Mobility and MANET

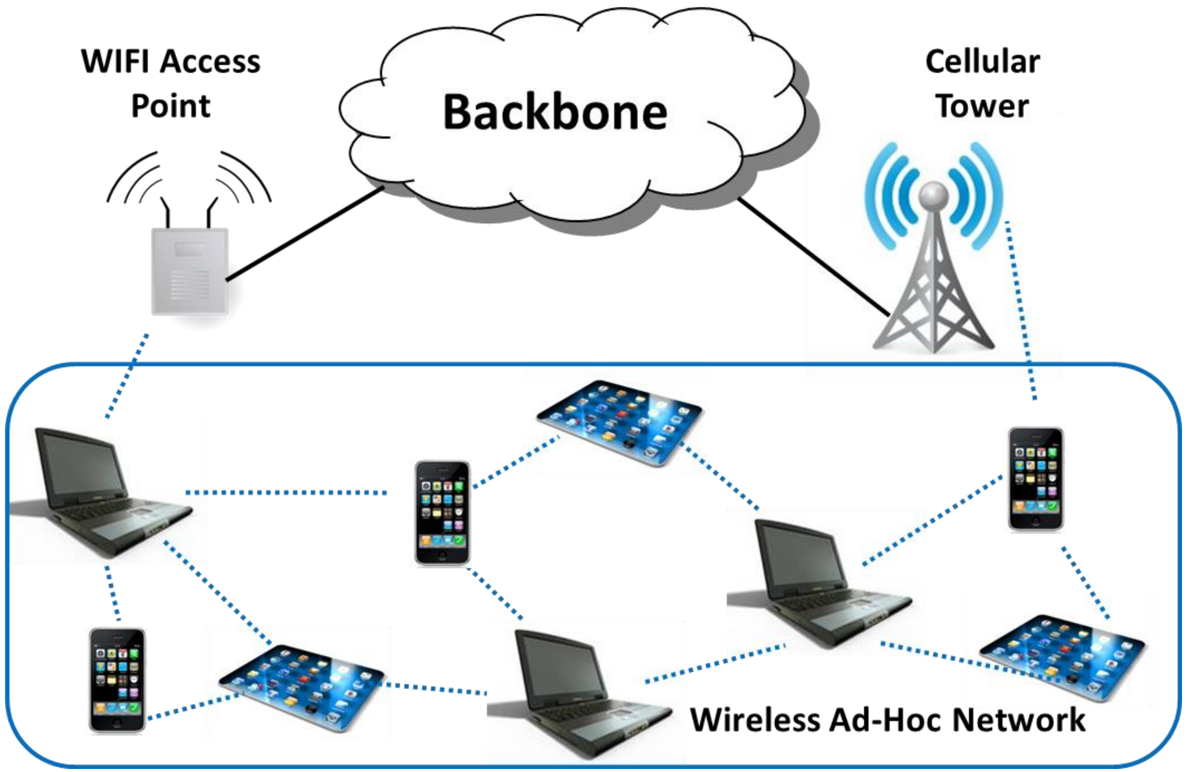
Intelligent Transportation Systems

Rolland Vida

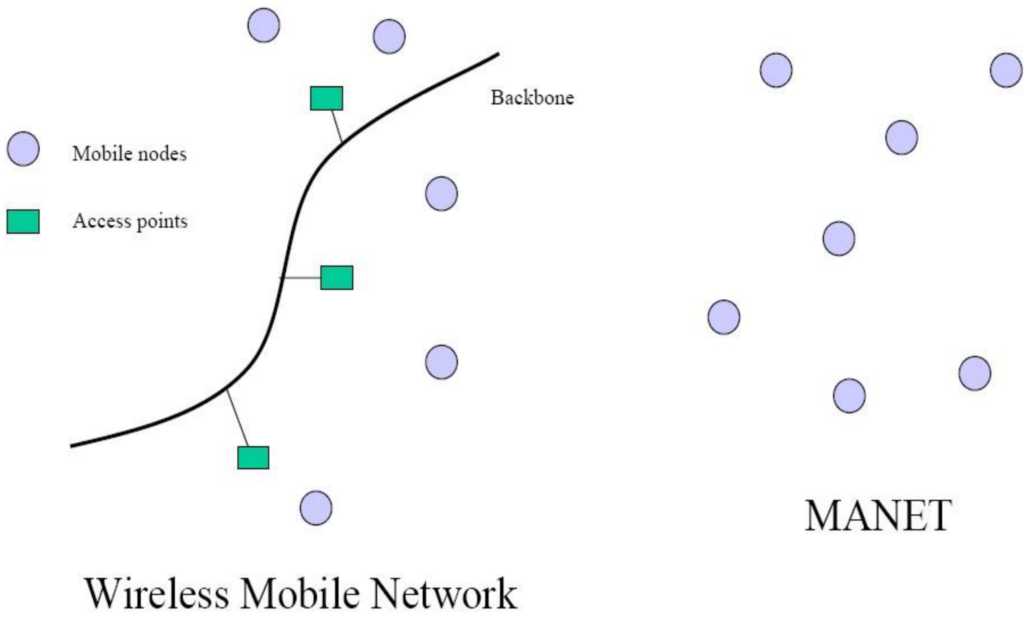
Overview

- MANET – Mobile Ad Hoc Networks

- Meaning of **„Ad Hoc”**
  - Immediate, provisional, without preparation



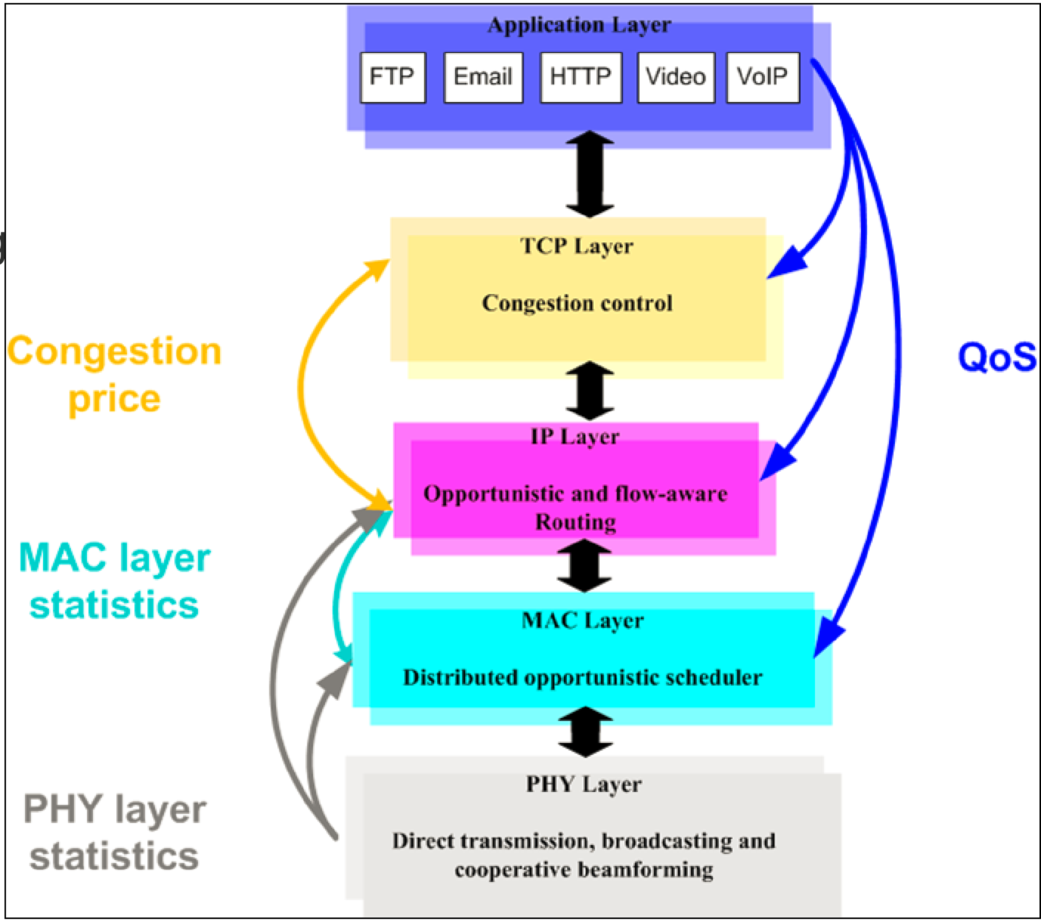
Ad hoc networks



- **No available infrastructure**
  - No internet connections, gateways, access points
  - No dedicated, deployed servers (AAA, DHCP, etc.), or services
- **No addressing based on IP subnets**
  - A problem for „classical” routing protocols
- **No reliable (stable) network devices**
  - Services provided by neighbors, fellow peer nodes
  - The status of my neighbor can change at any time – depleted battery, increased distance, etc.
  - I do not know my neighbors, I do not know if I can trust them
- **Self-organization**
  - Peer-to-peer paradigm (on the networking layer)
- **Multihop**
  - Communication (routing) over several hops (devices)

MANET research topics

- Physical layer -> „*mobility models*"
  - Energy-efficient operation – adjusting radio power, sleep scheduling
  - Mobility-aware radio technologies
- **Data-link layer**
  - MAC (shared medium access, efficiency, decreasing the chance of collisions)
- **Networking layer**
  - Routing (dynamically changing topology, prefix-based routing not working)
- Upper layers
  - Packet retransmissions, TCP (packet loss, unreliable transmission medium)
  - Security (can be extended to any of the layers)
- Cross-layer optimization
  - The parallel optimization of several layers in the ISO/OSI model
  - Each layer might have its own influence over mobility

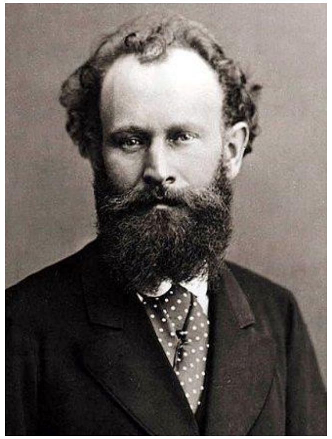


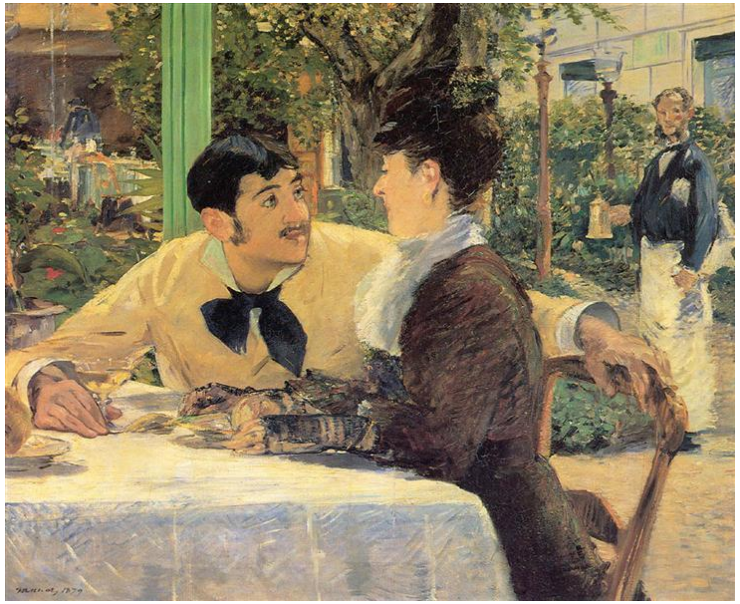
Mobility types

- Nomadic mobility (nomadicity)
  - No communication while moving – device turned off
  - When restarting, new IP address, rebuilding the interrupted connections
- Slow mobility
  - E.g., people walking around in a building
  - University campus – students walking, biking
- Fast mobility
  - Cars, bikes, …
- Moving networks…

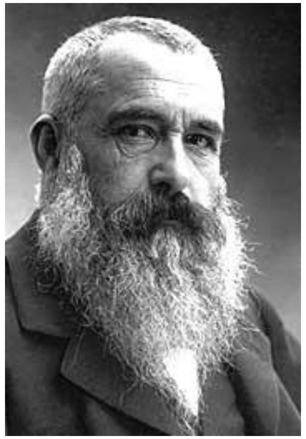
MANET vs. MONET

Edouard MANET





Claude MONET



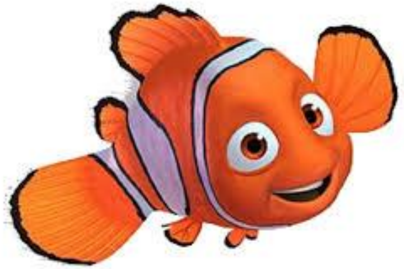
Mobile **A**d Hoc **Ne**twork

Moving **Net**works

- Networking devices moving together
  - E.g., passengers in a train, metro, bus, airplane
- Alternative name
  - **Networks in Motion – NEMO**

NEMO – Networks in Motion

- Many MNs moving together
  - If they move together, let’s handle their mobility together
- MR (mobile router) – default gateway
  - Provides the connection between NEMO-members and the outside world
  - Dedicated device, or one among the others assuming this role (periodic role changes)
    - Usually the biggest battery, the largest bandwidth, etc.
- The MNs have to register at the MR
  - They belong to the subnetwork of the MR
  - “Fixed” nodes in the network (relatively to the MR), their relative position does not change
    - Called also Fixed Local Nodes (FLN) because of that

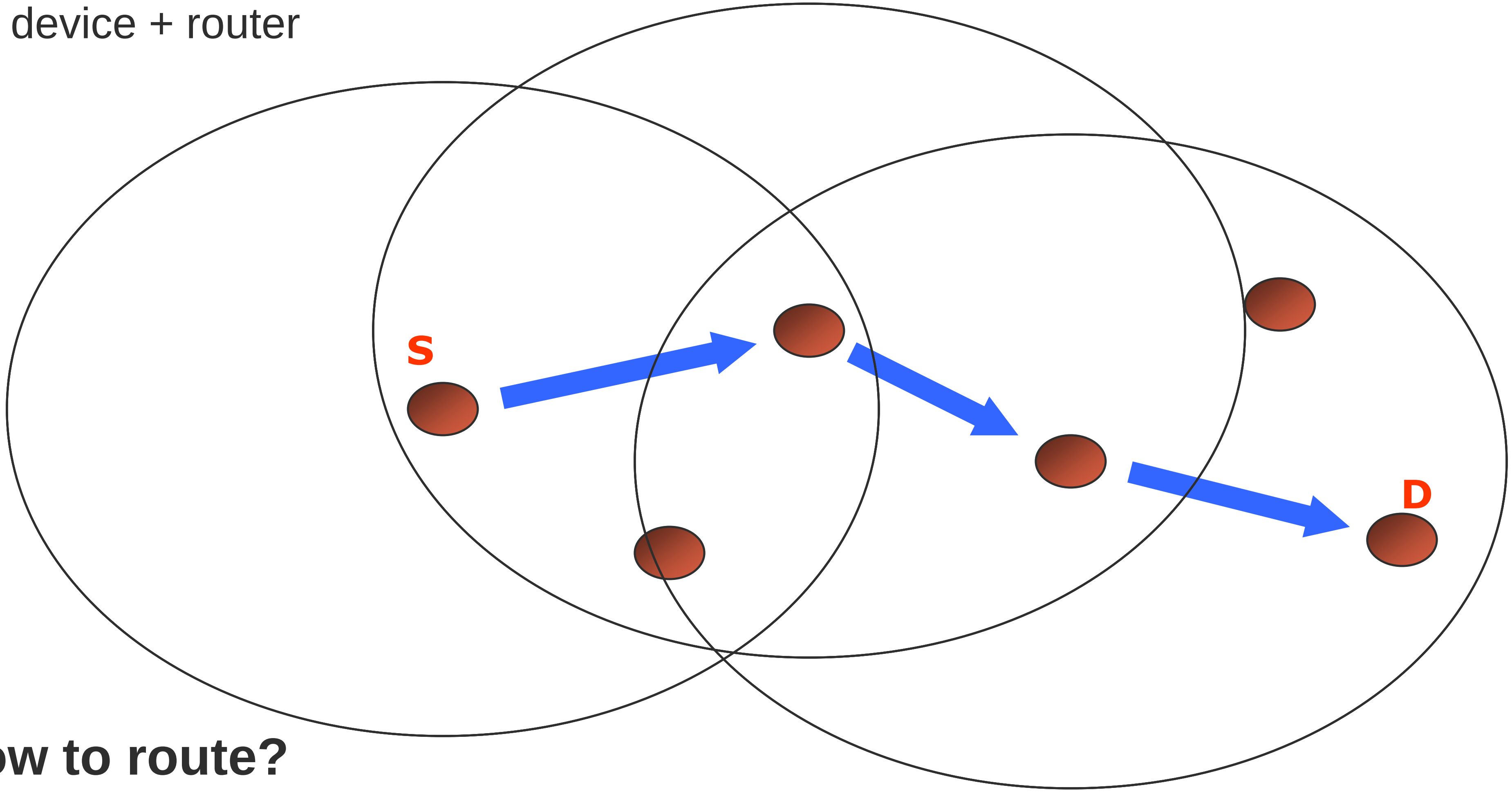


NEMO efficiency depends on the environment

- (Possible) drawbacks:
  - Case of 100 MNs with 3G/4G mobile internet access in a city
  - If the MNs do not join the NEMO
    - - personal mobility management needed for all the 100 MNs
    - + Any one of them receives the bandwidth provided by the given technology
  - If all the MNs join the same NEMO
    - The MR link capacity becomes a bottleneck
    - In the worst case, the MNs receive only 1/100 of the bandwidth provided in the previous case
- (Possible) advantage:
  - If 100 MNs on an airplane want to connect to the internet
    - The dedicated MR is the only node being able to connect
  - Mobility management is optimal
    - Only the mobility of the MR has to be handled

MANET routing

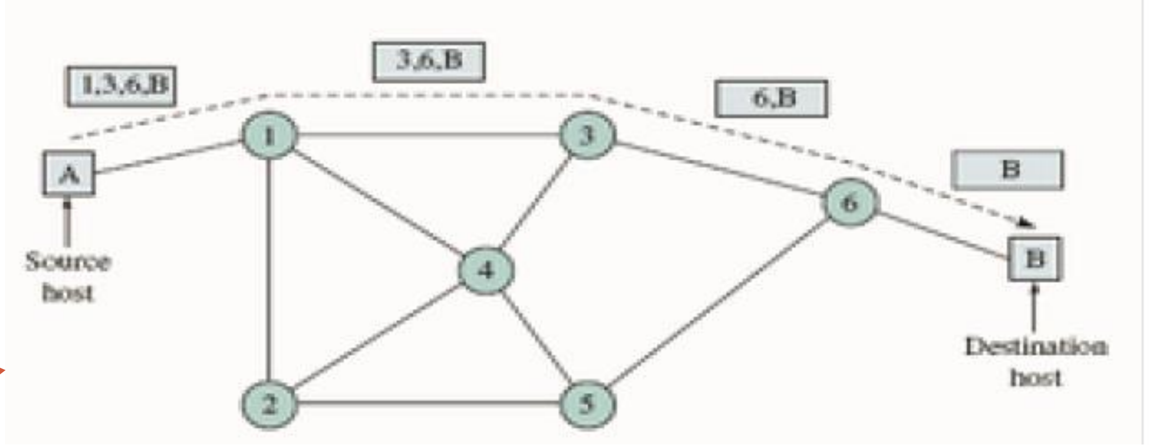
- Point-to-point
- Mobile node = end device + router

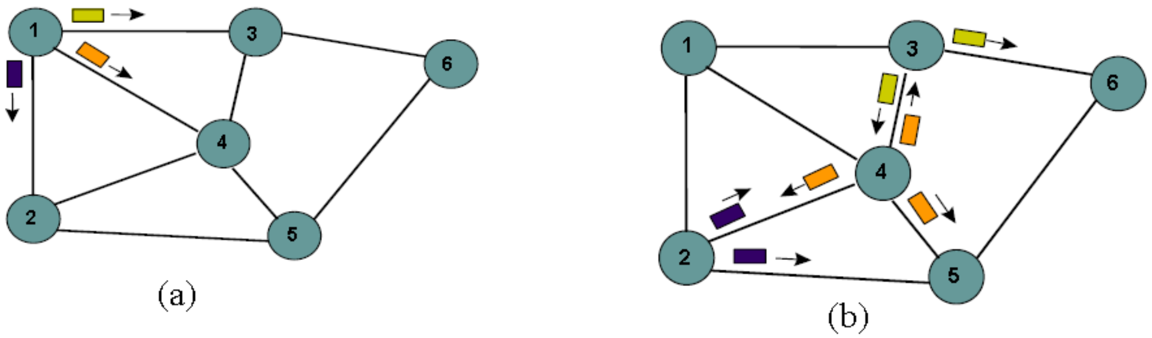


- **Who knows how to route?**

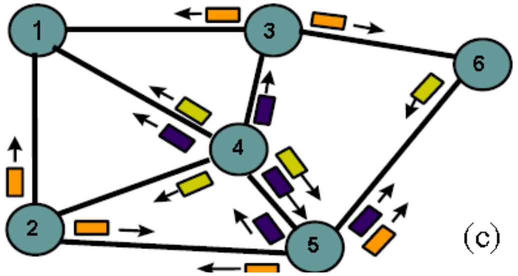
Where to send the packet?

- **Sometimes only the source knows**
  - All the route is stored in the header
    - Packet is routed based on the header
  - **Source routing,** as the entire route is decided by the source
    - **E.g., Dynamic Source Routing (DSR)**
  - Header can grow large
    - Fragmentation, low efficiency
    - Especially if long routes and not much data





- **Sometimes nobody knows**
  - **Flooding** solutions
    - Everyone rebroadcasts the received packet
    - Hopefully it will reach the destination
  - High burden on the wireless network, where resources are limited



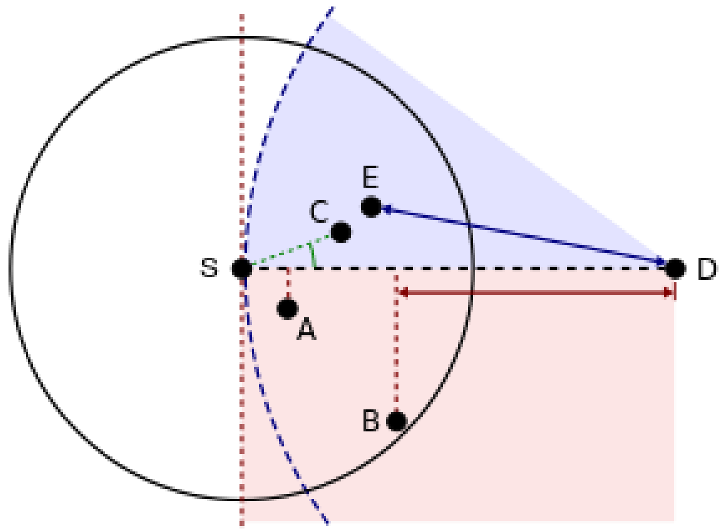
About routing in general

- Many routing protocols were developed
  - Some specific to MANETs
  - Some others adapted from the wired networks
- There is no one-size-fits-all protocol, which performs well in all circumstances

- Desired features for a MANET routing protocol
  - Distributed operation
  - Loop-free
  - Operation on demand
  - Security
  - Support for „sleeping" cycles
  - Support for one-directional links

MANET routing

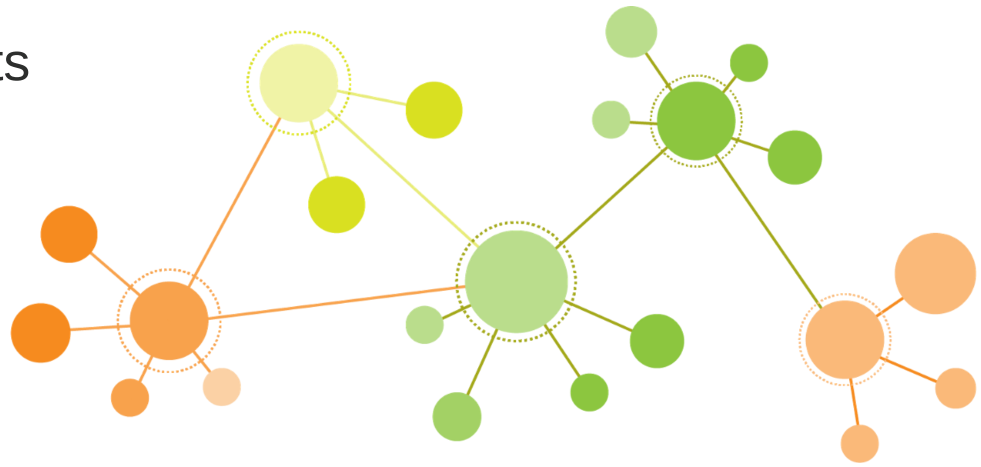
Position-based (geographic) routing protocols



- Make use of geographical position information for routing

Topology-based routing protocols

- Make us of topology (graph) information
- Which are the neighboring nodes, and what are the costs of the links



Topology-based 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

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

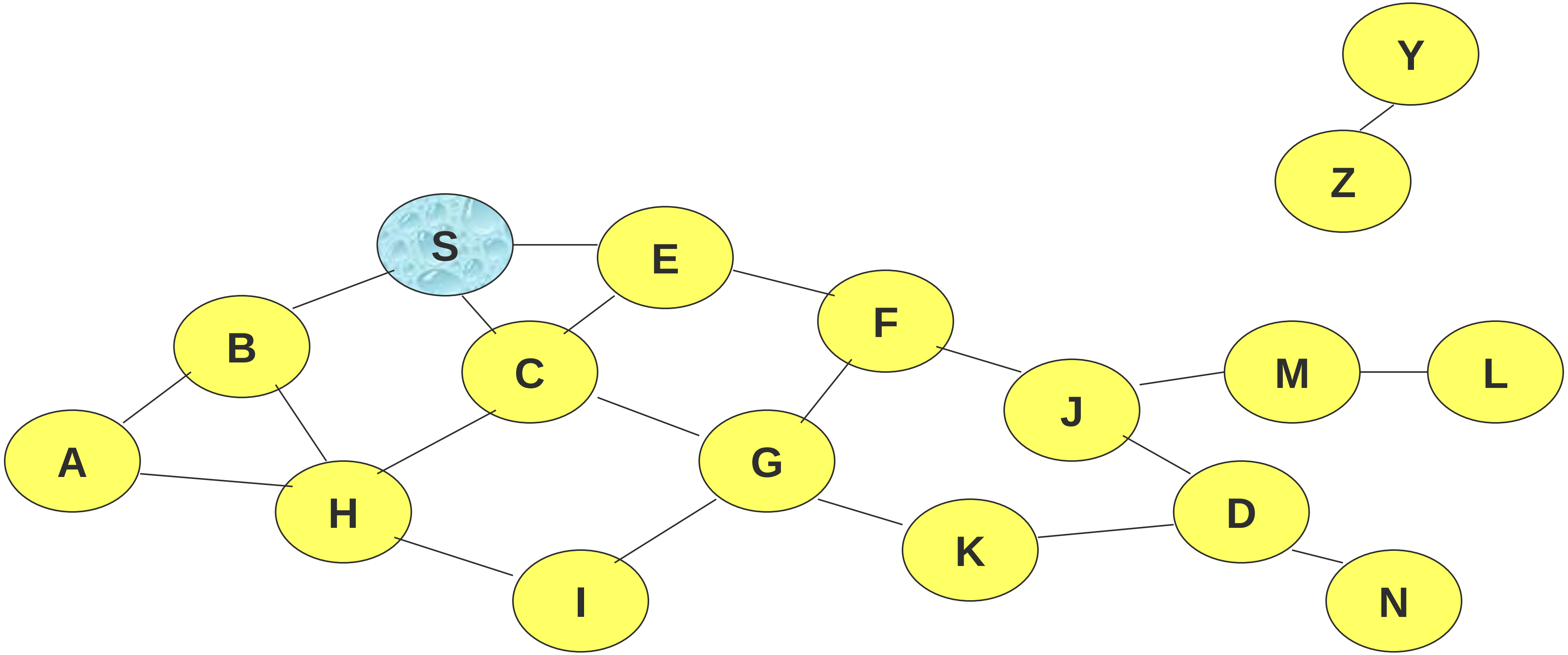
Ad Hoc On-Demand Distance Vector Routing (AODV)

- 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

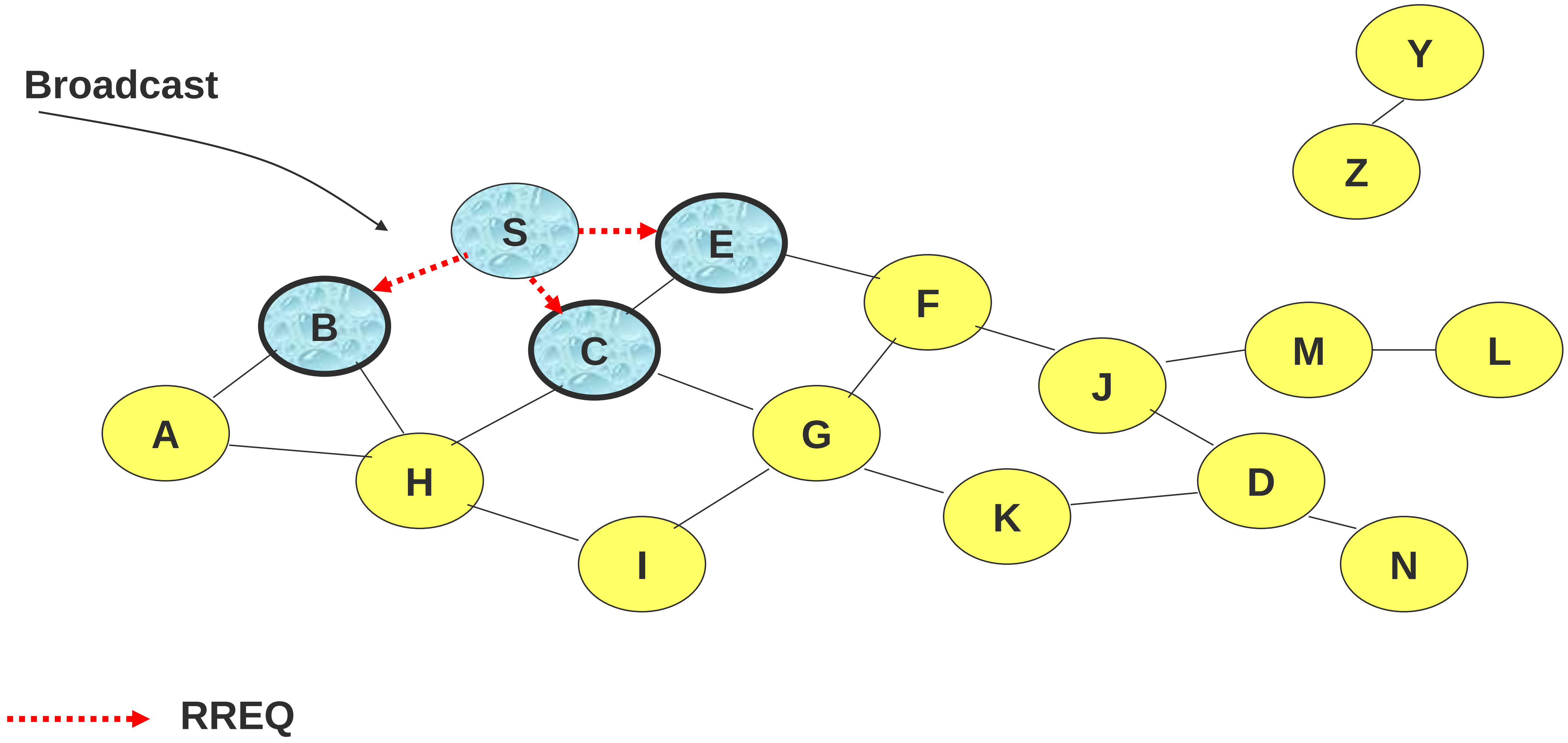
- To discover the route, the source broadcasts a **Route Request (RREQ) message**
- Those who receive it, rebroadcast it
- When a node rebroadcasts a Route Request message, it stores a **reverse path pointer** towards the node from where the request came
  - AODV symmetric (bi-directional) links
  - 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

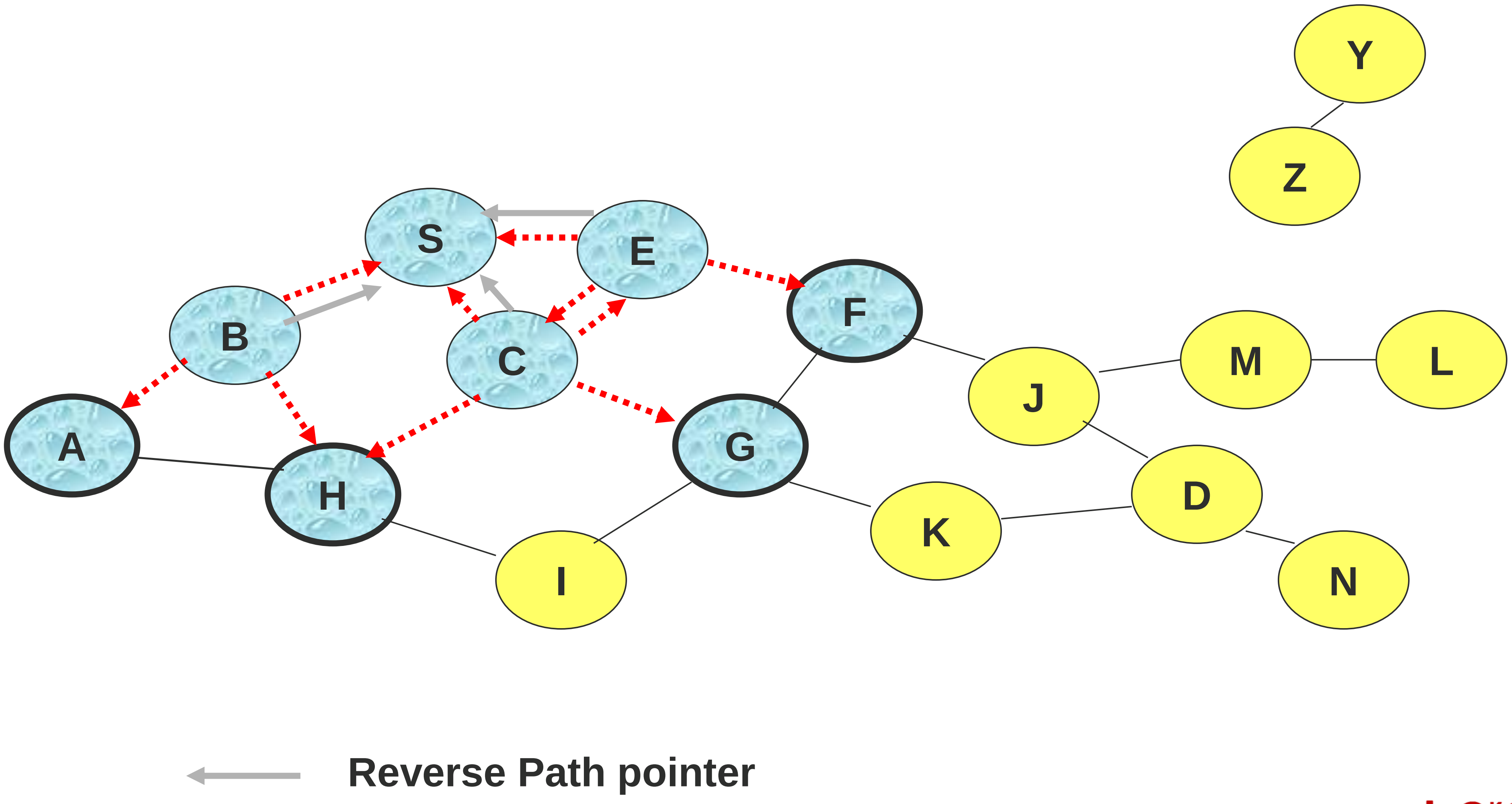


Node that already received a RREQ for D initiated by S

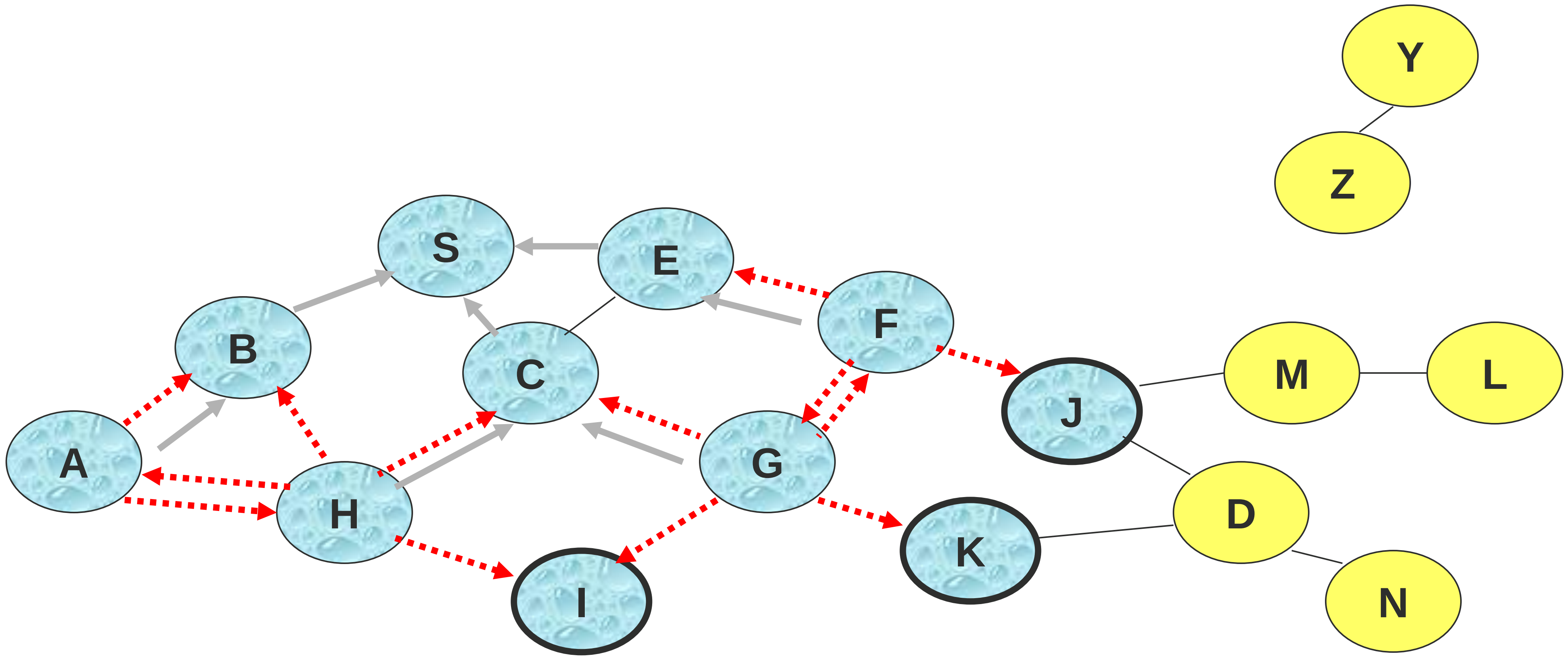
Route Request - AODV



Route Requests - AODV

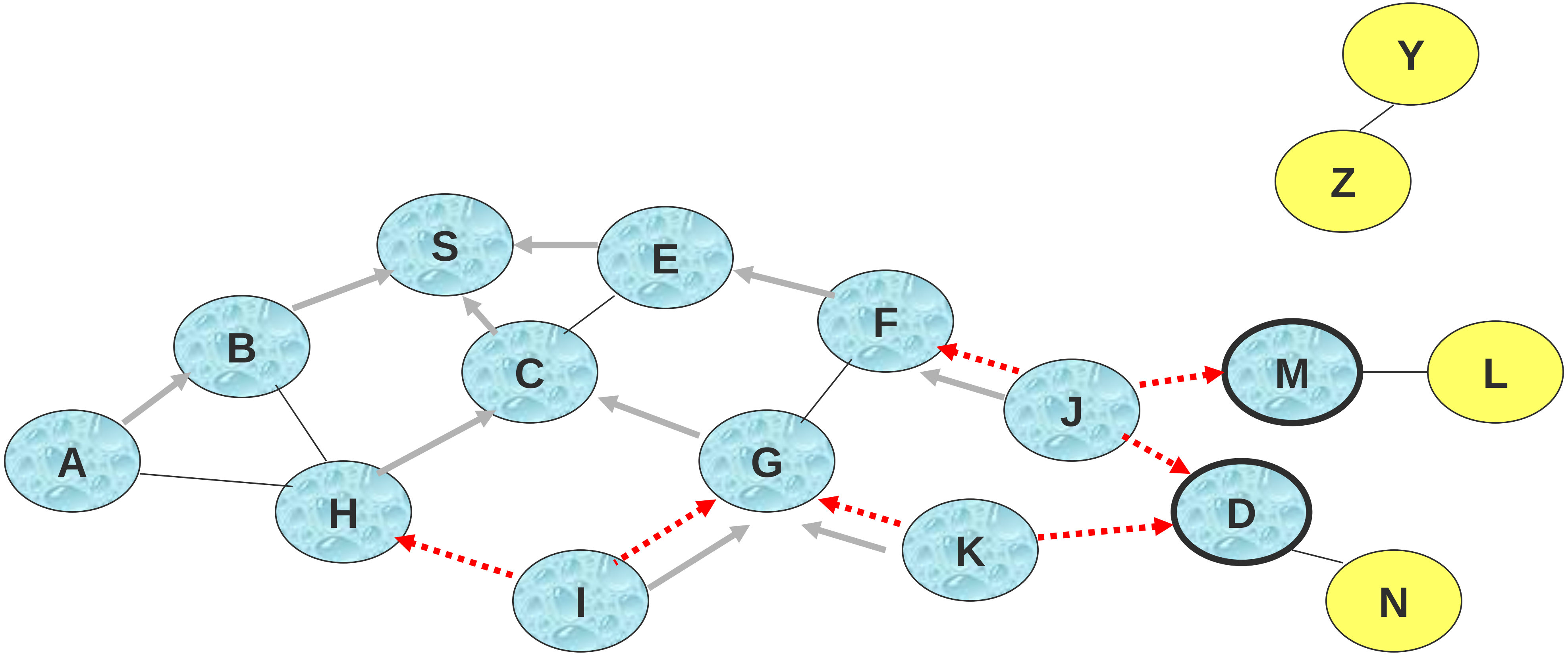


Reverse Path - AODV

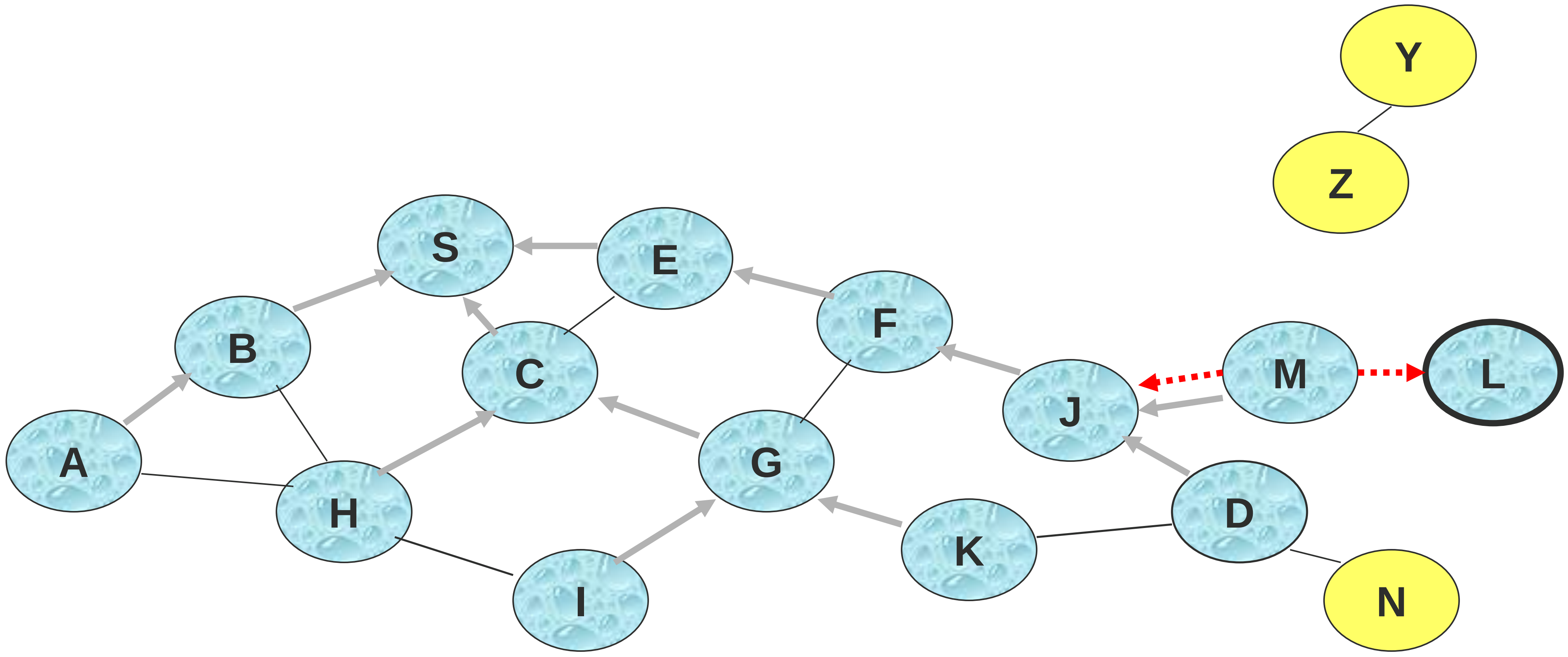


• C receives a RREQ from neighbors (G and H)
But does not rebroadcast it again

Reverse Path - AODV

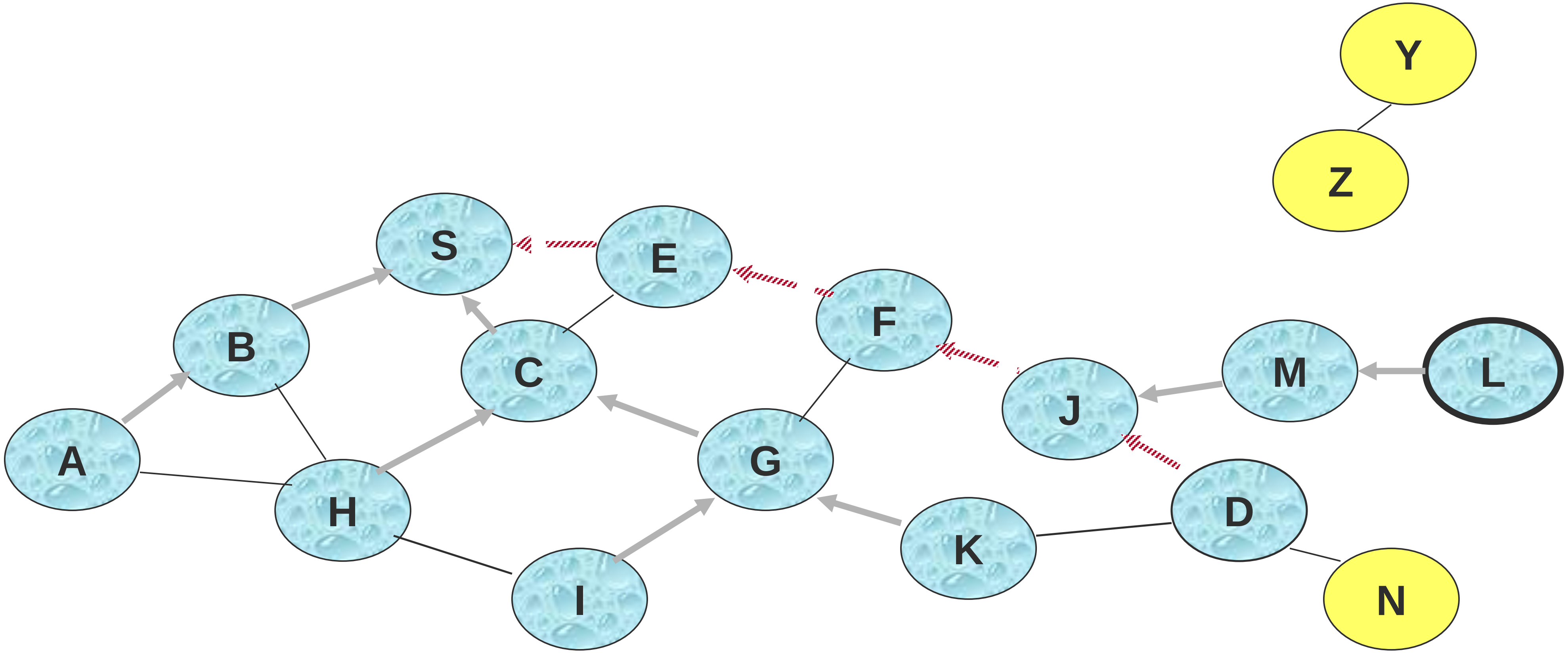


Reverse Path - AODV



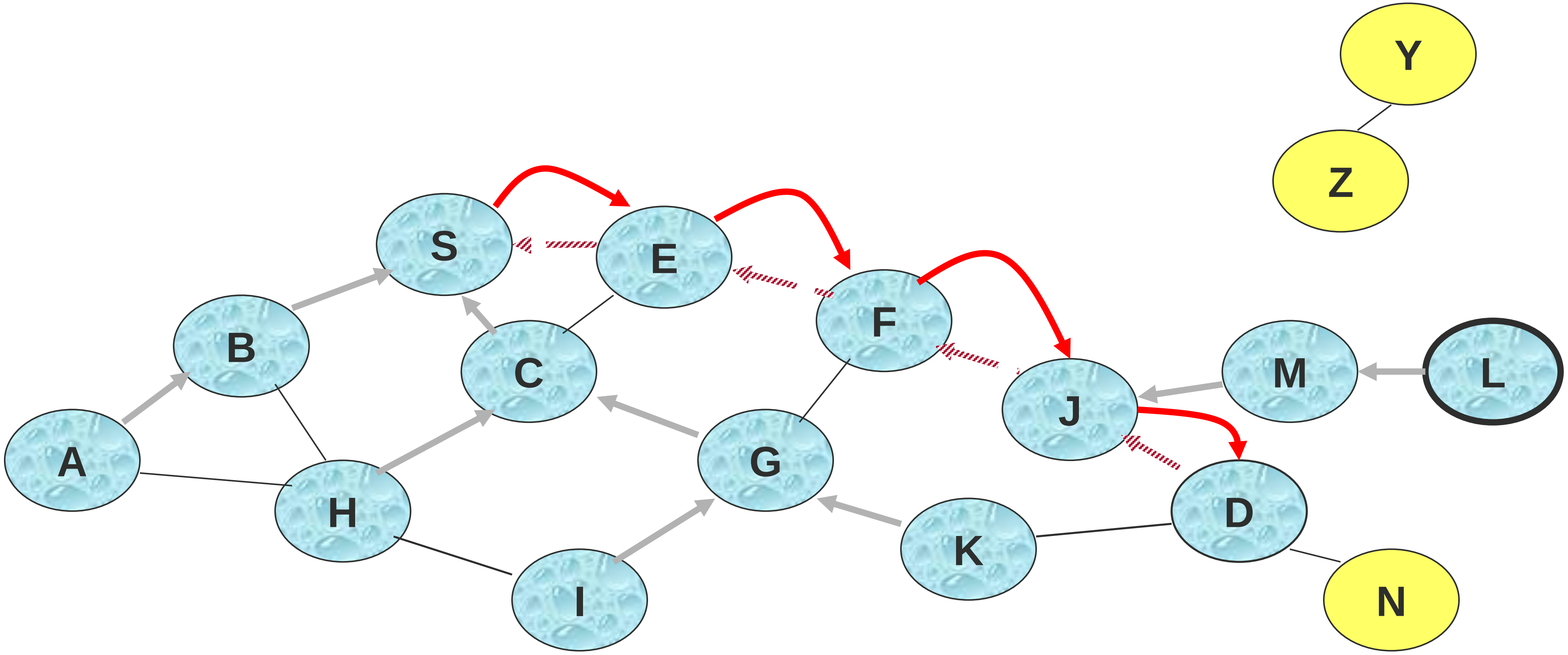
- node D does not forward anymore the RREQ message, as he is the destination

Route Reply - AODV



Path of the RREP message

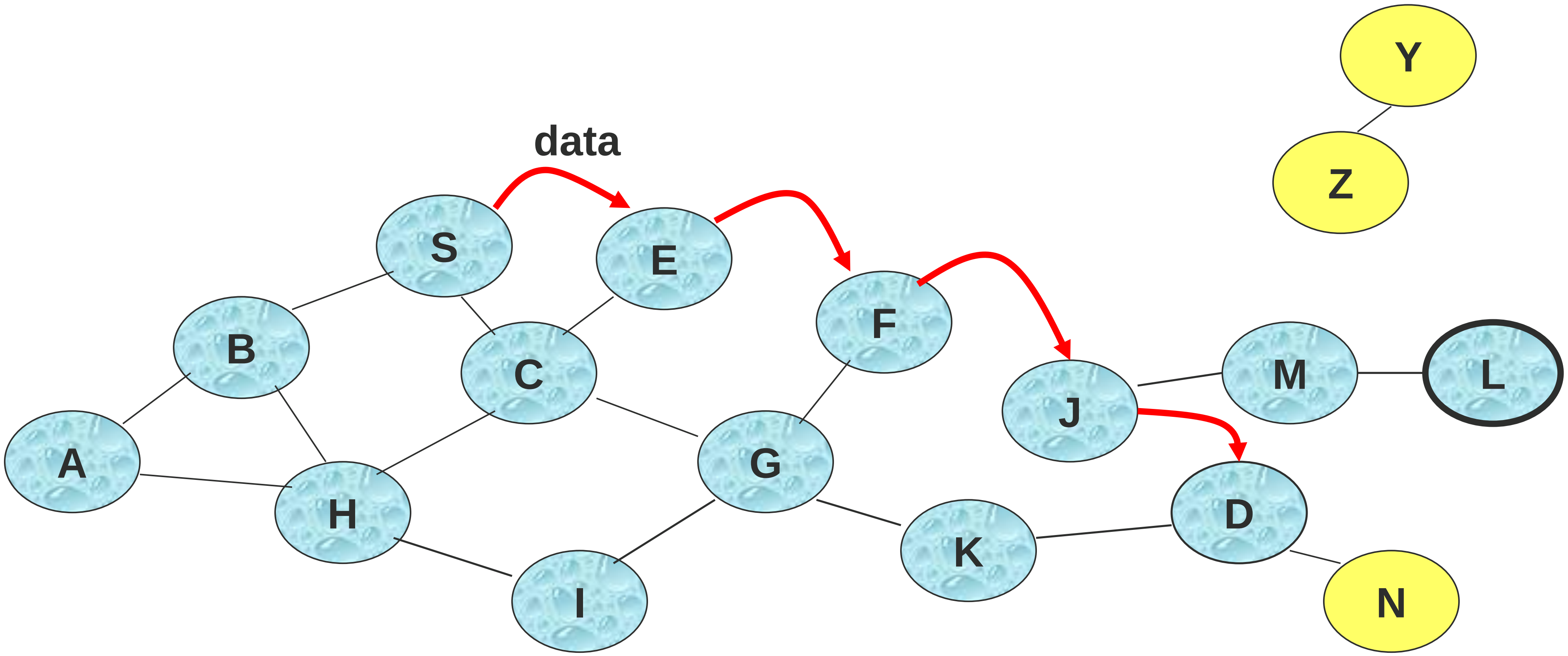
Forward Path - AODV



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

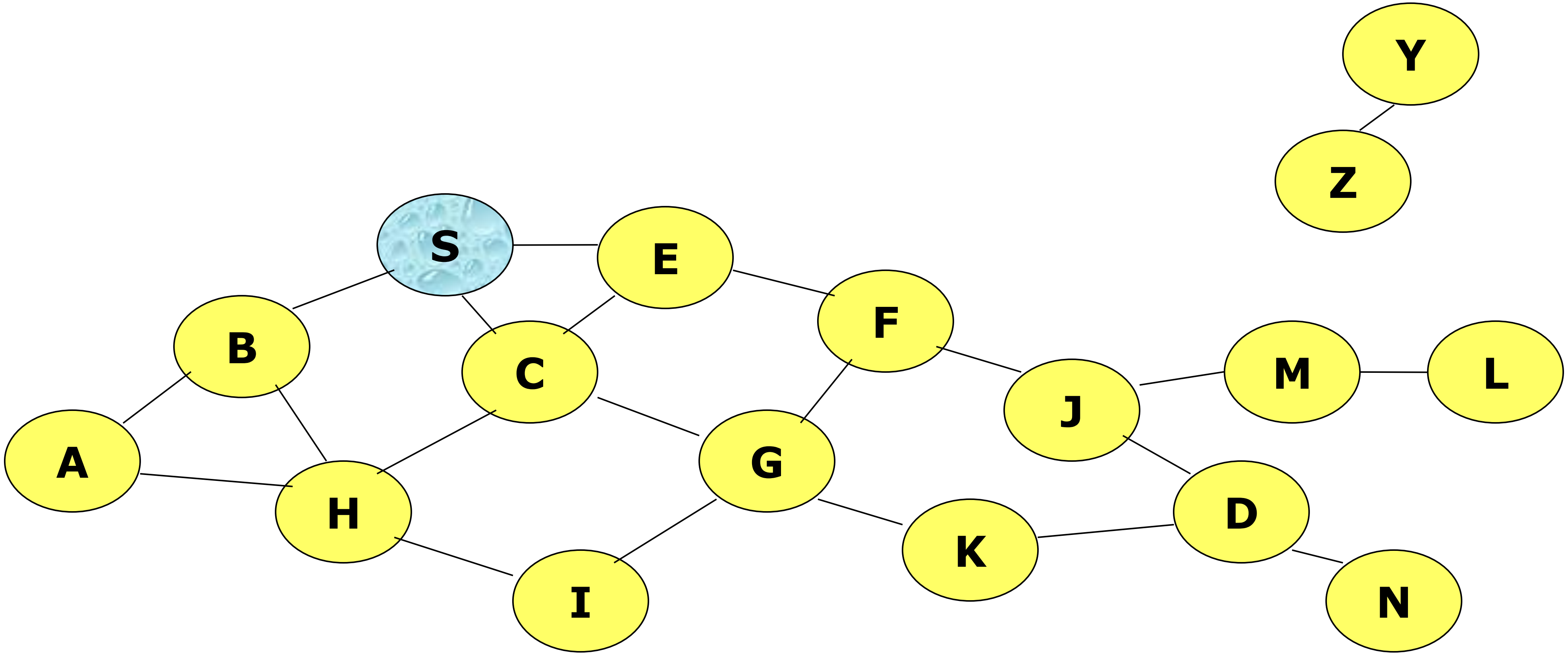
Optimization: Expanding Ring Search

- 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)

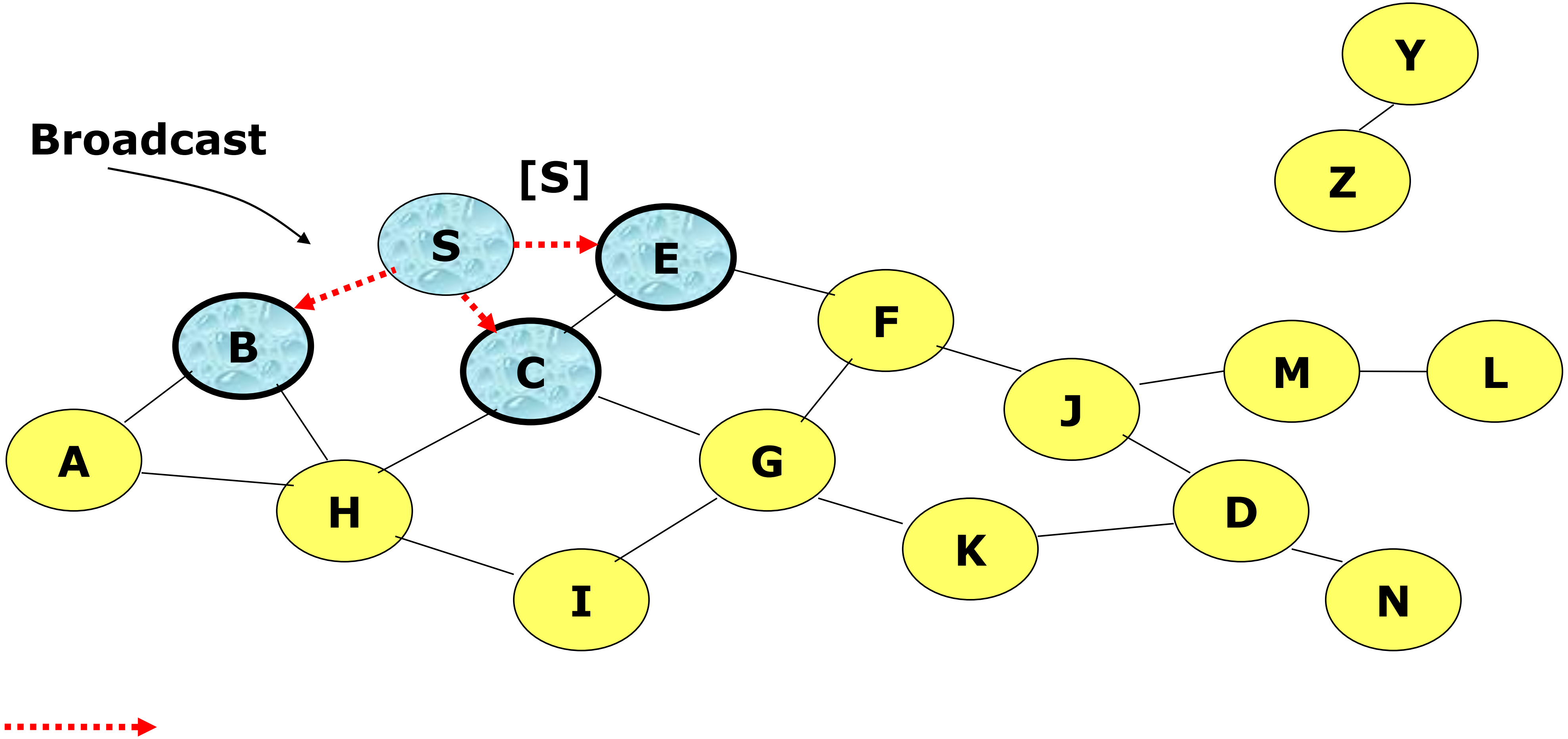
- If the source **S** wants to send something to destination **D,** it initiates route discovery
- **S** floods the network with Route Request (**RREQ**) messages
- Each intermediate node adds his ID to the RREQ before forwarding it

DSR Route Discovery



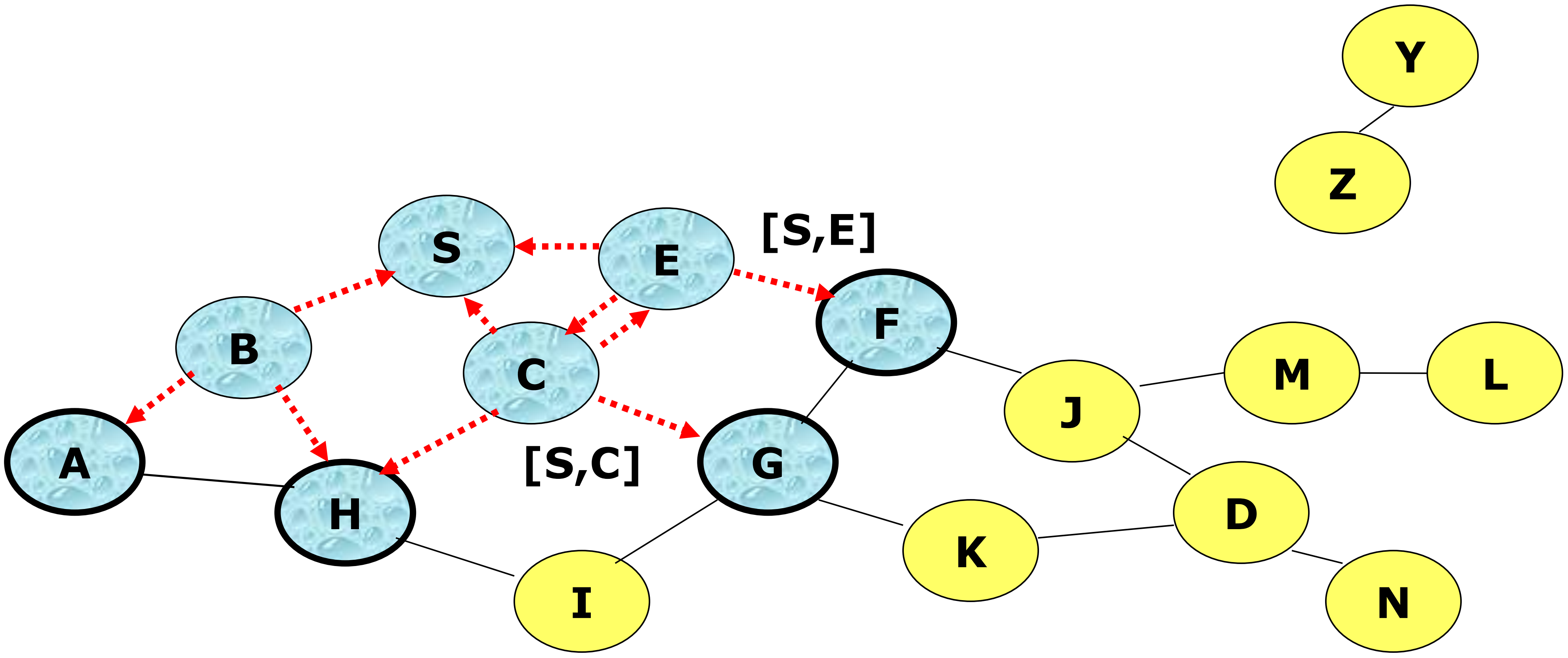
Nodes that already received the RREQ from S, regarding D

DSR Route Discovery

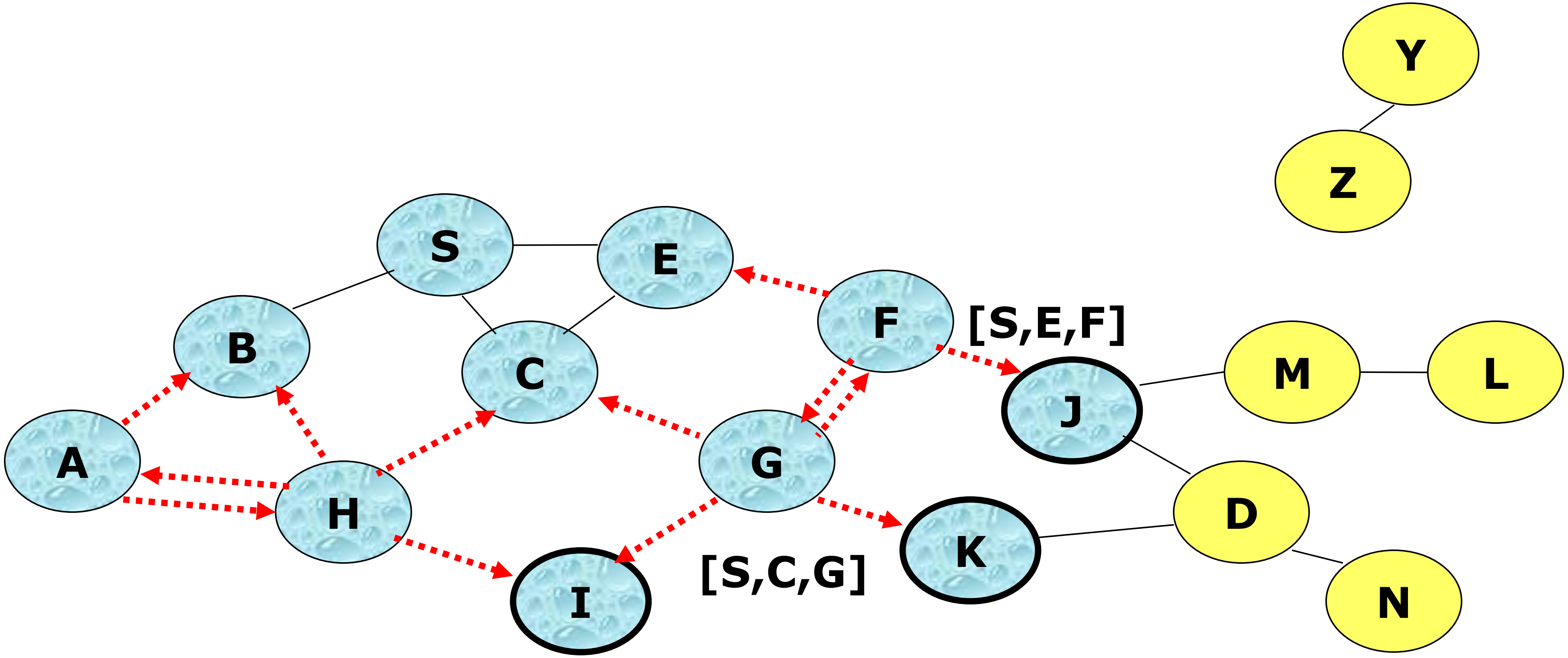


RREQ
[X, ...] intermediate nodes already added to the path

DSR Route Discovery

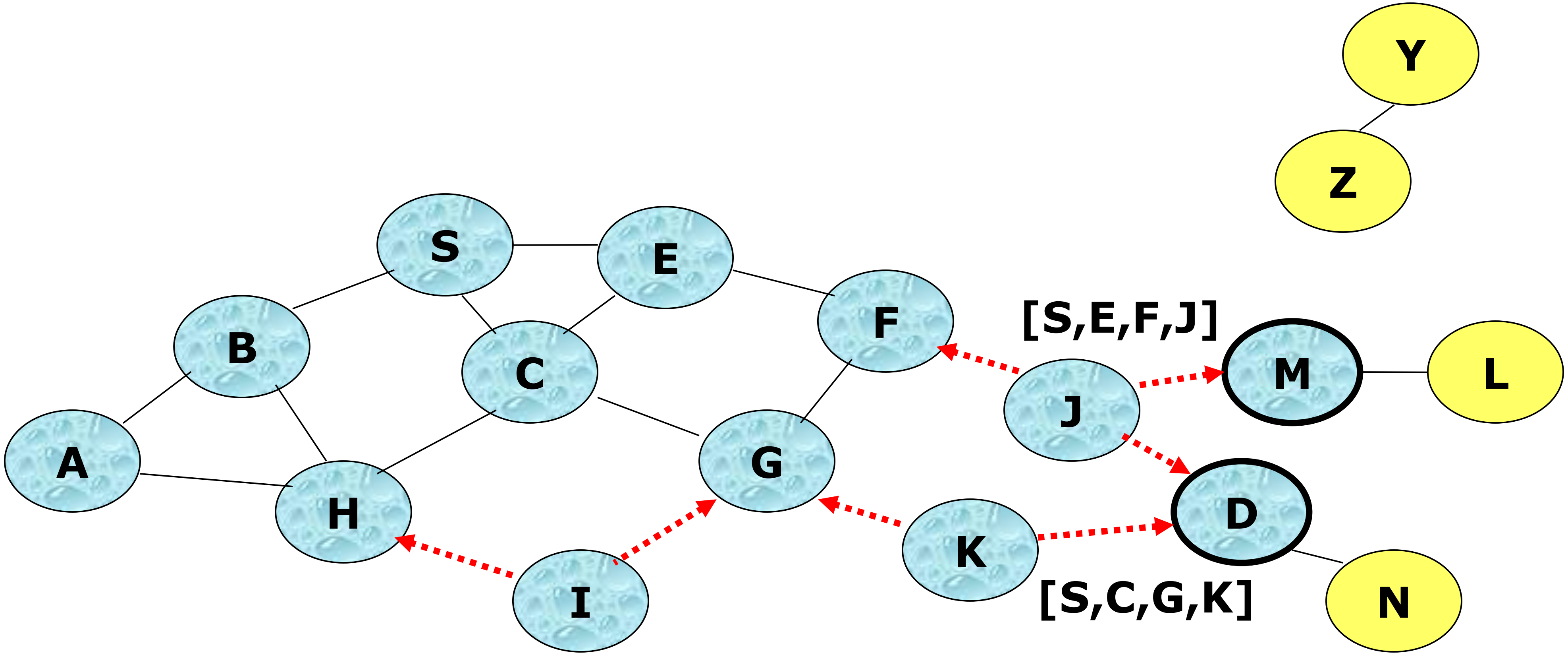


DSR Route Discovery

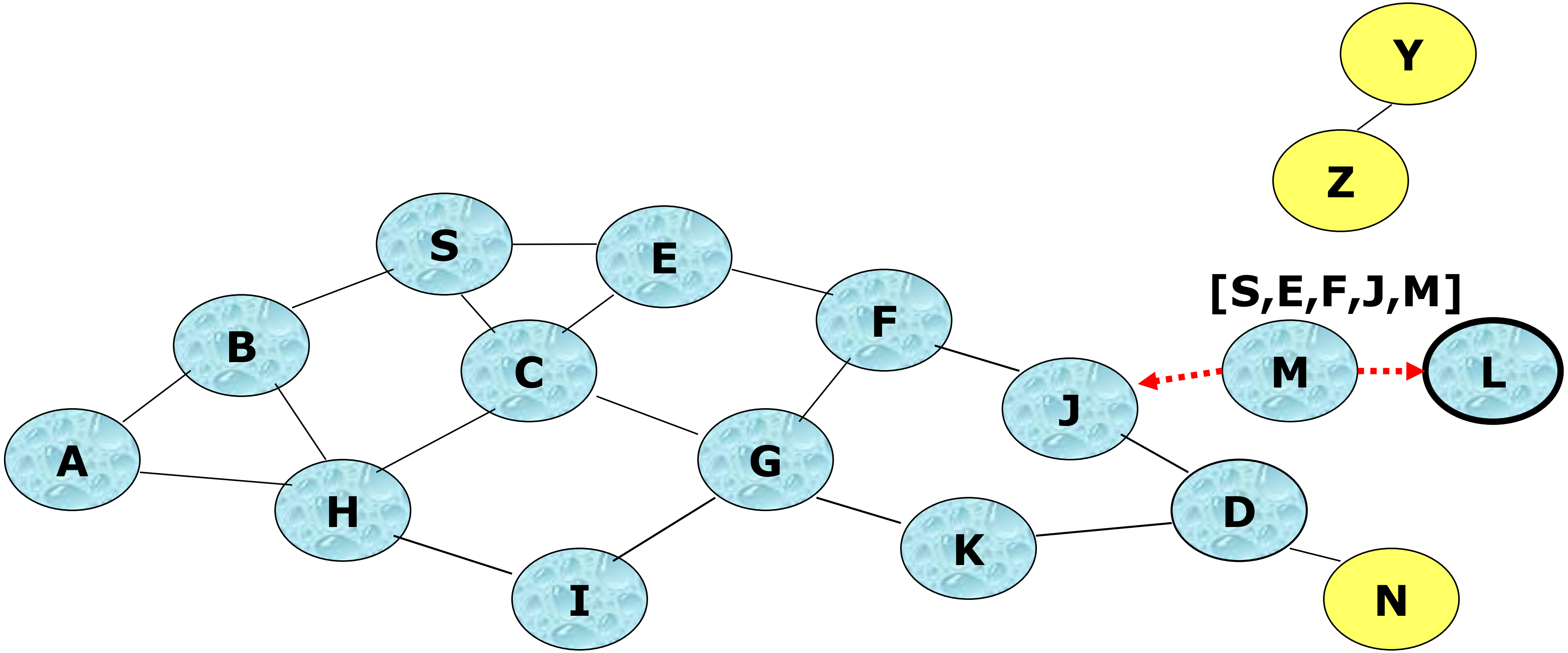


Restricting the flooding (like in AODV):
C receives the RREQ again from G and H, but does not forward it again

DSR Route Discovery



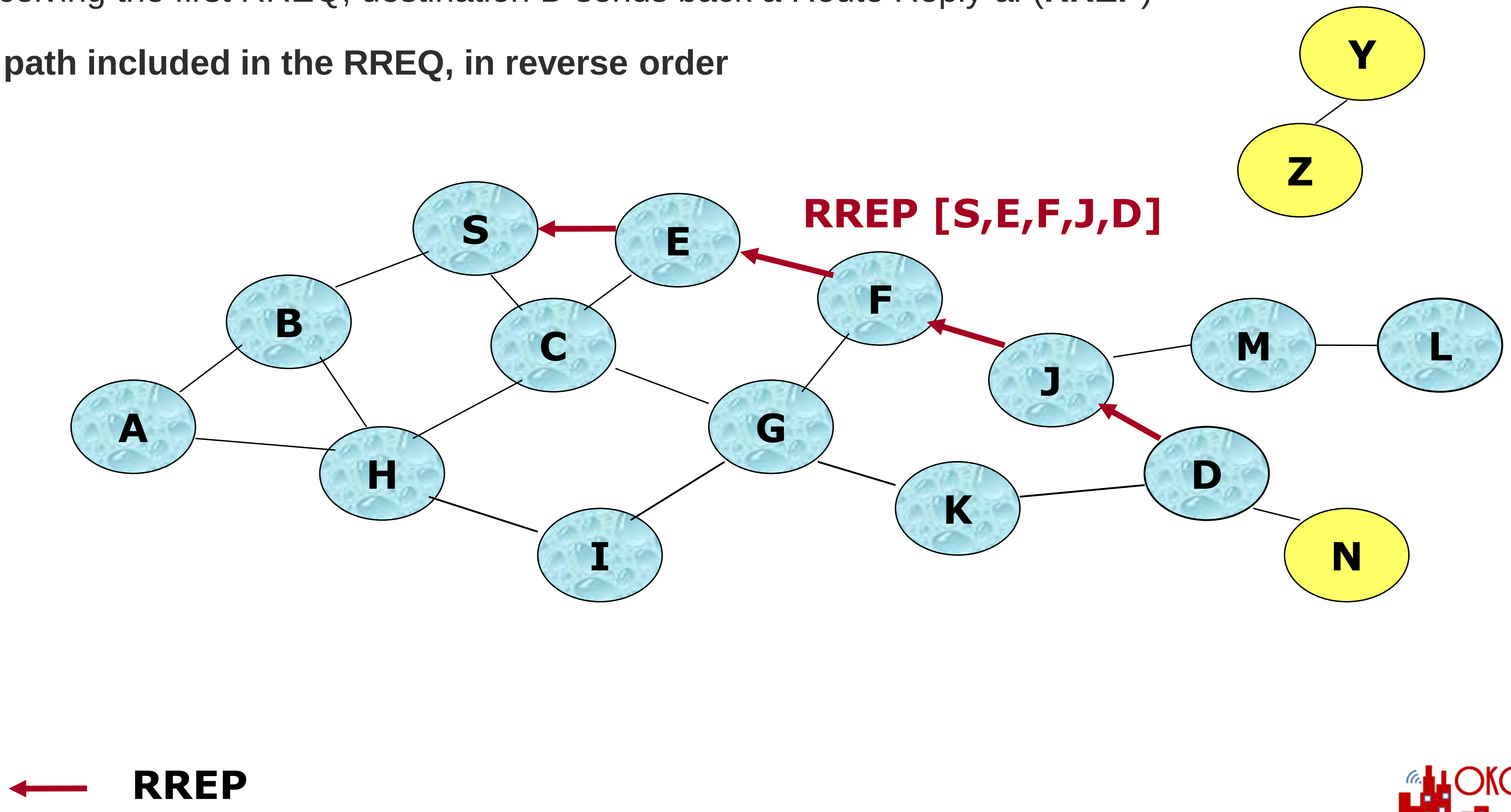
DSR Route Discovery



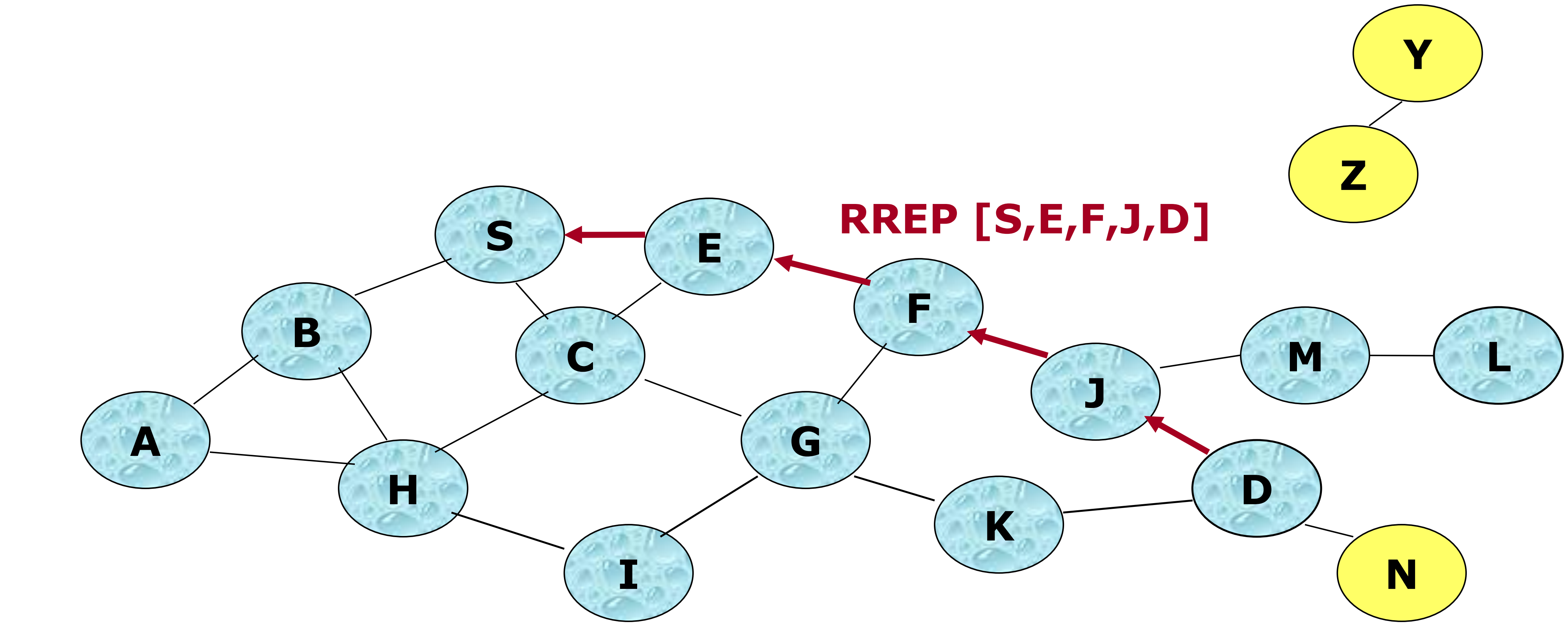
D stops the broadcast of RREQ, as it is the destination

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**

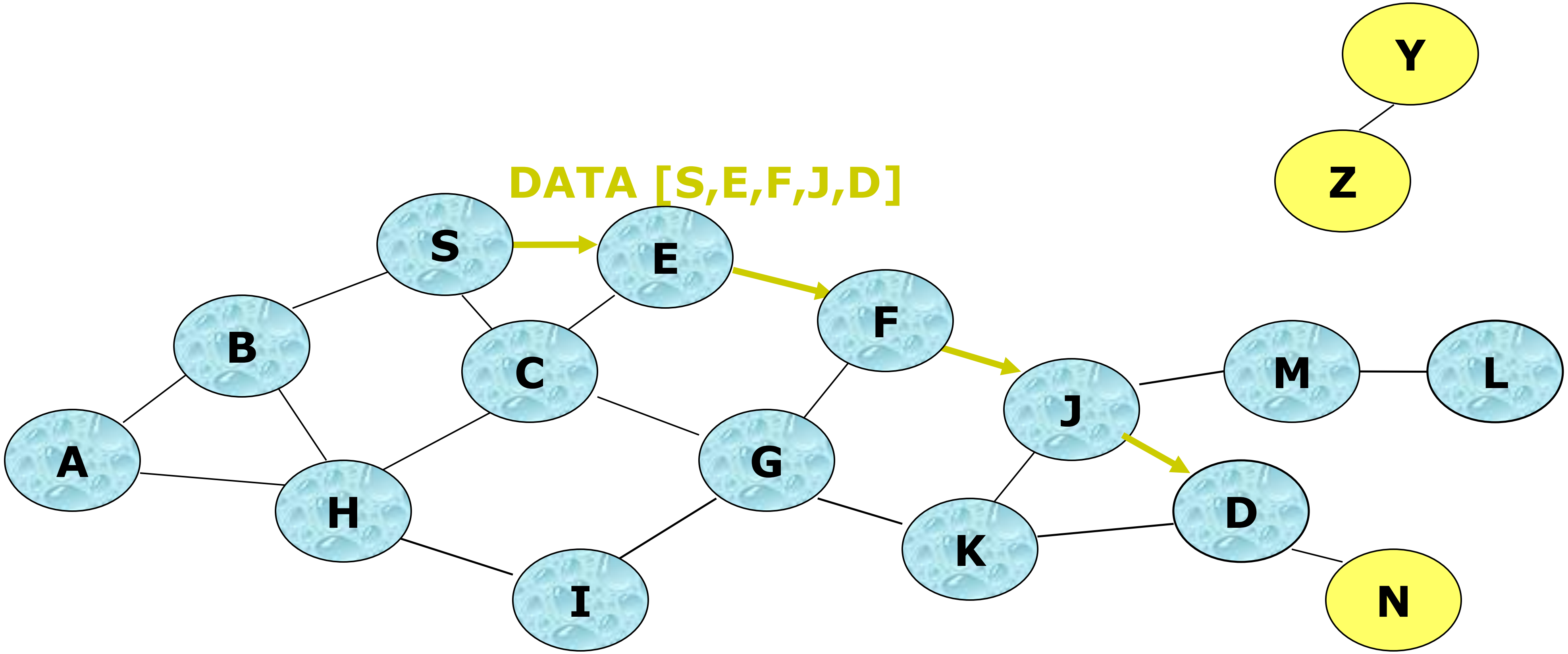


DSR Route Reply



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?

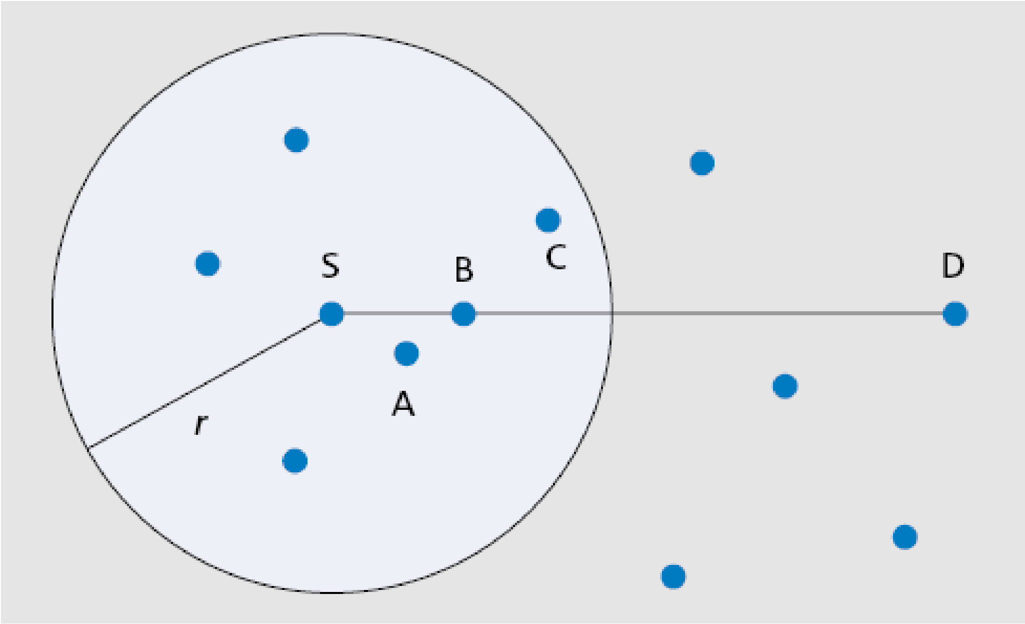
- If a source does not know the position of the destination, makes use of such a localization service
  - In case of a cellular (mobile) network, localization is centralized, and at cell level
  - It cannot be applied in ad hoc systems

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