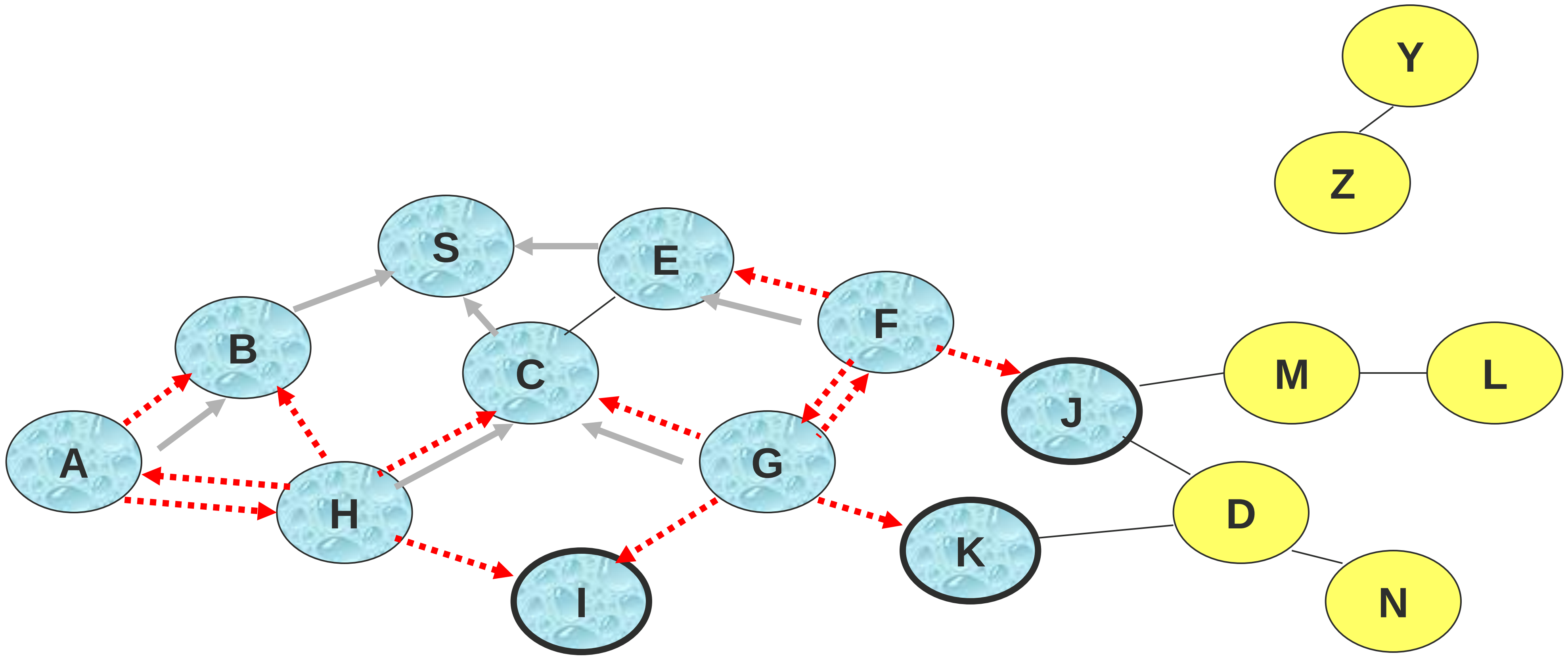
Route Request - AODV



Route Requests - AODV



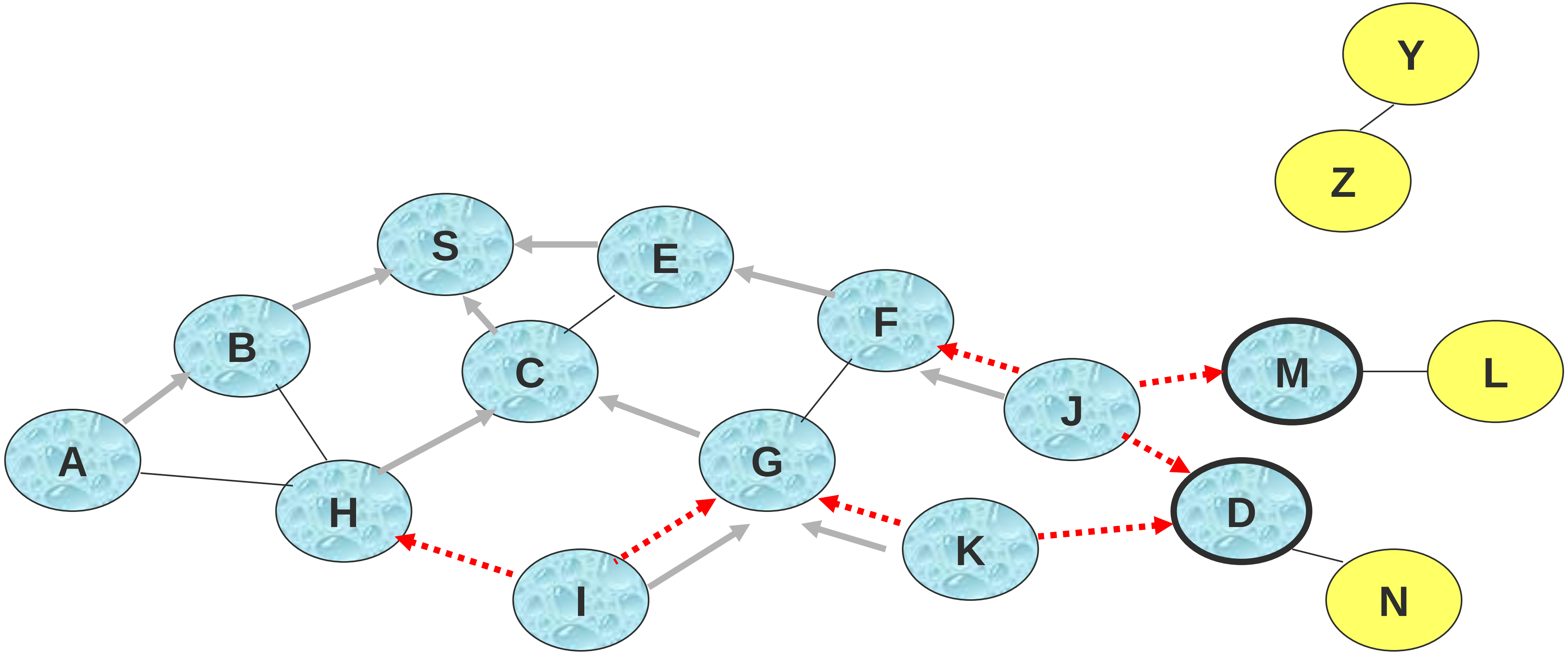
Reverse Path - AODV



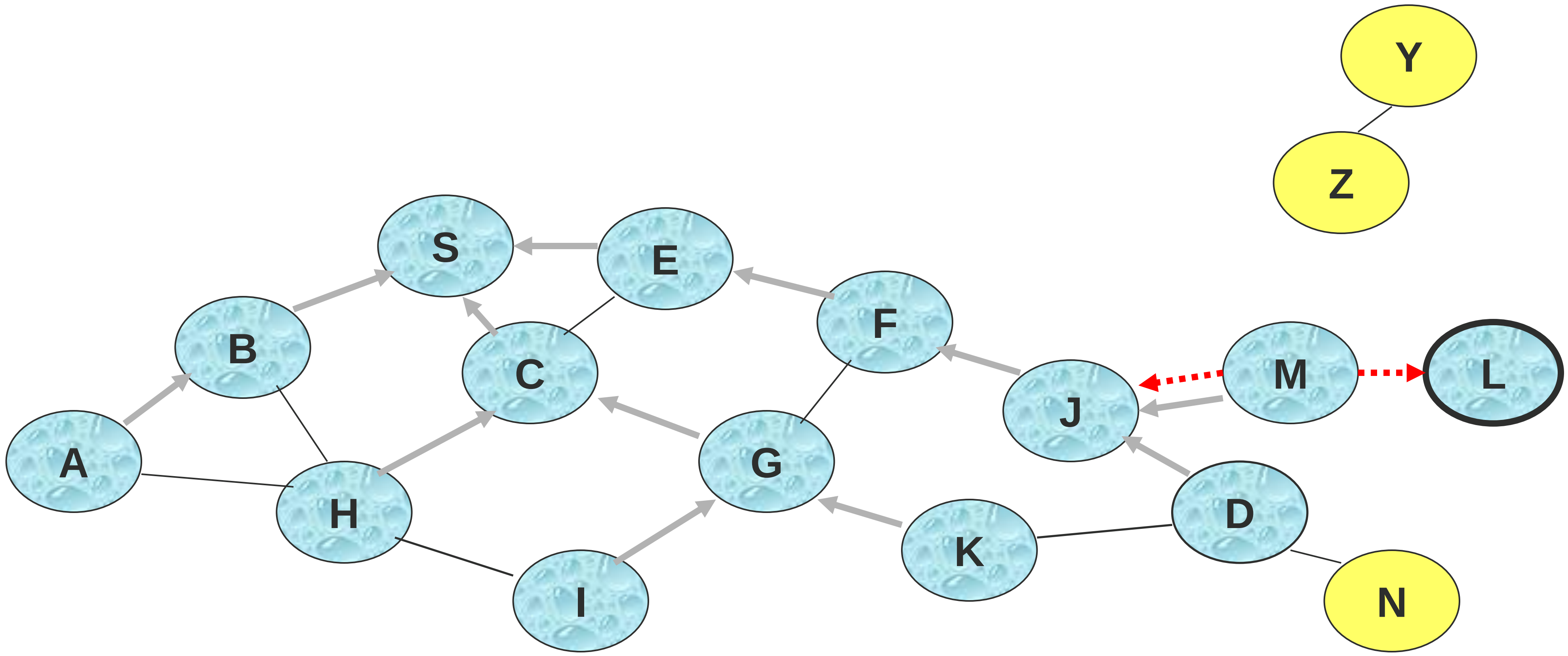
- C receives a RREQ from neighbors (G and H)

But does not rebroadcast it again

Reverse Path - AODV

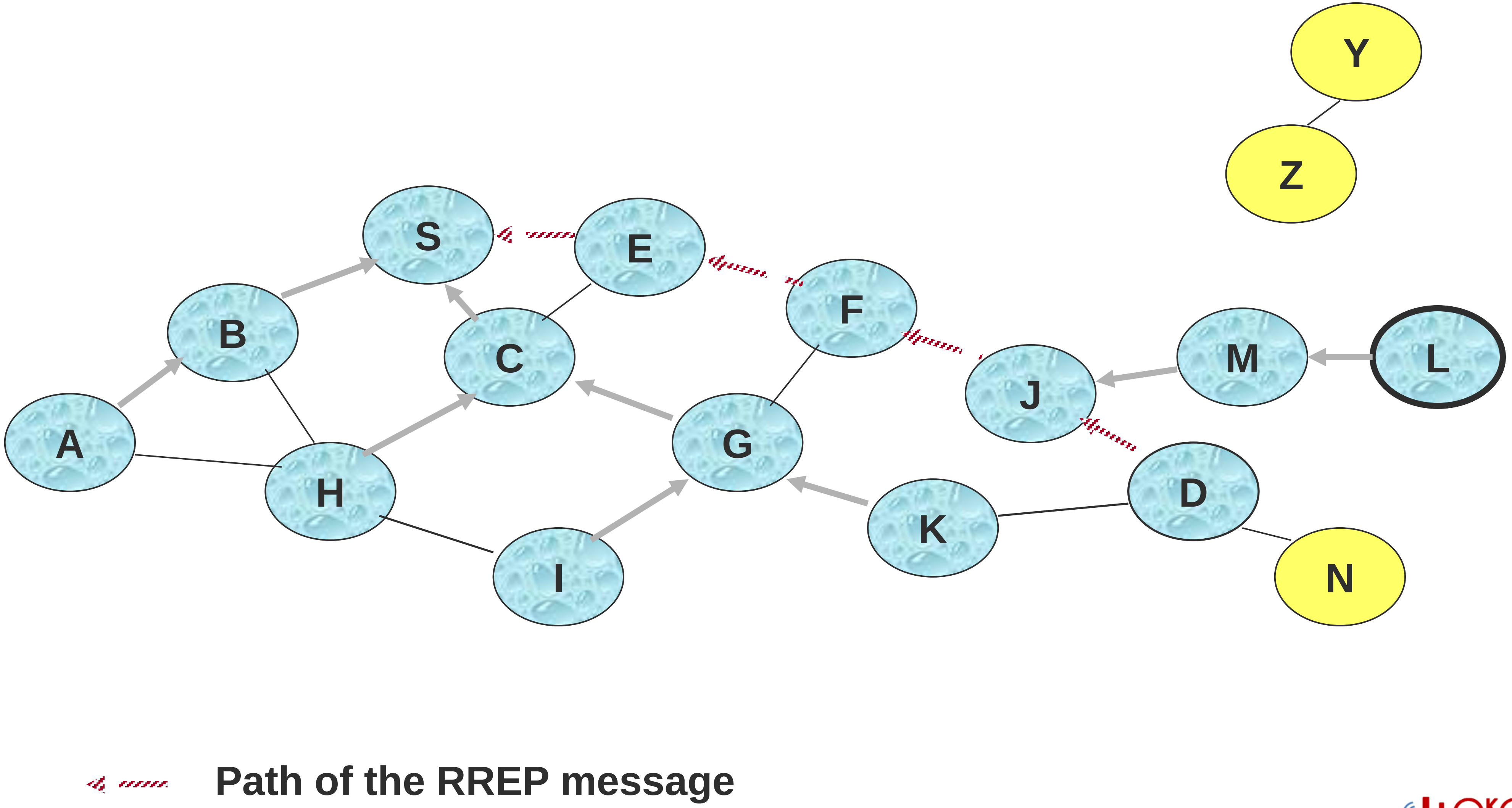


Reverse Path - AODV

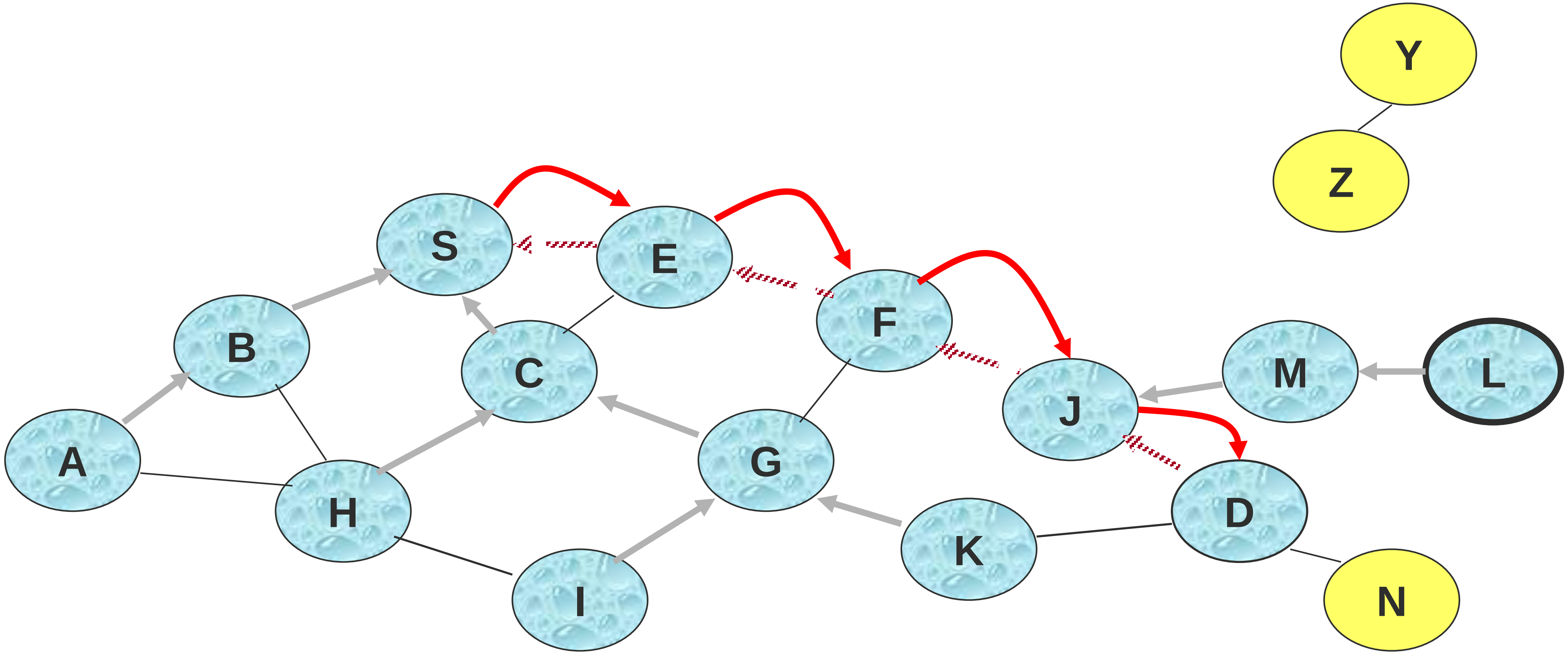


- node D does not forward anymore the RREQ message, as he is the destination

Route Reply - AODV



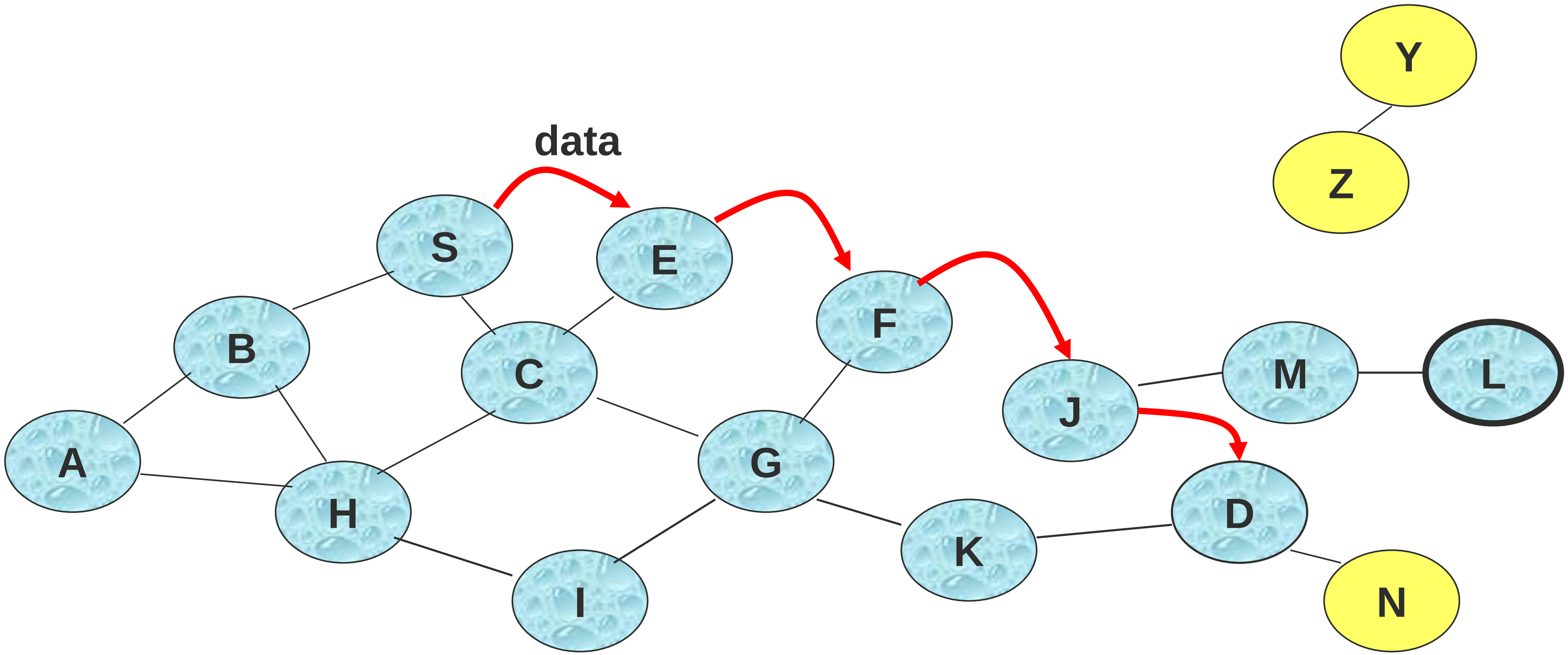
Forward Path - AODV



As the RREP message travels from D to S, forward path pointers are stored in the intermediate nodes

Forward path pointer

Data sending - AODV



For sending the useful data, these forward path pointers are used

The path is not included in the header

Timers

- The reverse path records are deleted after a while from the routing tables
  - We should take into account the specificities of the wireless domain and the size of the network, leave time for the RREP message to propagate back before deleting the record
- The forward path pointer is deleted if it becomes inactive – no traffic
  - *active_route_timeout*
  - If no traffic, the record is deleted, even if the path is still valid

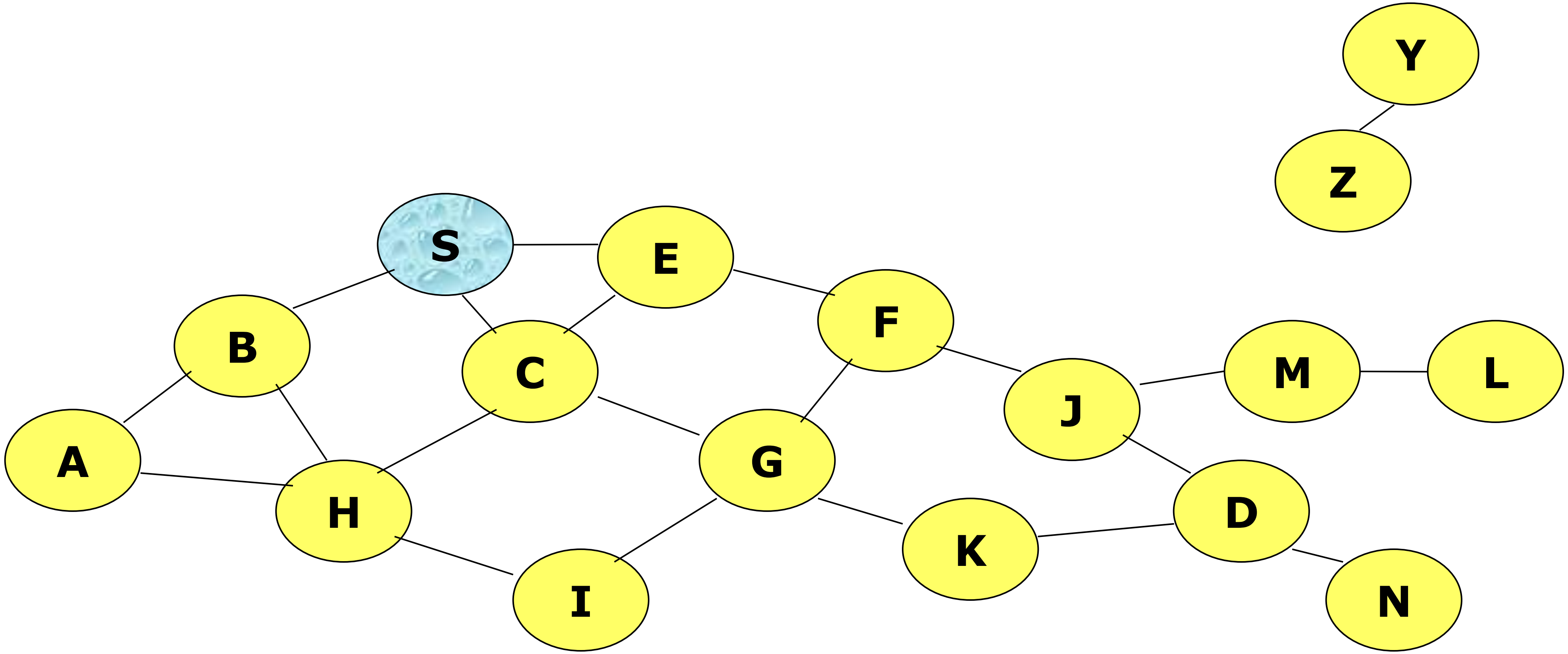
Optimization: Expanding Ring Search

- Searching an expanding territory
- The RREQ messages are first sent out with a small Time-to-Live (TTL) value
  - After each hop the TTL value is decreased
  - If 0, the message is dropped
  - Used in many protocols that are based on flooding
- If no Route Reply until a timer expires, the value of the TTL is increased
  - After a few steps the search will cover the entire topology

Dynamic Source Routing (DSR)

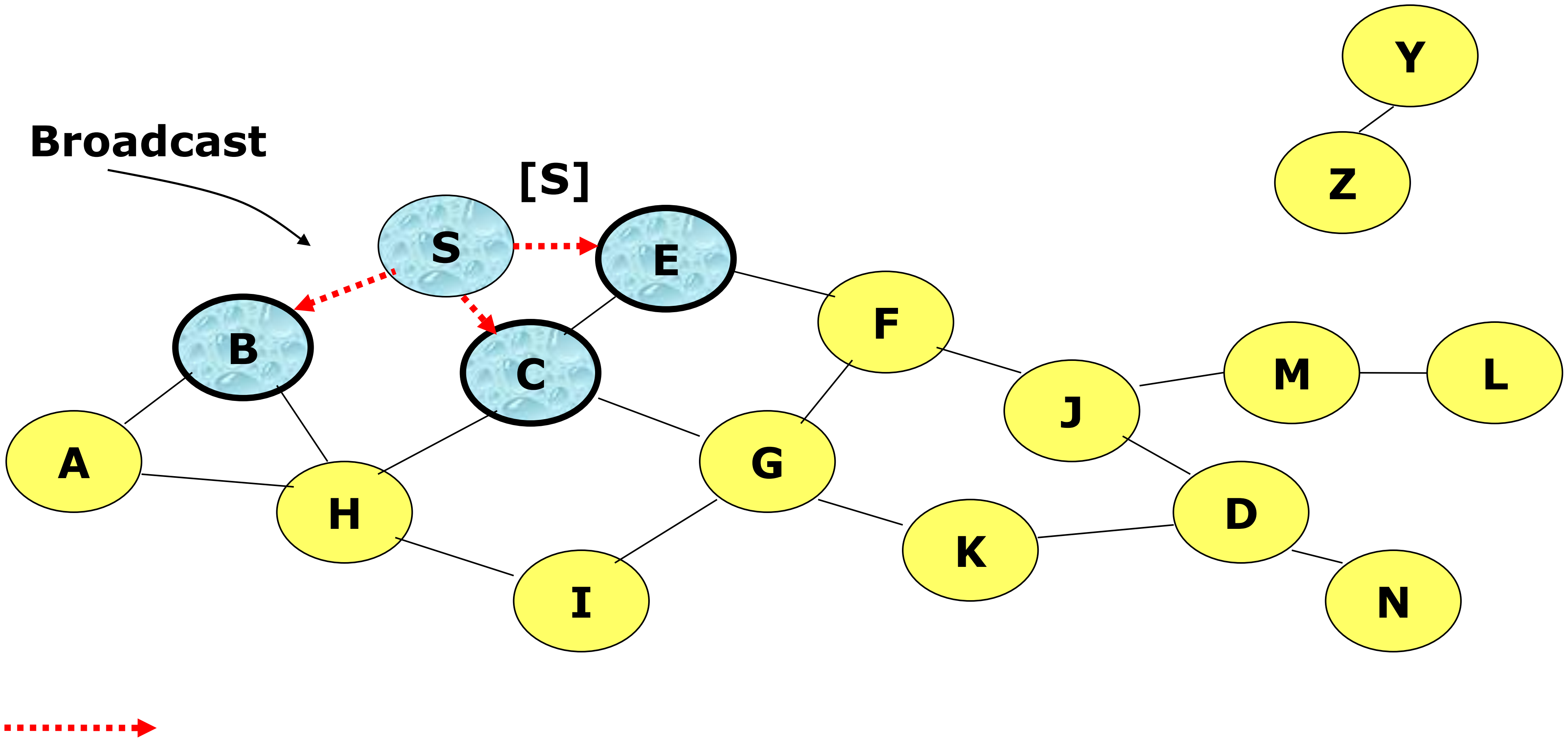
- If the source **S** wants to send something to destination **D,** it initiates route discovery
- **S** floods the network with Route Request (**RREQ**) messages
- Each intermediate node adds his ID to the RREQ before forwarding it

DSR Route Discovery



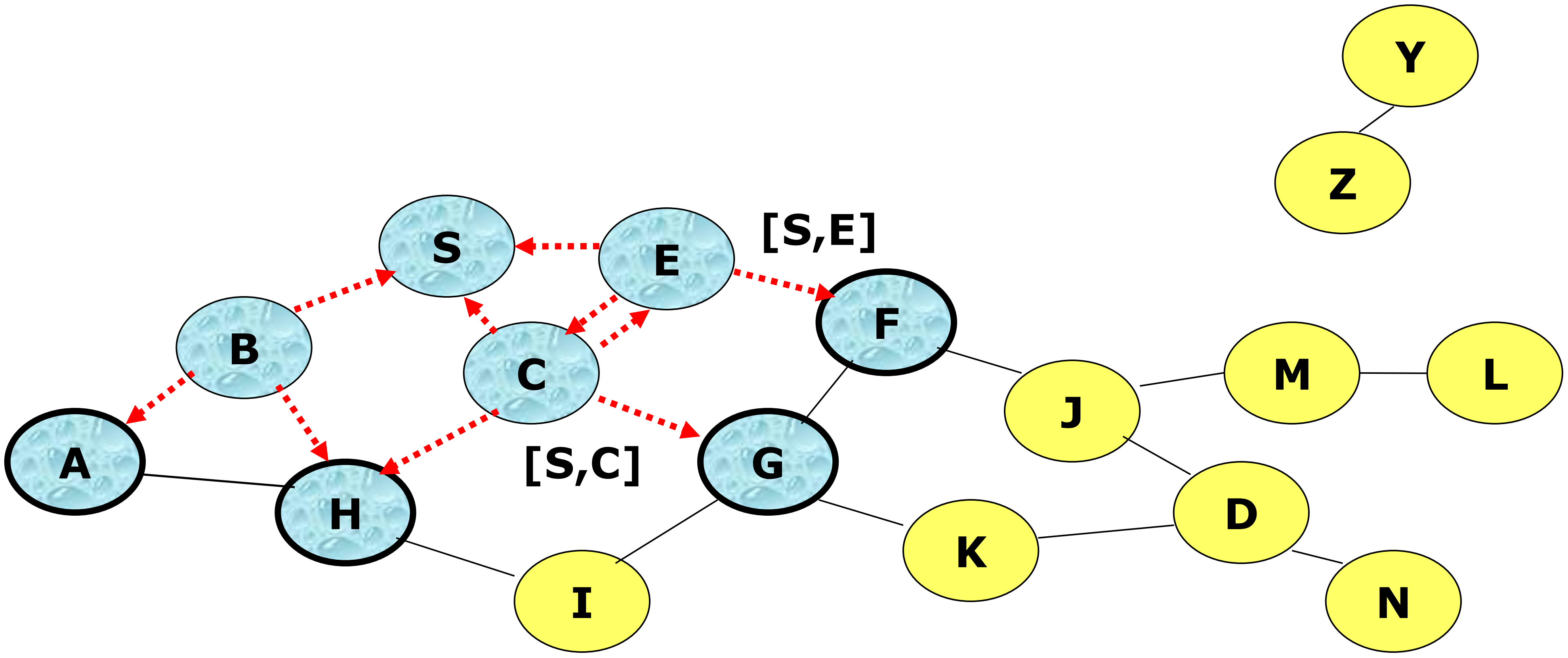
Nodes that already received the RREQ from S, regarding D

DSR Route Discovery

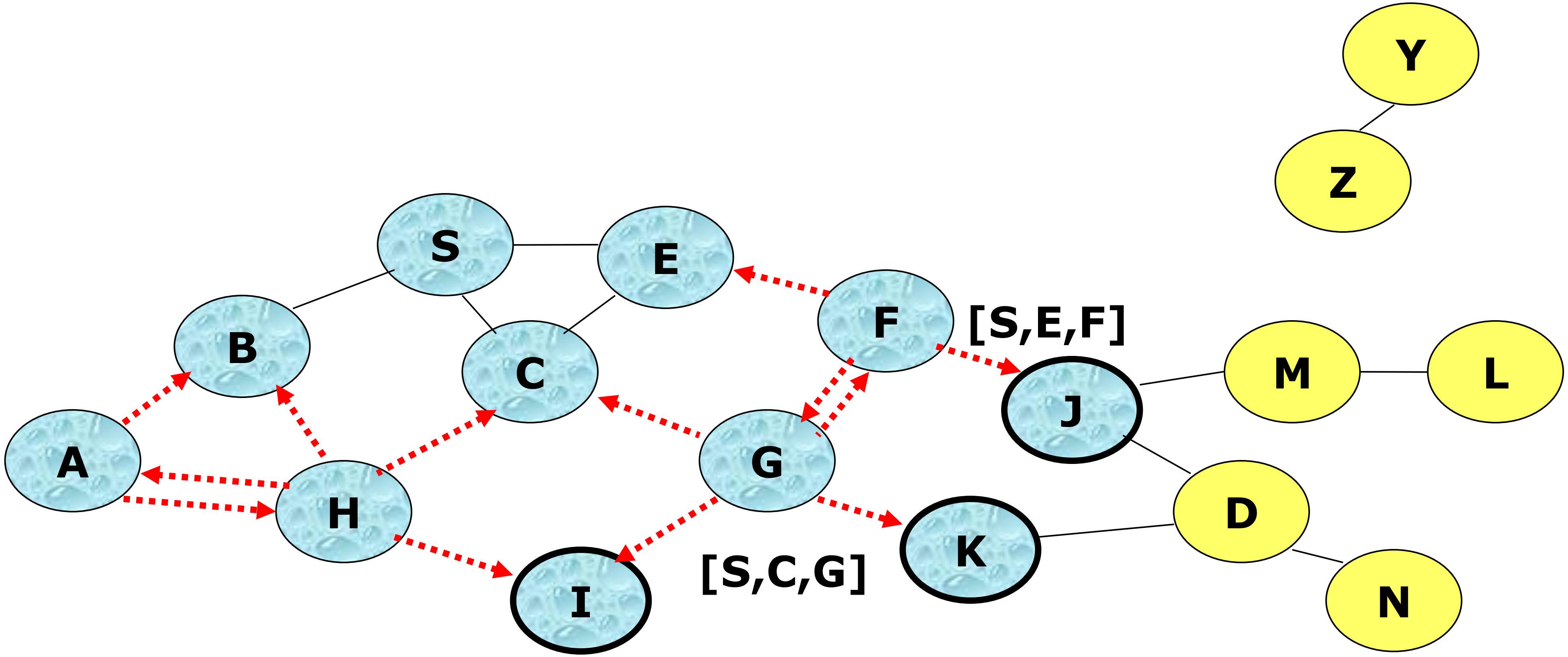


RREQ
[X, …] intermediate nodes already added to the path

DSR Route Discovery

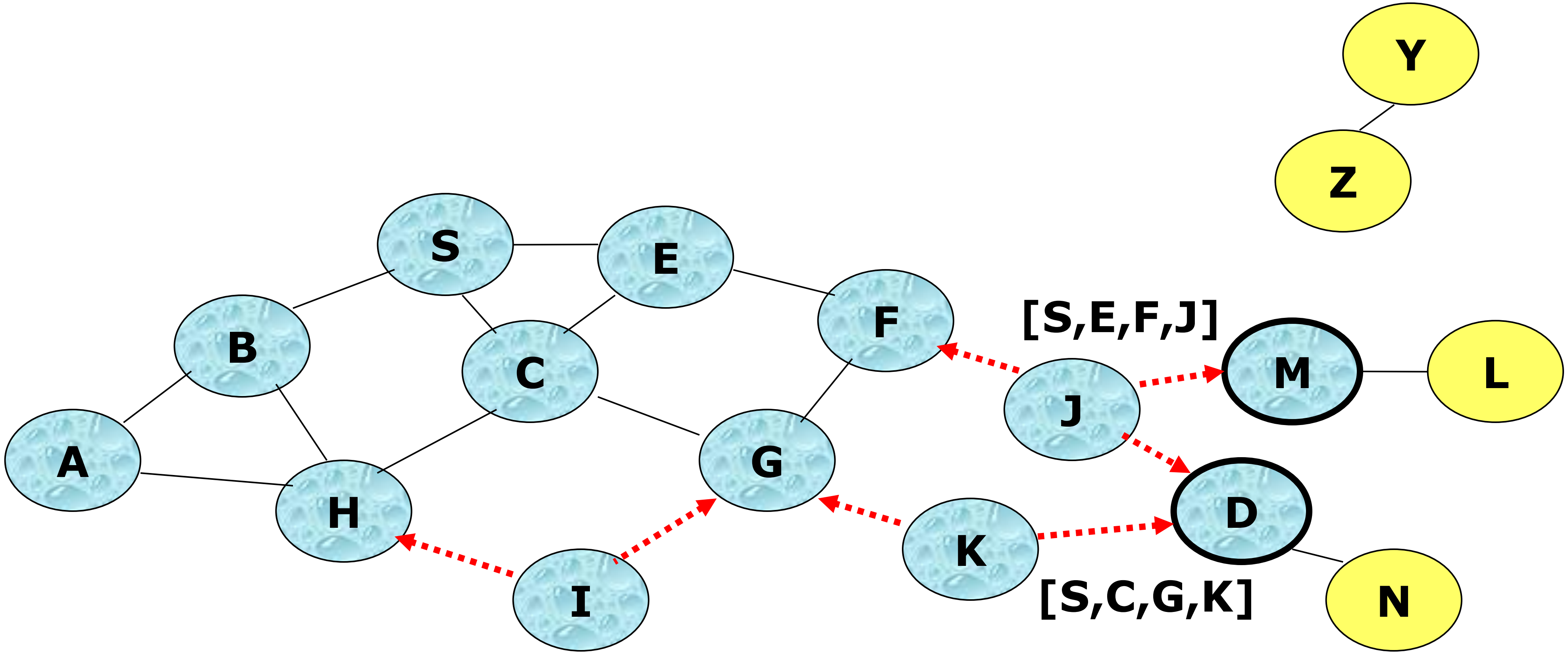


DSR Route Discovery

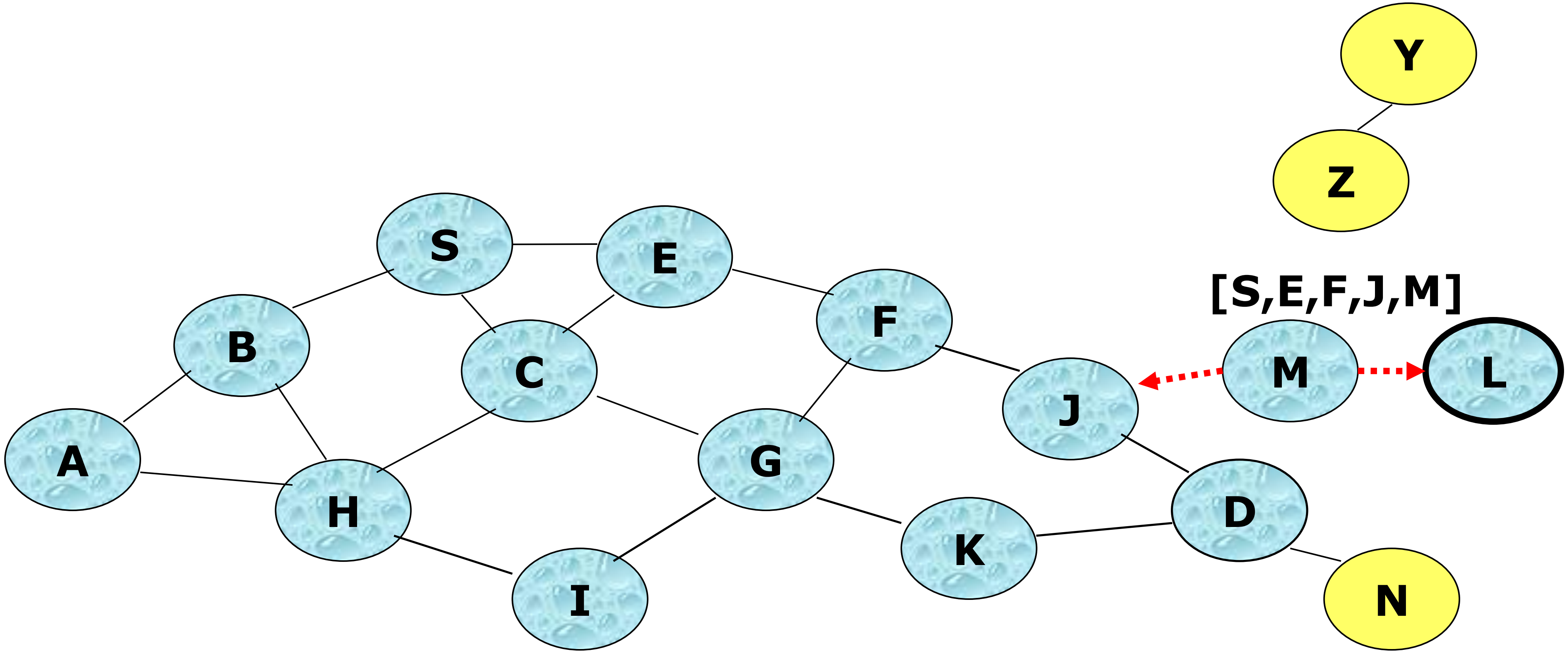


Restricting the flooding (like in AODV):
C receives the RREQ again from G and H, but does not forward it again

DSR Route Discovery



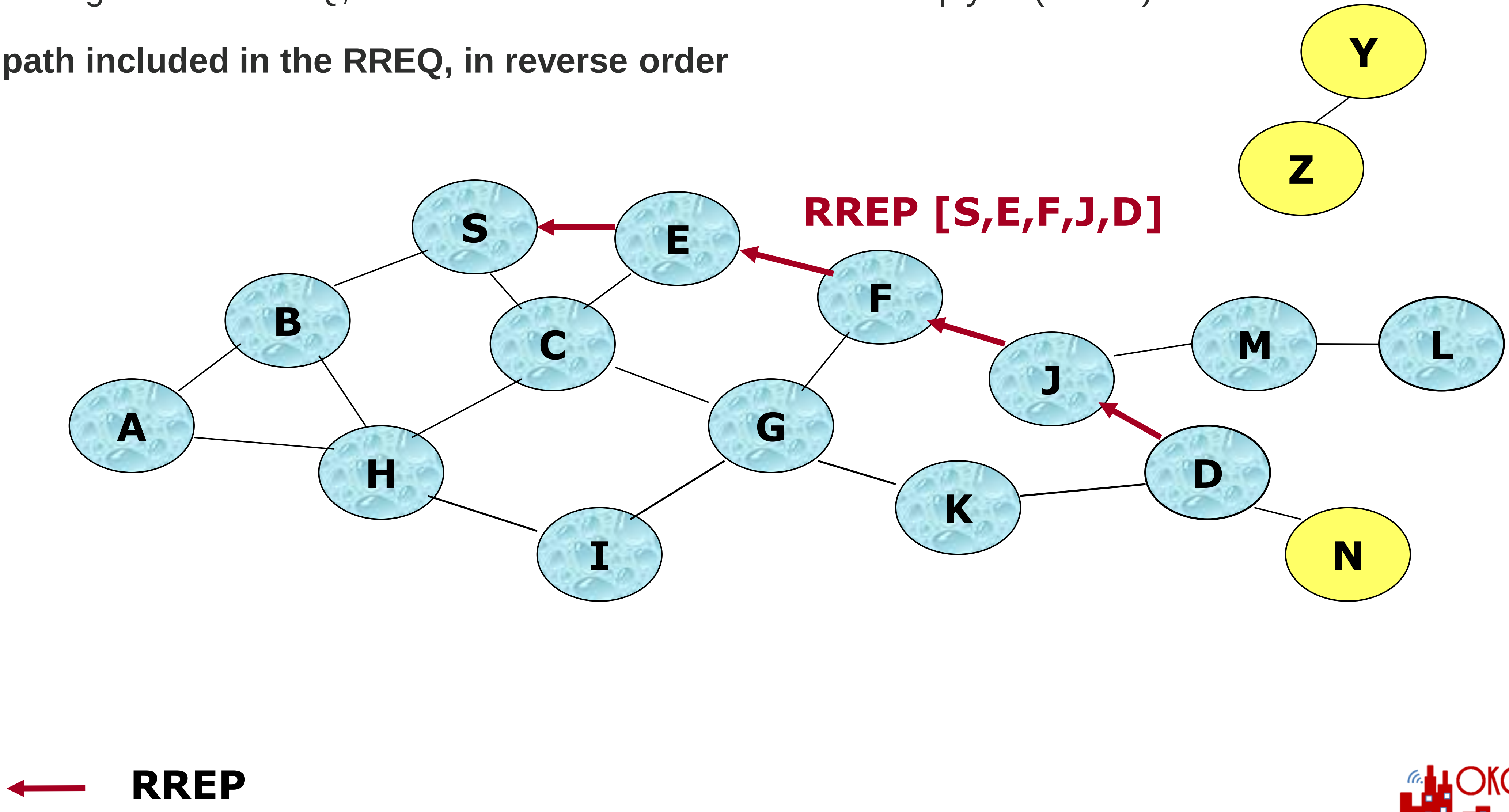
DSR Route Discovery



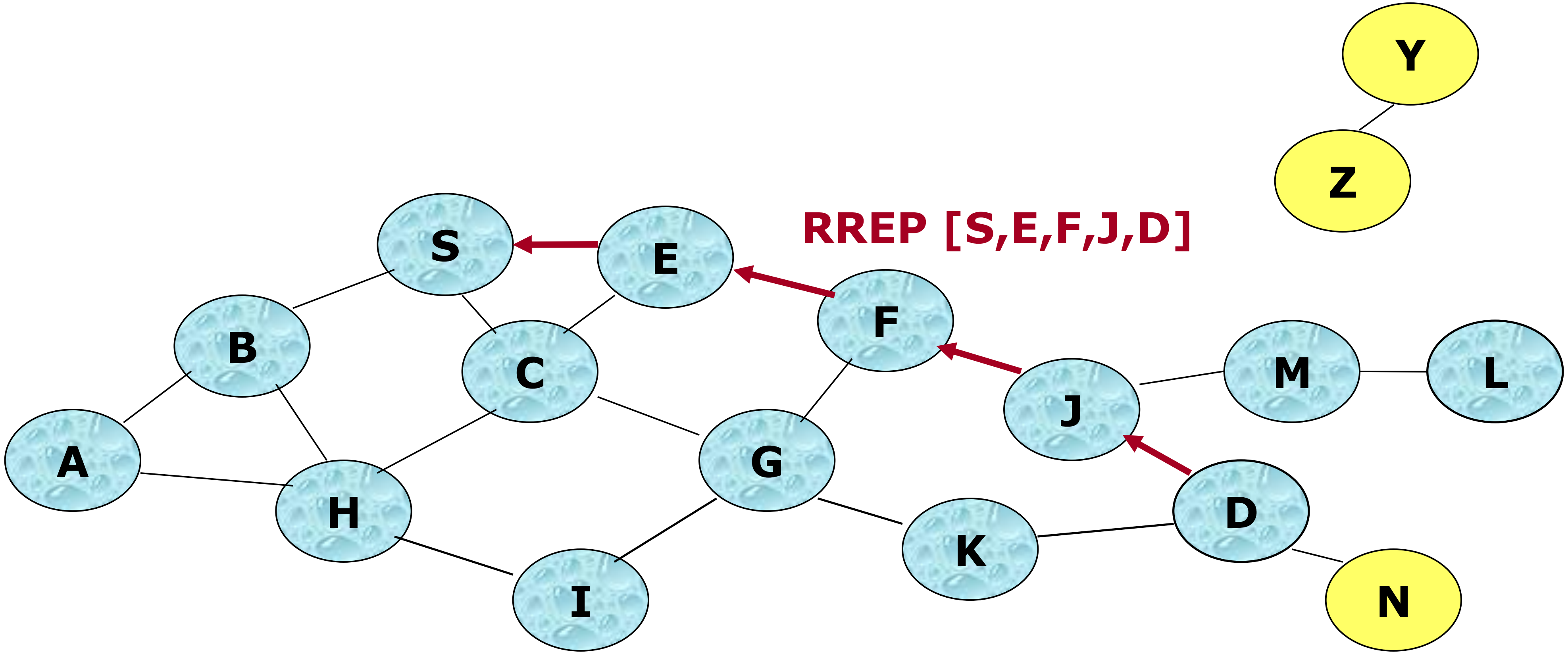
D stops the broadcast of RREQ, as it is the destination

DSR Route Discovery

- After receiving the first RREQ, destination D sends back a Route Reply-al (**RREP**)
- **On the path included in the RREQ, in reverse order**

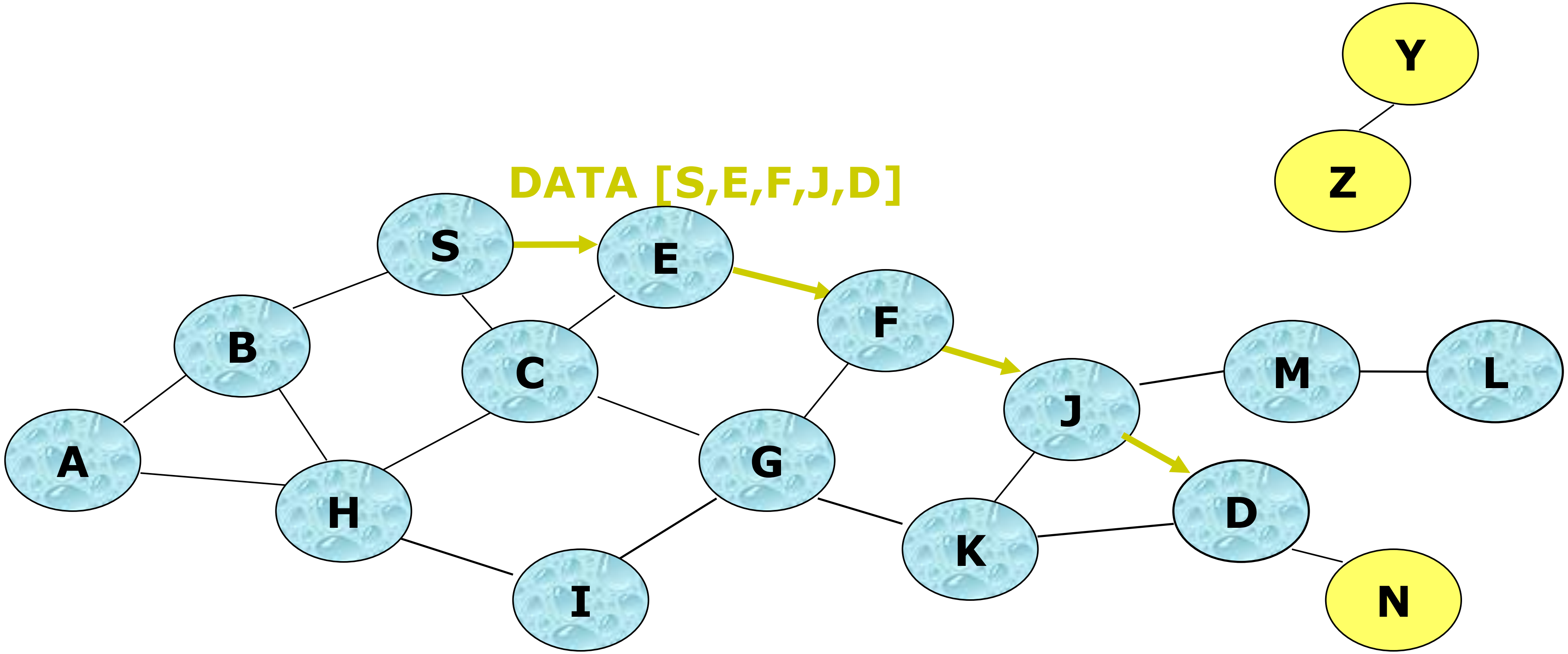


DSR Route Reply



RREP routing message

Data Delivery in DSR



The header increases with the path length

Position-based routing

- Eliminate some drawbacks of the topology-based routing algorithms
- The source makes use of some **localization service**, and finds out the geographical position of the destination.
- If we know the position of the destination, there is no need to build and maintain routes in advance
  - Instead of building the routes, we need a **forwarding strategy**
  - At each node, we select the next hop based on the position of the destination and the position of the neighbors

Localization service

- **Localization service**
  - Helps a node to determine its position
  - In an ad hoc network a localization server is not always available

- The localization service can be provided by one or several nodes:
  - „some/all to some/all"
  - „Chicken-egg" problem: but how do we know the position of the localization server?

- If a source does not know the position of the destination, makes use of such a localization service
  - In case of a cellular (mobile) network, localization is centralized, and at cell level
  - It cannot be applied in ad hoc systems

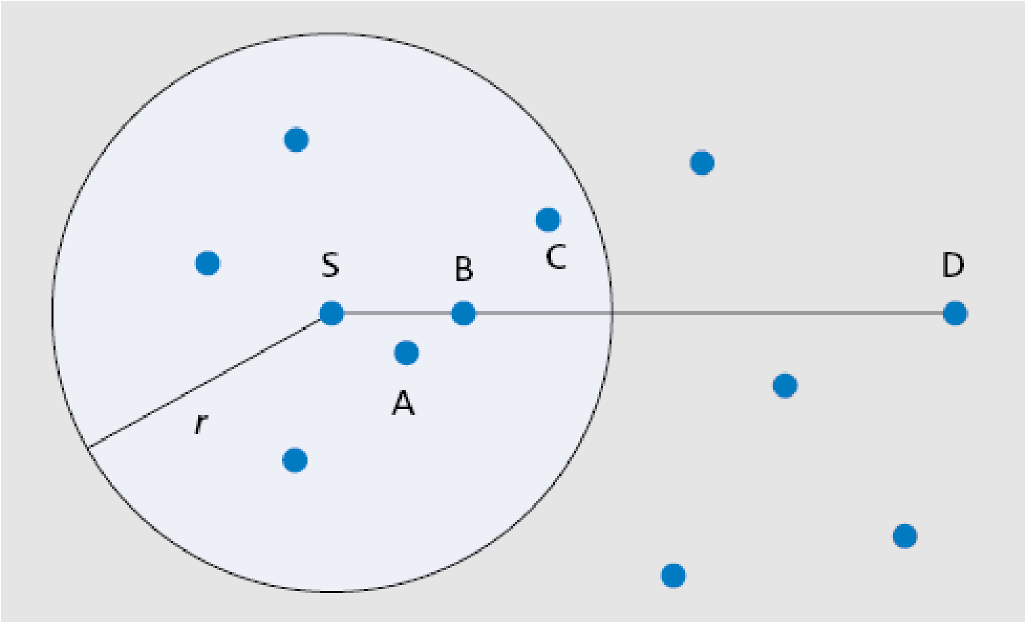
Forwarding strategies

- The forwarding decision of an intermediate node:
  - Based on the position information of the destination, embedded in the packet
  - Based on the position of one-hop neighbors
- Positions of the neighbors: known from periodic Hello messages

- Forwarding strategies:
  - Greedy forwarding
    - E.g. MFR, NFP, compass routing
  - Restricted directional flooding
    - E.g., LAR, DREAM
  - Hierarchic solutions

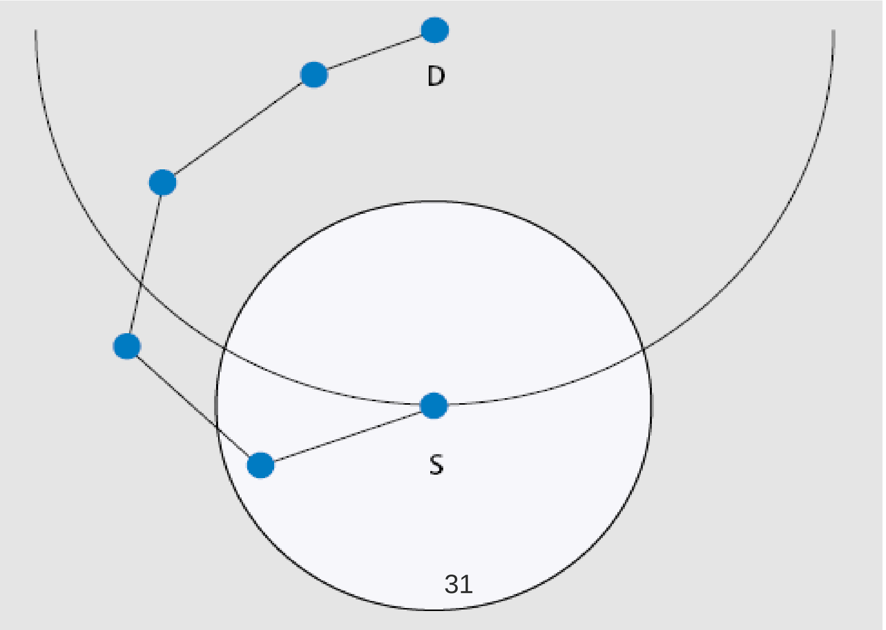
Greedy forwarding

- Which strategy should be used to select the next hop?
- **Most forward within *r* (MFR)**
  - Choose the node that is closest to the destination **D** (Node **C** in the figure)
  - The number of hops is minimized
  - Good strategy if the radio power cannot be changed
- **Nearest with forward progress (NFP)** (node **A**)
  - If the radio power can be adapted
  - Decreases the probability of collisions
- **Compass routing** (node **B**)
  - The smallest angle compared to the SD line
- **Random** choice of a neighbor in the good direction
  - No precise position information needed about neighbors
  - Lower overhead



Greedy forwarding

- Problems:
  - **S** might be closer to the destination **D** than any other node
  - Forwarding might arrive to a local maximum, where there is no way forward
  - **Recovery** mode:
    - If the greedy forwarding stops, we switch to recovery mode
    - If a neighbor can be found again, we switch back to the greedy mode



Restricted directional flooding

Location-Aided Routing (LAR)

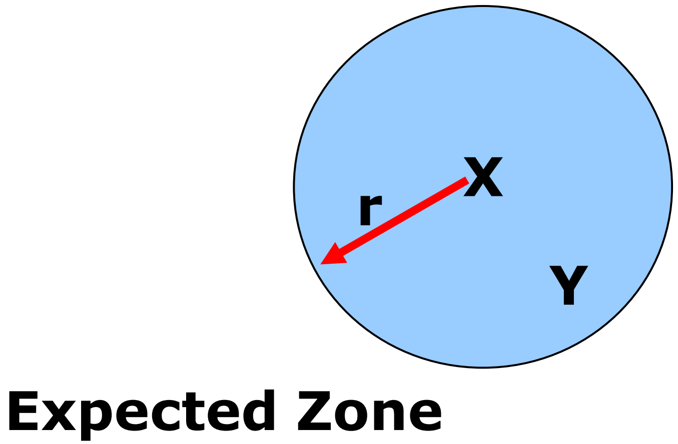
- Use the position information of the destination node to limit the flooding
- Introduces the notion of **Expected Zone**
  - The zone where the destination is expected to be
  - Estimation, based on the previous location of the destination, its speed and direction information
- RREQ messages forwarded only inside a **Request Zone**
  - The Request Zone includes the Expected Zone, together with the area linking the source with the Expected Zone

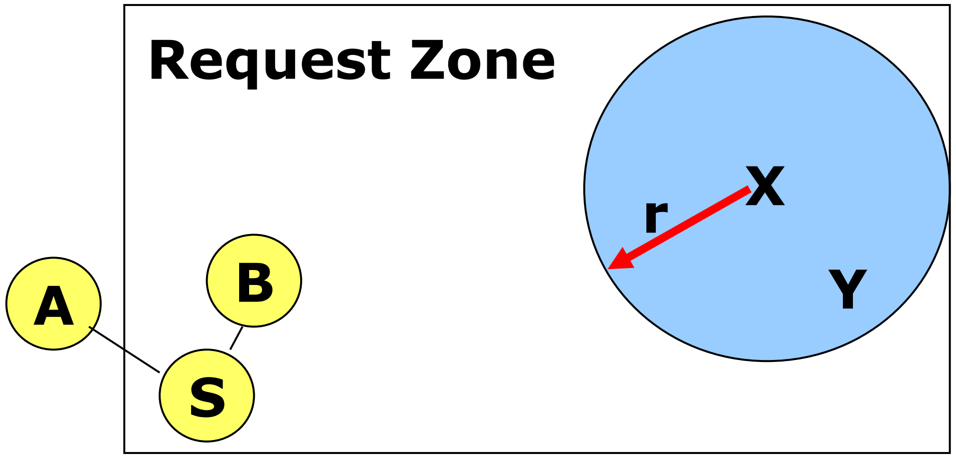
LAR Expected Zone, Request Zone

X = the last known position of the destination **D,** at time t_0

Y = the current position of the destination node **D** at time t_1 (S is not aware of it)

r = $(t_1 - t_0)$ * [estimated speed of **D**]





LAR Request Zone (2)

- RREQ messages forwarded only inside the Request Zone
  - The Request Zone **might be** the smallest rectangle including the source and the Expected Zone
  - E.g., in the example, B forwards the RREQ, but A does not

- The Request Zone explicitly defines whether the RREQ message should be dropped or not

- Each node knows its own position, knows if it is inside the Request Zone or not

LAR Request Zone (3)

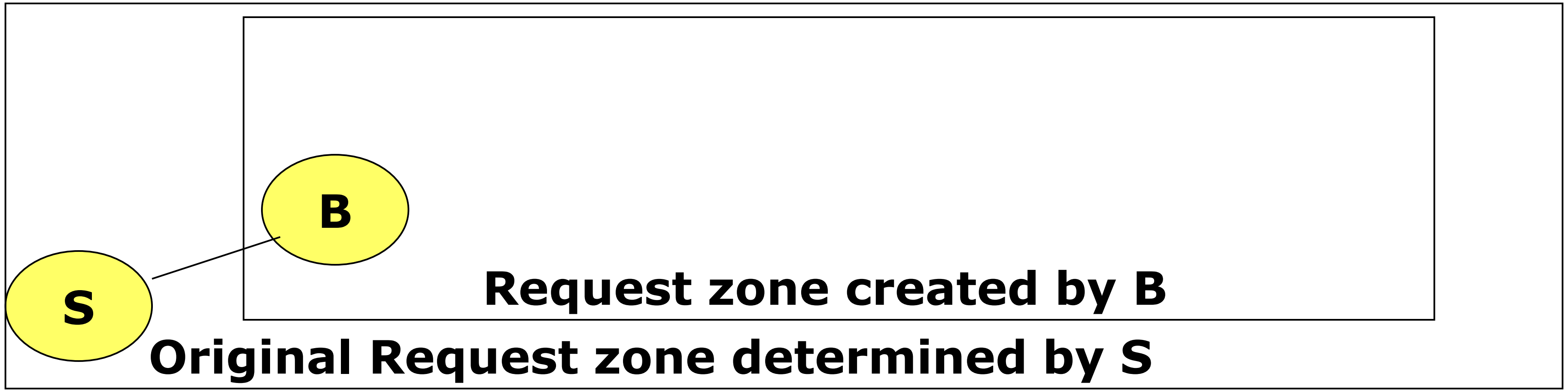
- If the source did not estimate well the position of the destination, the Request Zone might not contain it
  → the route discovery will fail*!*

- After a timeout, the source starts a new search…
  - Increases the size of the Request Zone;
  - If needed, the entire network is included in the Request Zone

- The following steps of LAR are similar to **DSR**
  - In the RREQ message we include the path, step by step
  - The destination sends back a RREP, following this path
  - The path is then included in the header of the data packet
  - Routes have to be refreshed from time to time

LAR versions: Adaptive Request Zone

- The Request Zone stored in the RREQ can be modified by each internal node, if
  - It has fresher information about the destination
  - **AND** the resulting Request Zone is included in the original one



LAR overview

- Advantages
  - The area of spreading of the RREQ message is limited
  - Smaller overhead for route discovery

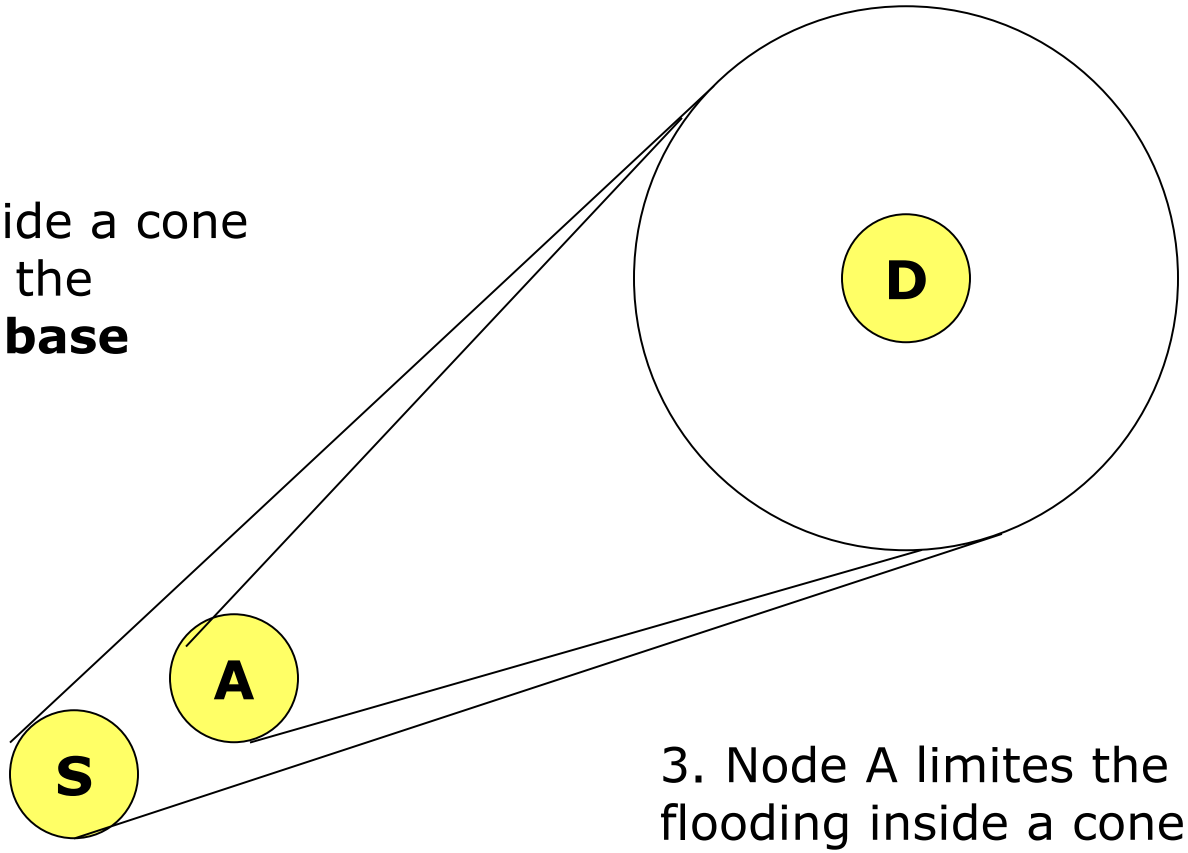
- Drawbacks
  - Nodes have to know their location
  - Doesn’t take into account possible problems in the radio transmission

Distance Routing Effect Algorithm for Mobility (DREAM)

- Uses information about position and speed (as in LAR) for reducing the area flooded with **data packets**
- Data is distributed by flooding, as opposed to LAR, where we only use flooding to discover the best route

DREAM localization

2. Data is flooded inside a cone where S is the **apex,** the expected zone is the **base**



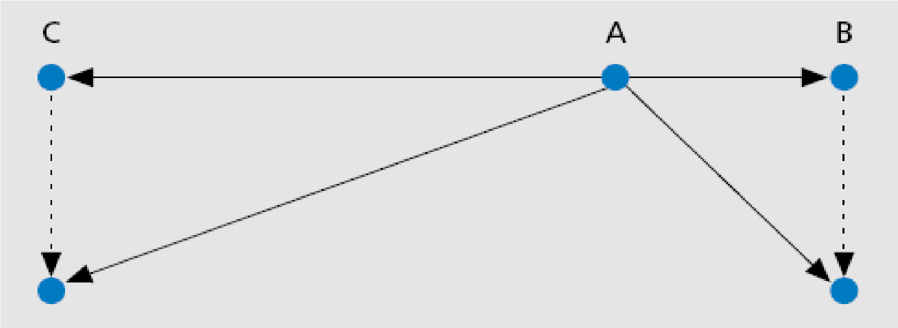
1. Expected zone („as in LAR”)

3. Node A limites the flooding inside a cone where A is the apex

DREAM distance effect

- Nodes periodically broadcast their position

- „Distance effect” = Remote nodes move with a smaller angular speed.



→ *Close nodes should refresh their data more often*

  - Playing with the *time-to-live* (TTL) field
  - Adaptive TTL