OKOS VÁROS
@ BME TMIT

Mobility and MANET
Intelligent Transportation Systems

Rolland Vida

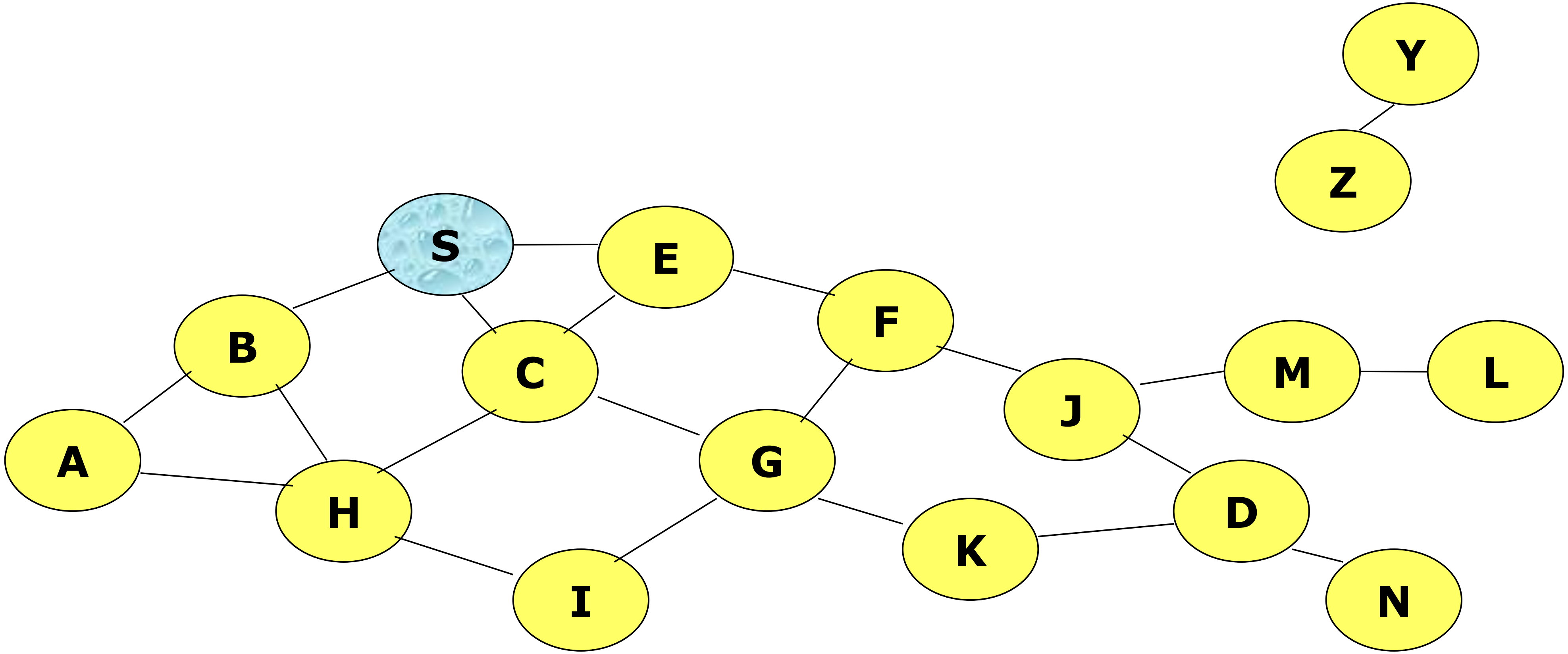
Optimization: Expanding Ring Search

- 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)

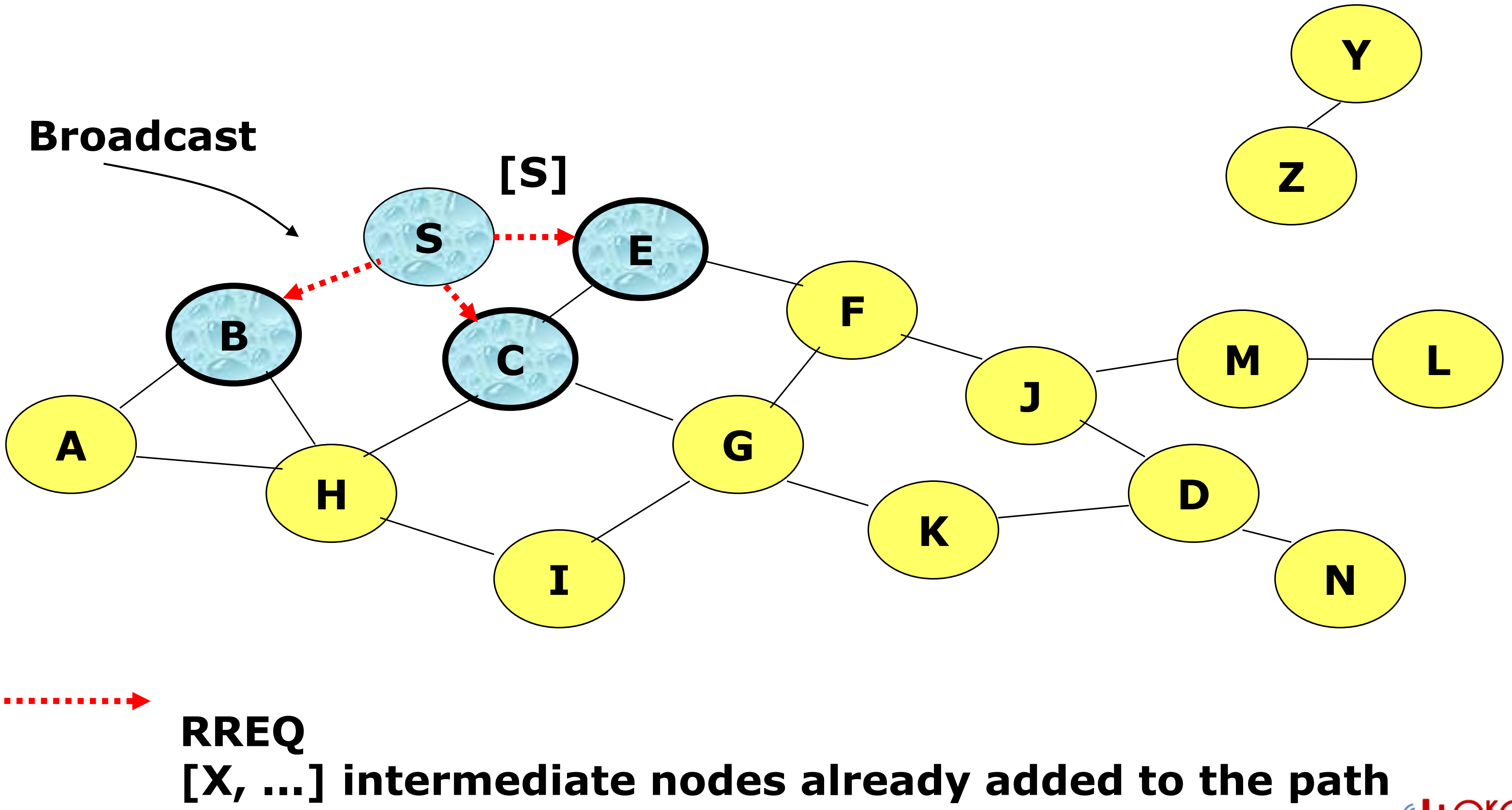
- If the source **S** wants to send something to destination **D,** it initiates route discovery
- **S** floods the network with Route Request (**RREQ**) messages
- Each intermediate node adds his ID to the RREQ before forwarding it

DSR Route Discovery

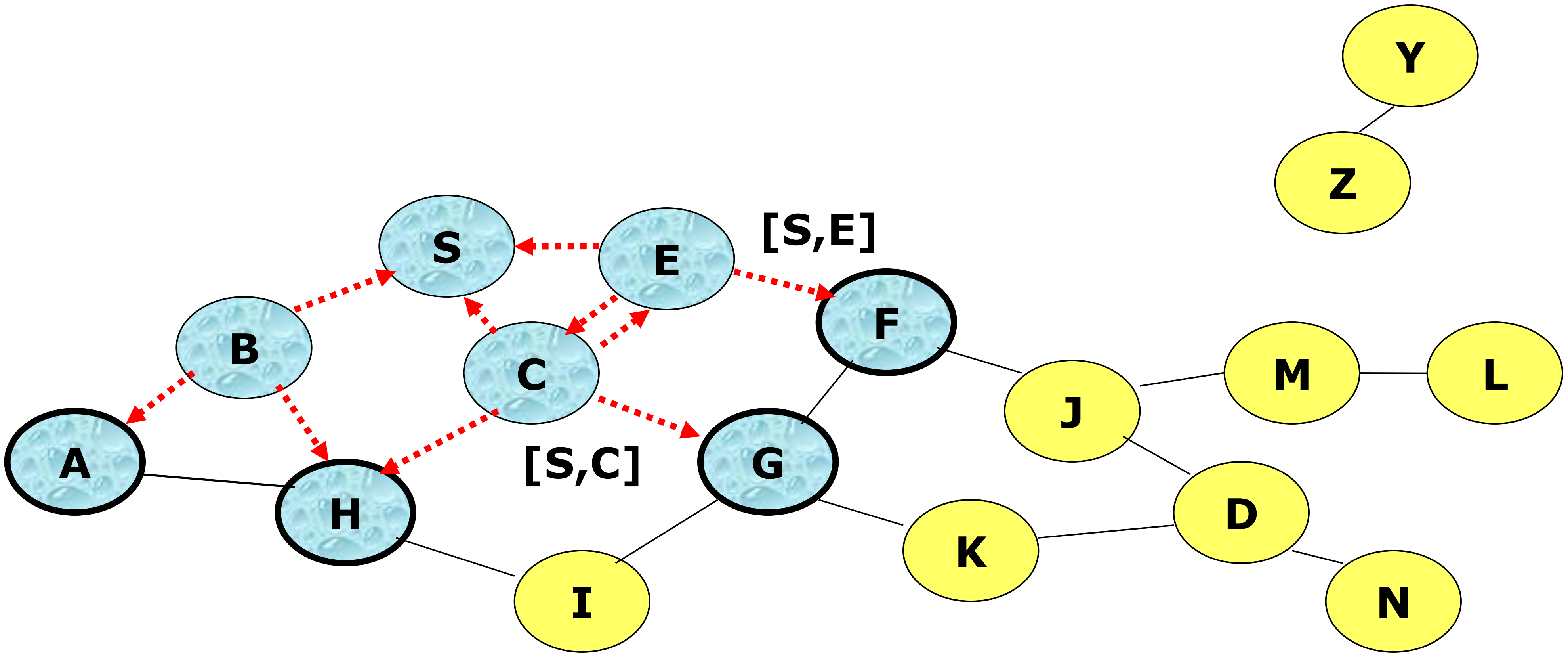


Nodes that already received the RREQ from S, regarding D

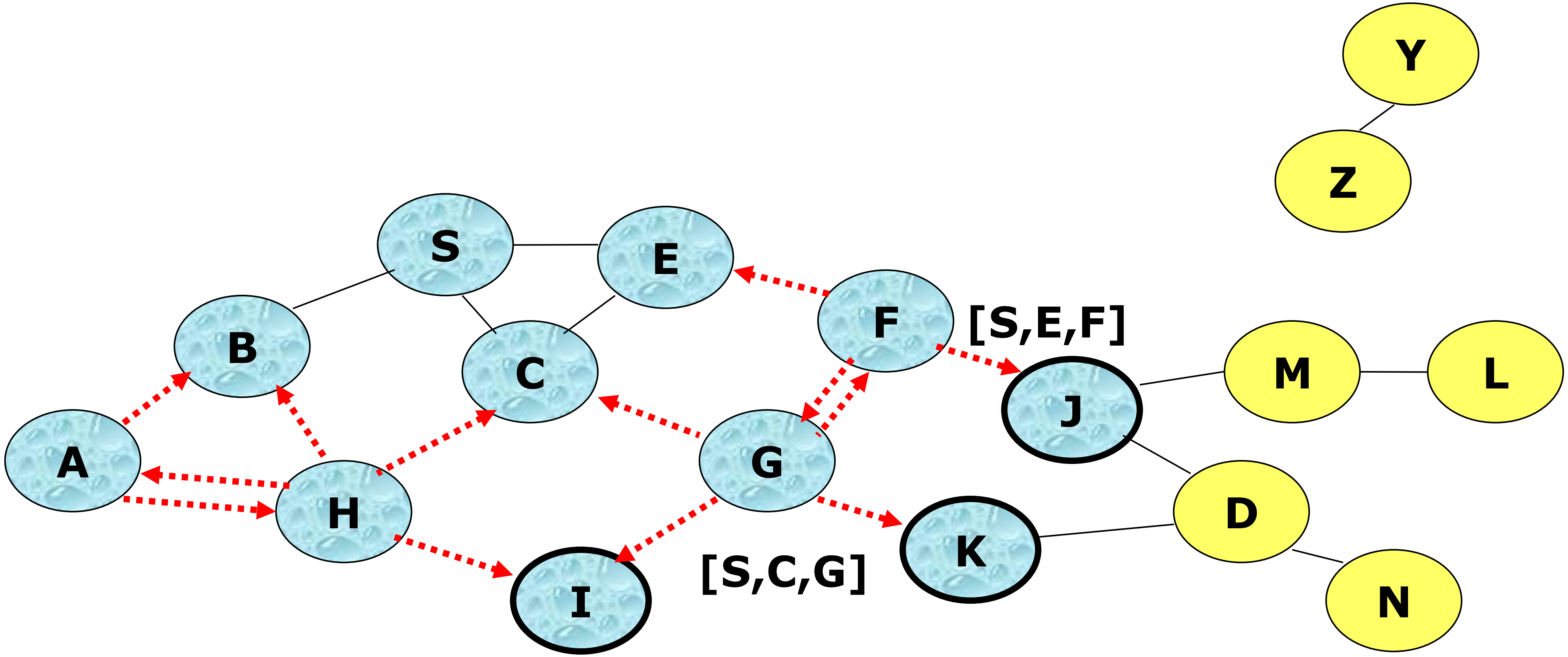
DSR Route Discovery



DSR Route Discovery

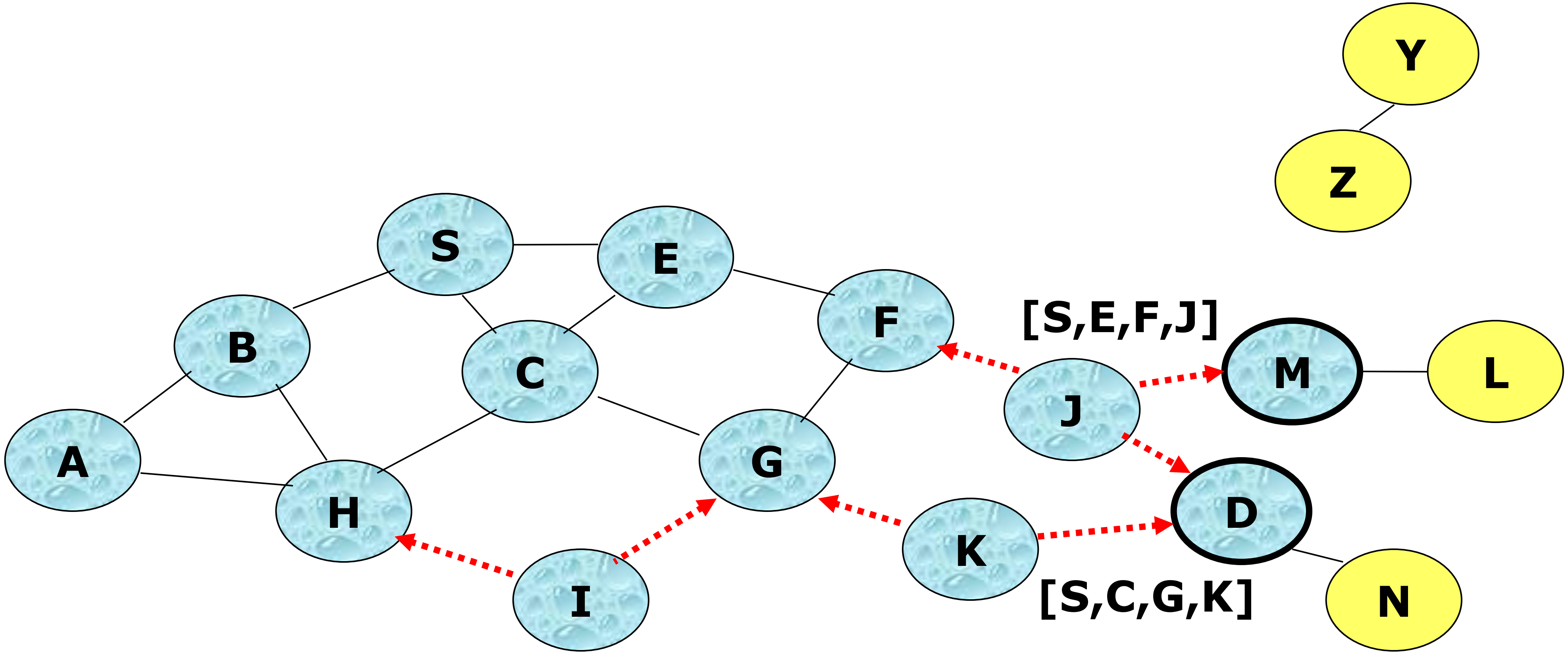


DSR Route Discovery

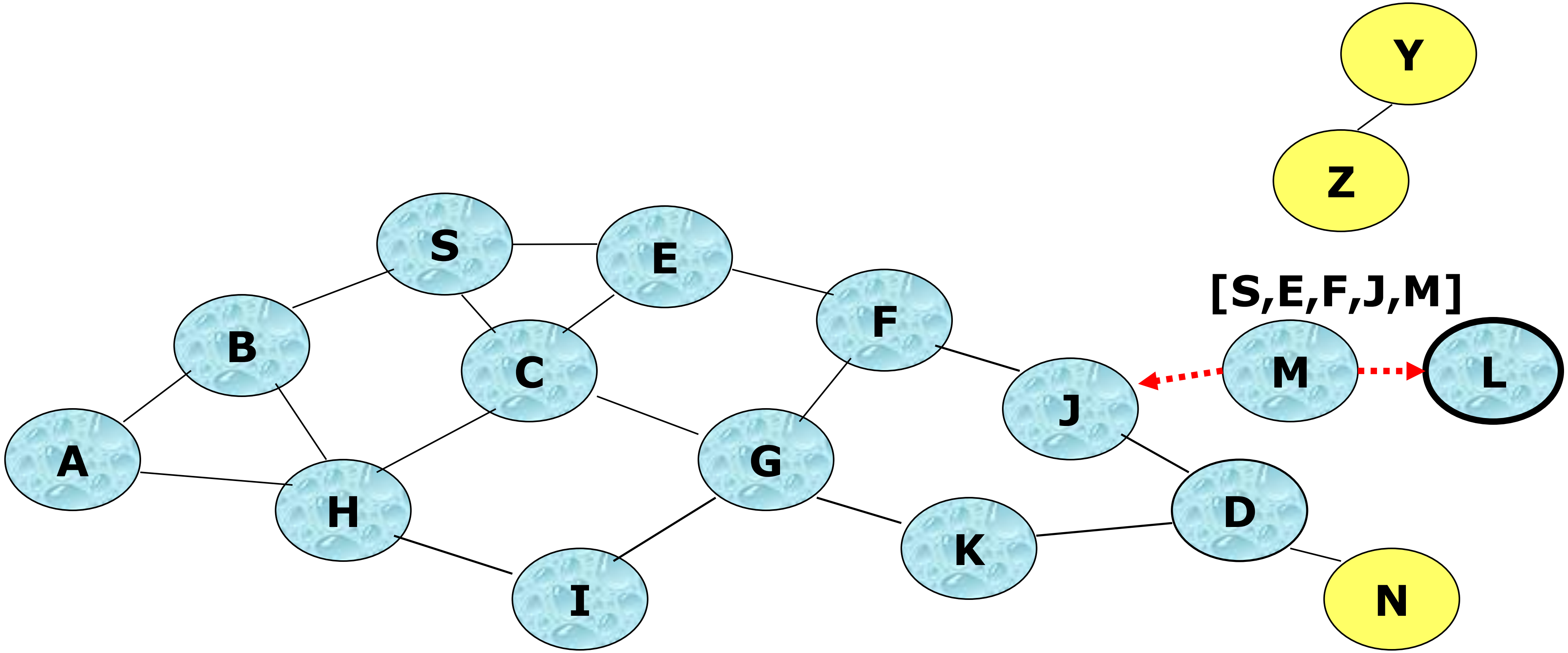


Restricting the flooding (like in AODV):
C receives the RREQ again from G and H, but does not forward it again

DSR Route Discovery



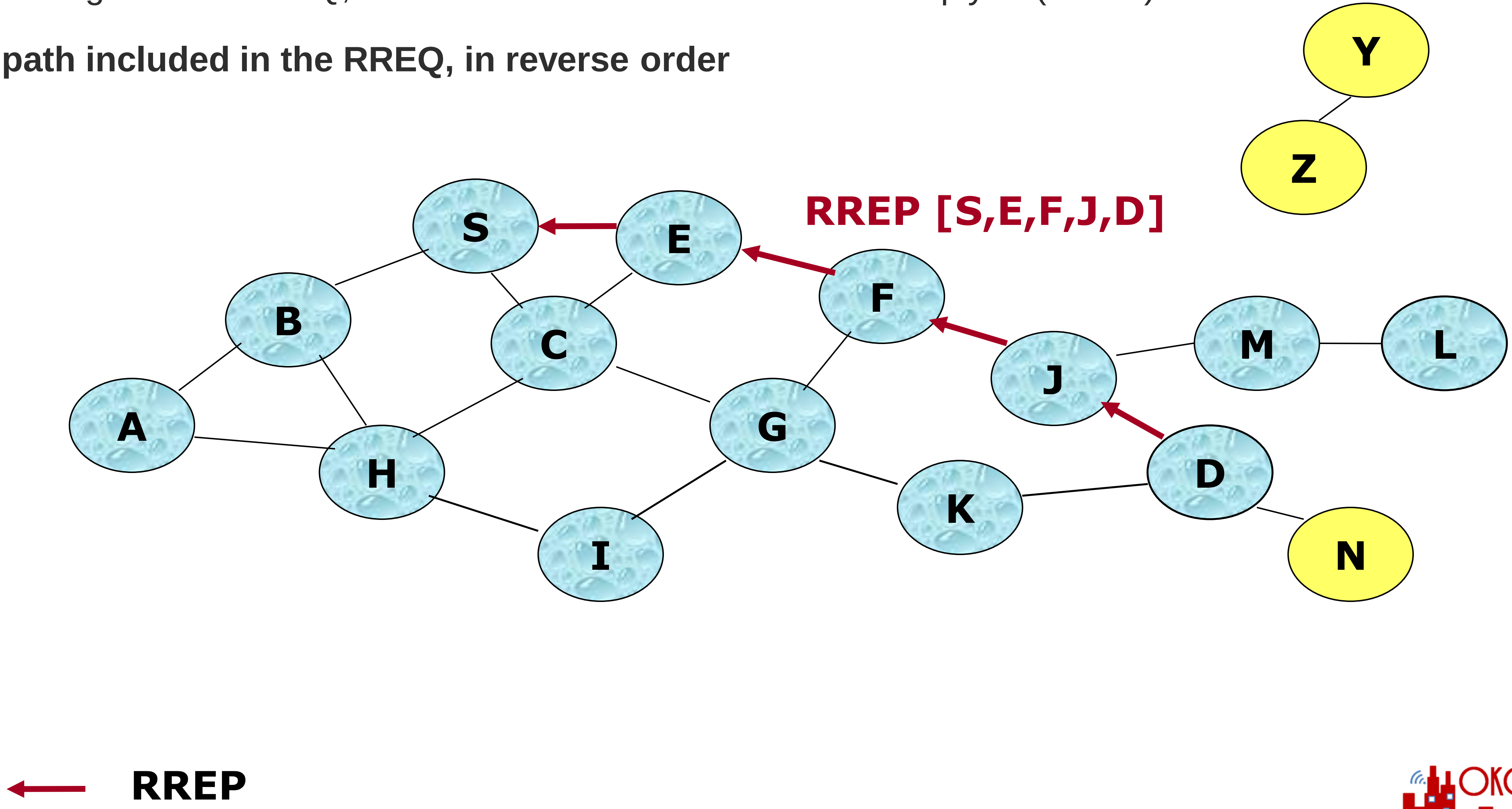
DSR Route Discovery



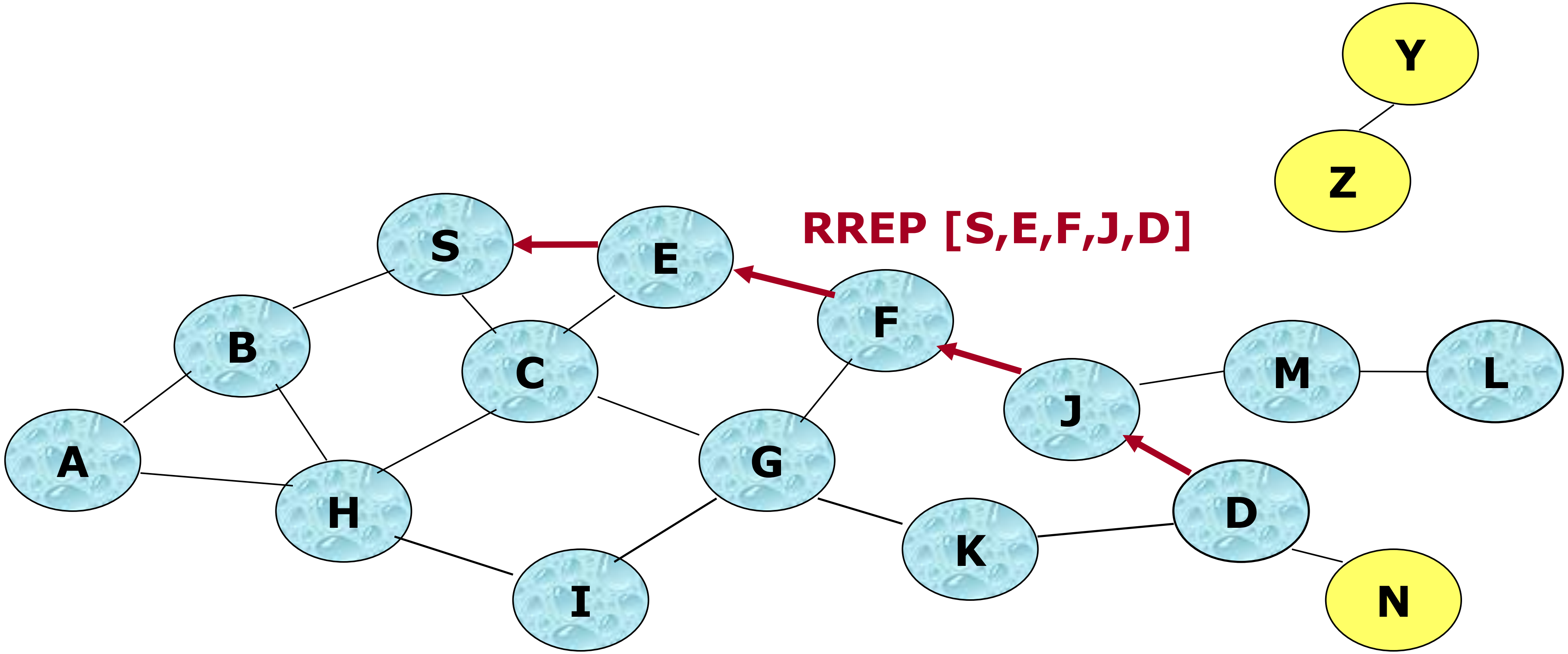
D stops the broadcast of RREQ, as it is the destination

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**

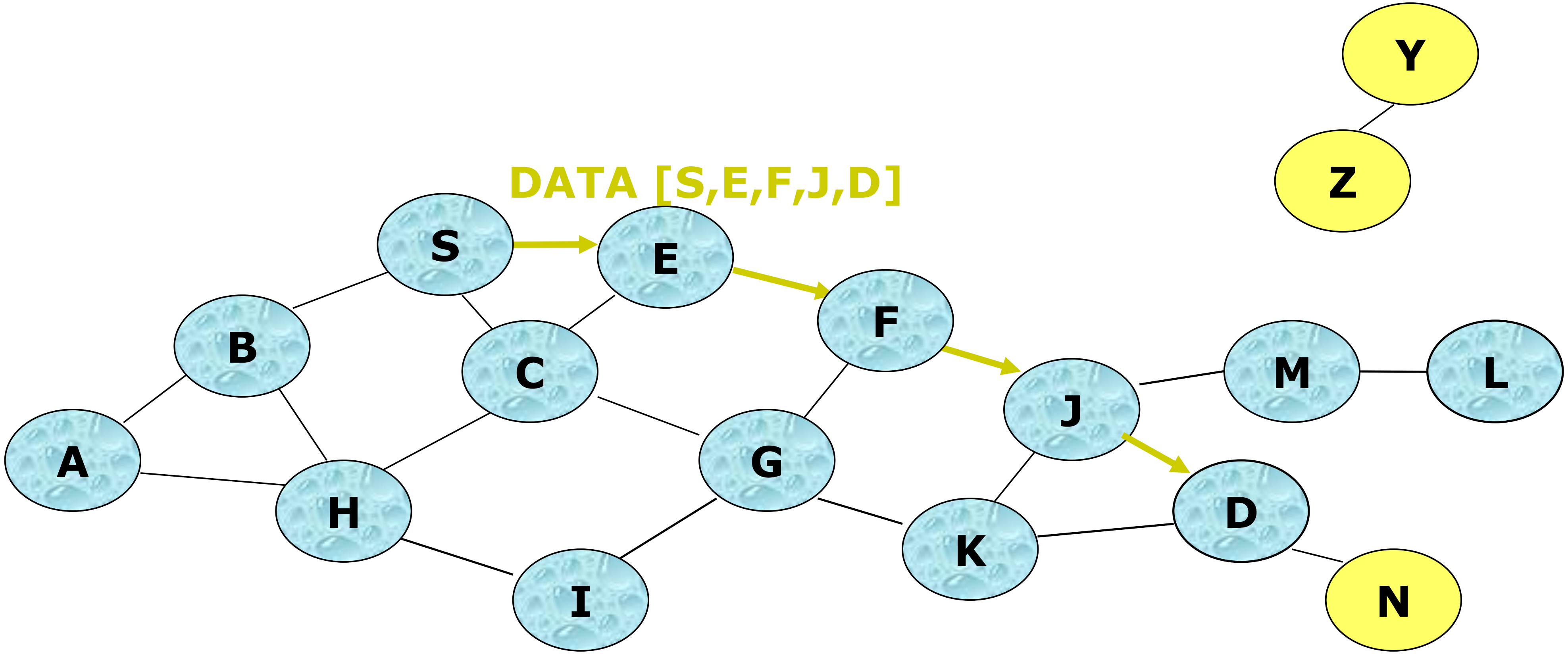


DSR Route Reply



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

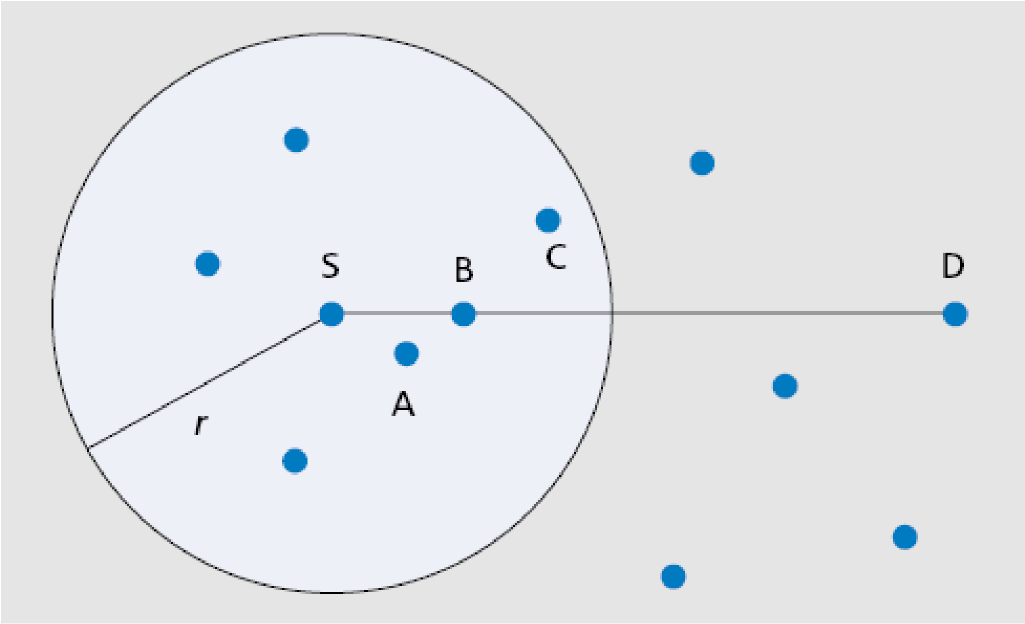
Forwarding strategies

- 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

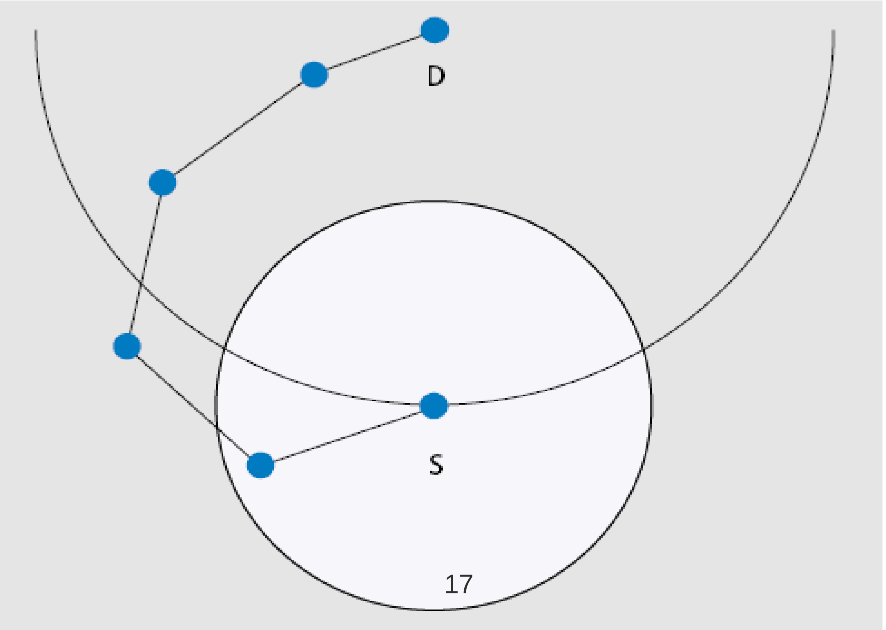
Greedy forwarding

- 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)

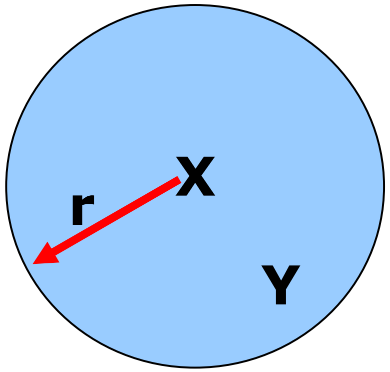
- Use the position information of the destination node to limit the flooding
- Introduces the notion of **Expected Zone**
  - The zone where the destination is expected to be
  - Estimation, based on the previous location of the destination, its speed and direction information
- RREQ messages forwarded 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

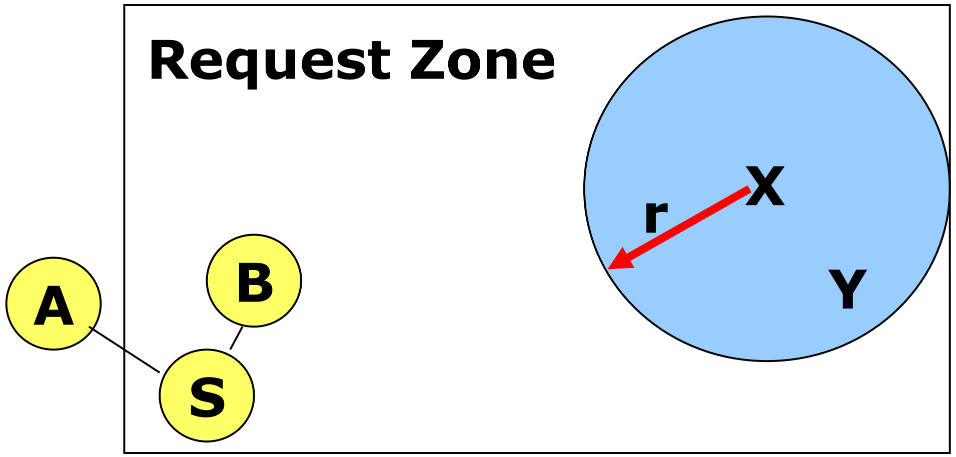
X = the last known position of the destination **D,** at time t_0

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**]



Expected Zone



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)

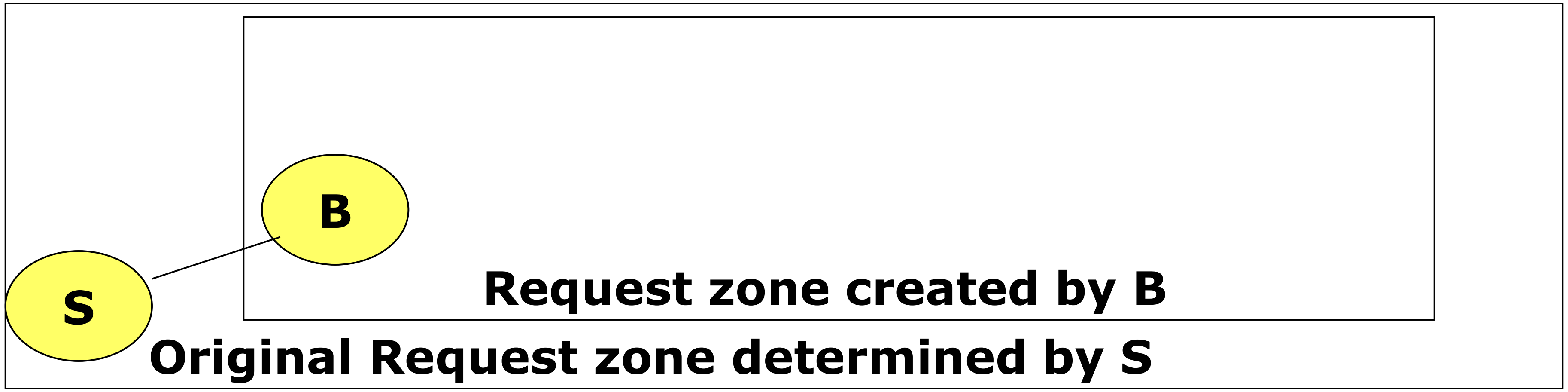
- If the source did not estimate well the position of the destination, the Request Zone might not contain it
  → the route discovery will fail!

- 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)

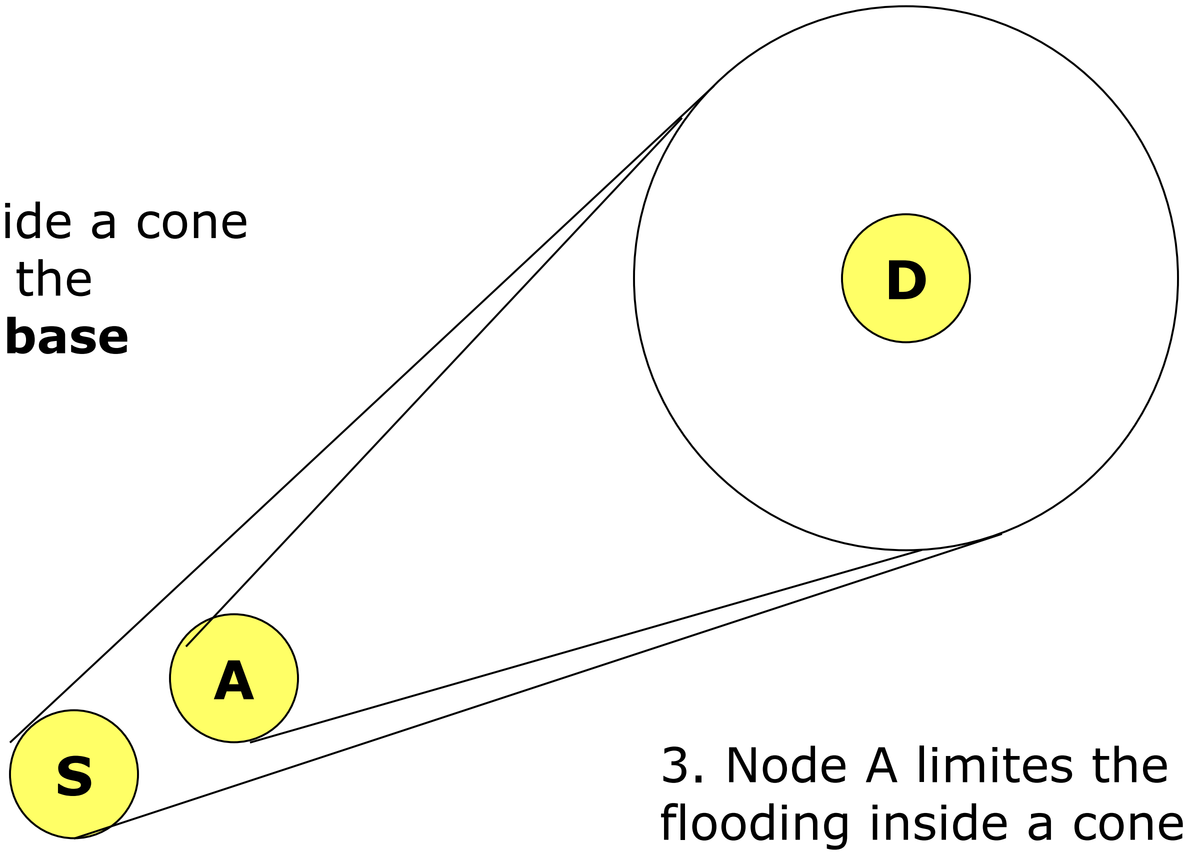
- Uses information about position and speed (as in LAR) for reducing the area flooded with **data packets**

- Data is distributed by flooding, as opposed to LAR, where we only use flooding to discover the best route

DREAM localization

1. Expected zone („as in LAR”)

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

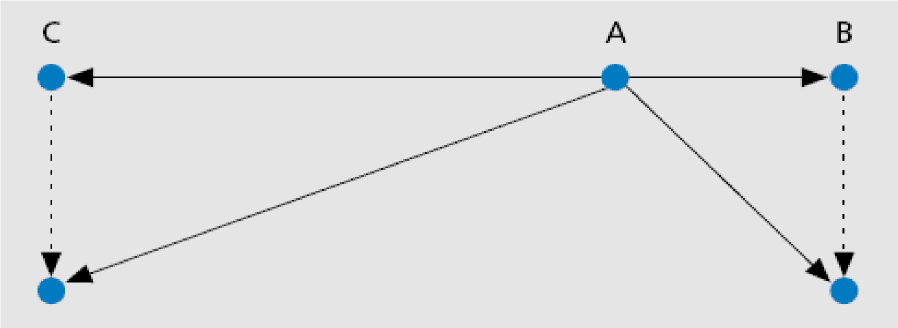


3. Node A limites the flooding inside a cone where A is the apex

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

CBF (Contention Based Forwarding)

- In position-based routing solutions a node learns about the position of its neighbors via periodic beacon messages
  - Mobility and energy-efficiency should be taken into account when calculating the frequency of beaconing
- Proposal **CBF (Contention Based Forwarding)**
  - **Greedy forwarding, without any knowledge on the position of the neighbors**
  - Distributed next hop selection, hop-by-hop
  - Advantages:
    - Each node has to know only its own position
    - No burden on the network because of the beacon (hello) messages
- Comment: In some cases, if local maximum is reached, recovery mode might have to be activated, but this is a different problem.

Contention Based Forwarding

- How it works:
  - The next hop is selected based on a **contest**
  - **Suppression**: lowers the probability of collisions, as normally just one node is selected as next hop
- Steps:
  1. The source broadcasts the message to its neighbors.
  2. Each node sets a timer for its own retransmission
     - The timer inversely proportional to the distance form the source
  3. The timer of the furthest away node will expire first
  4. He retransmits, all the others hear it, and cancel their own retransmission
- Decentralized selection of the next hop

Vehicle-to-vehicle communication

- „Traditional” ad hoc protocols:
  - Reactive: AODV, DSR
    - High signaling load for topology discovery, slow discovery
    - Not efficient for cars, as they move faster
  - Position-based: LAR, DREAM
    - Needs localization service
    - In some cases it leads to local maximums, needs a recovery mode
    - In urban scenarios there is a high chance for such local maximums, the physical distance is not so relevant when many buildings obstructing the communication

- New solutions needed for vehicle-to-vehicle (V2V) communication

AODV versions for VANETs

- **AOMDV: Multipath**
  - Not only one path is stored, but all those that were discovered
    - This can be done without extra burden, as the path discovery is anyhow based on flooding
  - If the primary path is broken, we can switch rapidly to a back-up path
    - We need to search for new paths only if all the previously known paths are broken (or their number is getting very low)
- **SD-AOMDV: Speed and Direction**
  - The speed and direction of nodes is taken into account when selecting the best path out of the discovered ones
  - A node can be next hop only if it goes in the same direction, with roughly the same speed
- **R-AOMDV: Retransmission count**
  - Takes into account the quality of the links, besides the hop count
    - Link quality: number of retransmissions at MAC layer, until a successful retransmission
  - **Problem:** link quality changes rapidly
  - Cross-layer optimization – information from lower layers is used for routing at networking layer

AODV versions for VANETs

- **AODV+PGB: Preferred Broadcast Group**
  - If the next hop is too close, the message does not advance rapidly
  - If the next hop is too far, there is a high chance for the link to break
  - **Proposal**: select as next hop nodes which are at a medium distance (the signal strength is average), they will form the Preferred Group

- **BAODV: Bus-AODV**
- **P-AODV**
- **I-AODV**
- **Improved-AODV**
- **AODV-BD**
- **AODV-VANET**
- **etc.**

Link-stability based routing

- **Movement Prediction based Routing (MOPR)**
  - Takes into account the position, speed and direction of the cars
  - Builds routes with nodes that move in similar ways