MOBILE ADHOC NETWORKS (MANETs): *An Introduction*

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AN OVERVIEW

- Wireless Networks
- MANET (Defn. , applications)
- Routing (Defn. , Types)
- Routing Protocols in MANET
  - Proactive (6)
  - Reactive (5)
  - Hybrid (1)

Wireless Networks

- Need: Access computing and communication services, on the move

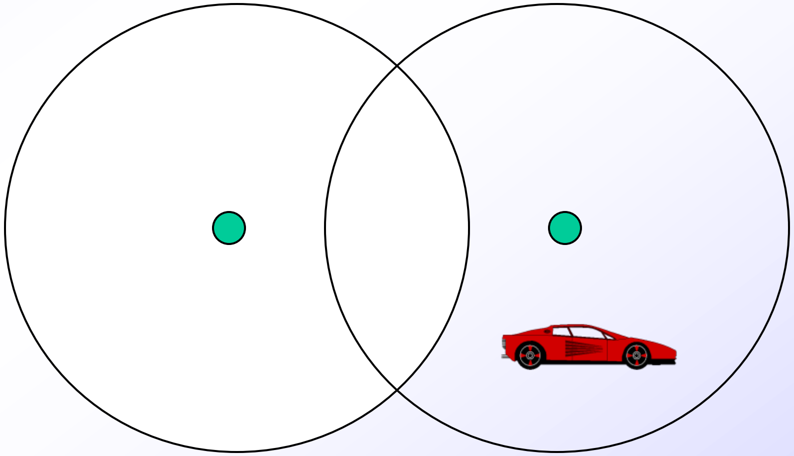
- Infrastructure-based Networks
  - –traditional cellular systems (base station infrastructure)

- Wireless LANs
  - – Infrared (IrDA) or radio links (Wavelan)
  - –very flexible within the reception area; ad-hoc networks possible
  - –low bandwidth compared to wired networks (1-10 Mbit/s)

- Ad hoc Networks
  - –useful when infrastructure not available, impractical, or expensive
  - –military applications, rescue, home networking

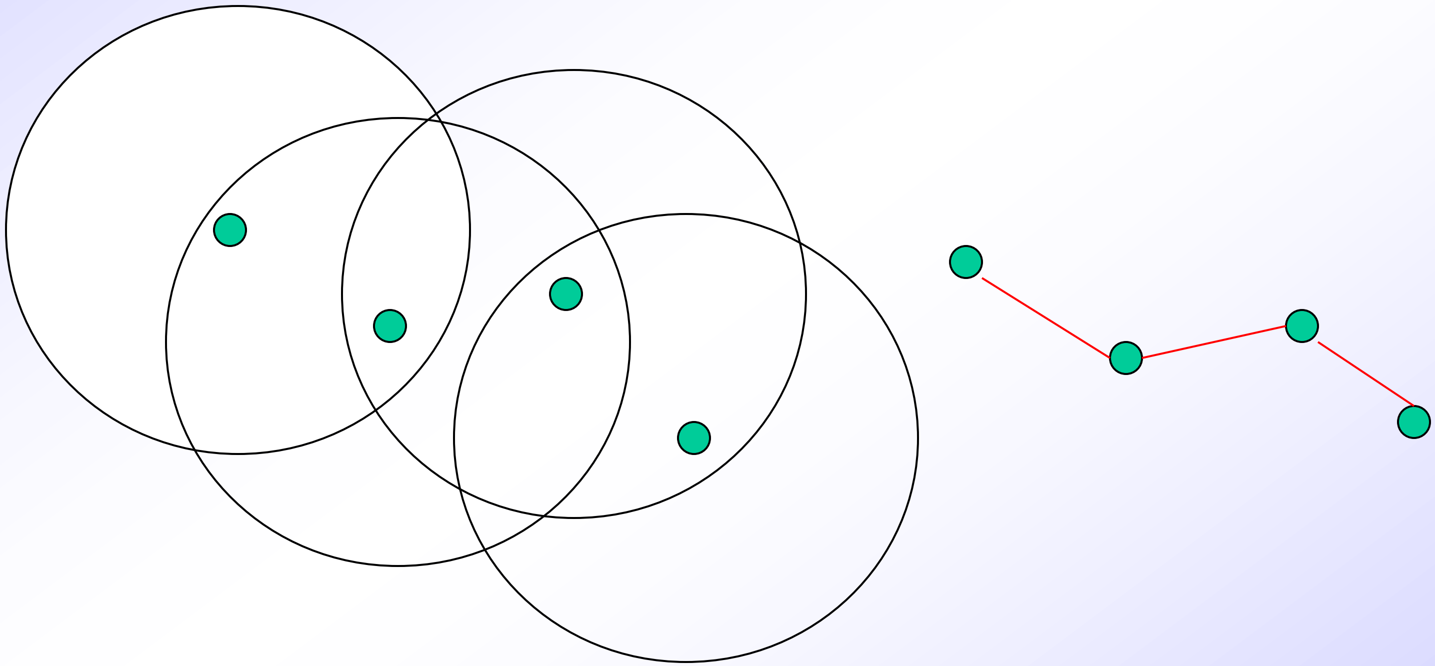
Cellular Wireless

- Single hop wireless connectivity to the wired world
  - –Space divided into cells
  - –A base station is responsible to communicate with hosts in its cell
  - –Mobile hosts can change cells while communicating
  - –Hand-off occurs when a mobile host starts communicating via a new base station



Multi-Hop Wireless

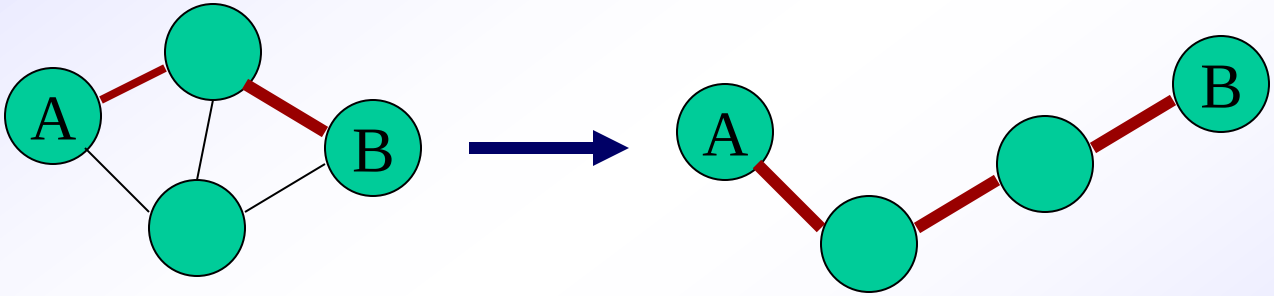
- May need to traverse multiple links to reach destination



- Mobility causes route changes

Mobile Ad hoc Networks (MANETs)

- Host movement frequent
- Topology change frequent



- No cellular infrastructure. Multi-hop wireless links
- Data must be routed via intermediate nodes

WHY ADHOC NETWORKS?

- Setting up of fixed access points and backbone infrastructure is not always viable

  - Infrastructure may not be present in a disaster area or war zone

  - Infrastructure may not be practical for short-range radios; Bluetooth (range ~ 10m)

- Ad hoc networks:

  -Do not need backbone infrastructure support

  - Are easy to deploy

  - Useful when infrastructure is absent, destroyed or impractical

Applications of MANET

- Personal area networking
  - –cell phone, laptop, ear phone, wrist watch
- Military environments
  - –soldiers, tanks, planes
- Civilian environments
  - –taxi cab network
  - –meeting rooms
  - –sports stadiums
  - –boats, small aircraft
- Emergency operations
  - –search-and-rescue
  - –policing and fire fighting

Challenges in Mobile Environments

- Limitations of the Wireless Network
  - packet loss due to transmission errors
  - variable capacity links
  - frequent disconnections/partitions
  - limited communication bandwidth
  - Broadcast nature of the communications

- Limitations Imposed by Mobility
  - dynamically changing topologies/routes
  - lack of mobility awareness by system/applications

- Limitations of the Mobile Computer
  - short battery lifetime
  - limited capacities

Routing in MANETs

Challenges for Routing Protocols

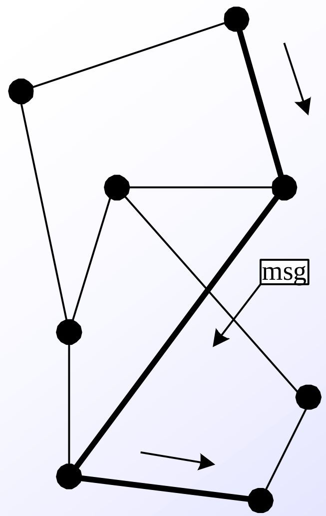
- No centralized entity
- Host is no longer just an end system
- Acting as an intermediate system
- Changing network topology over time
- Every node can be mobile

Effect of mobility on the protocol stack

- Application
  - –new applications and adaptations
- Transport
  - –congestion and flow control
- Network
  - –addressing and routing
- Link
  - –media access and handoff
- Physical
  - –transmission errors and interference

ROUTING ?

- Network with nodes, edges
- **Goal:** Devise scheme for transferring message from one node to another.
  - –Which path?
  - –Who decides – source or intermediate nodes?

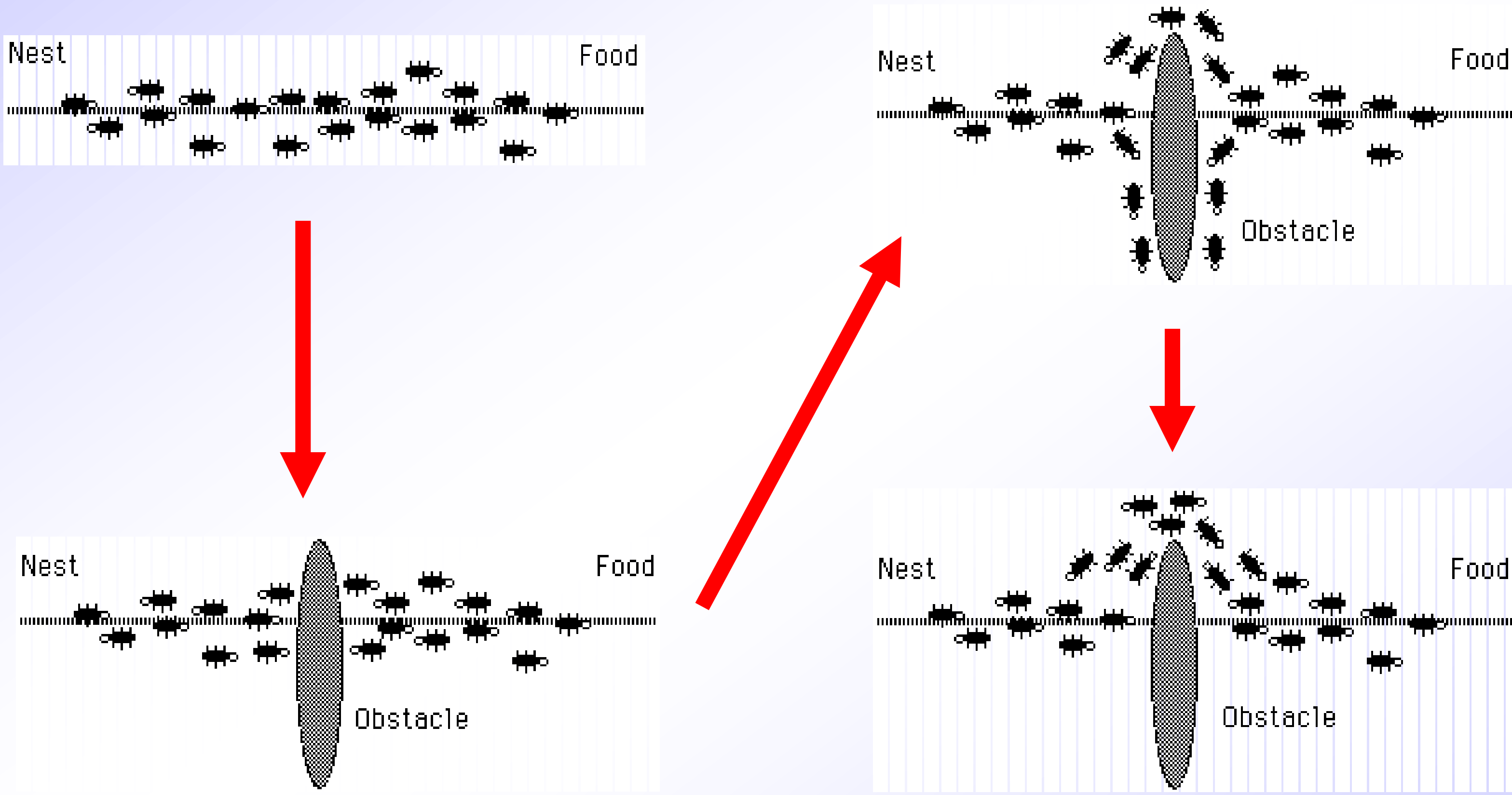


WHICH PATH?

- Generally try to optimize something:
  - –Shortest path (fewest hops)
  - –Shortest time (lowest latency)
  - –Shortest weighted path (utilize available bandwidth)
  - –Etc.

Routing ?
Ants Searching for Food

Example:



Nest
Food
Nest
Food
Obstacle
Nest
Food
Obstacle
Nest
Food
Obstacle

Three Main Issues in Ants' Life

- Route Discovery:

  Searching for the places with food

  Packet Forwarding:

  Delivering foods back home

  Route Maintenance:

  When foods move to new place

Who determines route?

2 General Approaches:

- **Source ("path") routing**

  Source specifies entire route: places complete path to destination in message header: A – D – F – G

  Intermediate nodes just forward to specified next hop: D would look at path in header, forward to F

  Like airline travel – get complete set of tickets to final destination before departing…

Who determines route? …..contd.

- **Destination (“hop-by-hop”) routing**

  –Source specifies only destination in message header: G

  –Intermediate nodes look at destination in header, consult internal tables to determine appropriate next hop

  –Like postal service – specify only the final destination on an envelope, and intermediate post offices select where to forward next…

Comparison

- Source routing
  - –Moderate source storage (entire route for each desired dest.)
  - –No intermediate node storage
  - –Higher routing overhead (entire path in message header, route discovery messages)

- Destination routing
  - - No source storage
  - - High intermediate node storage (table w/ routing instructions for all possible dests.)
  - - Lower routing overhead (just dest in header, only routers need deal w/ route discovery)

AD HOC ROUTING

- Every node participates in routing: no distinction between “routers” and “end nodes”

- No external network setup: “self-configuring”

- Especially useful when network topology is dynamic (frequent network changes – links break, nodes come and go)

ROUTING PROTOCOLS IN MANET

- Many protocols have been proposed
- Some specifically invented for MANET
- Others adapted from protocols for wired networks
- 9 routing protocols in draft stage, 4 drafts dealing with broadcast / multicast / flow issues

  (Other protocols being researched)

- Standardization efforts in IETF
  - –MANET, MobileIP working groups
  - –**http://www.ietf.org**

ROUTING PROTOCOLS IN MANET .....contd.

- Proactive protocols *(Table-Driven approach)*
  - –Traditional distributed shortest-path protocols
  - –Maintain routes between every host pair at all times
  - –Based on periodic updates; High routing overhead
  - –Example: DSDV (destination sequenced distance vector)

- Reactive protocols *(Demand-Based approach)*
  - –Determine route if and when needed
  - –Source initiates route discovery
  - –Example: DSR (dynamic source routing)

- Hybrid protocols
  - –Adaptive; Combination of proactive and reactive
  - –Example : ZRP (zone routing protocol)

I) PROACTIVE PROTOCOLS (TABLE DRIVEN)

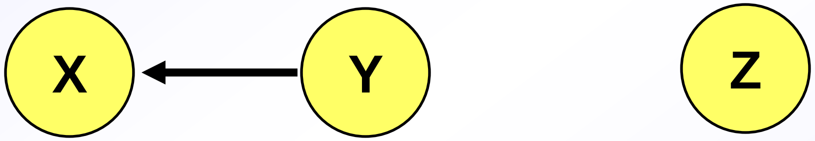
- Distance Sequenced Distance Vector (DSDV)
- Wireless Routing Protocol (WRP)
- Global State Routing (GSR)
- Fisheye State Routing (FSR)
- Hierarchical State Routing (HSR)
- Common Gateway Switch Routing (CGSR)

1a) DSDV

- Each node maintains a routing table which stores
  - next hop, cost metric towards each destination
  - a sequence number that is created by the destination itself
- Each node periodically forwards routing table to neighbors
  - Each node increments and appends its sequence number when sending its local routing table
- Each route is tagged with a sequence number; routes with greater sequence numbers are preferred
- Each node advertises a monotonically increasing even sequence number for itself
- When a node decides that a route is broken, it increments the sequence number of the route and advertises it with infinite metric
- Destination advertises new sequence number

DSDV….contd.

- When X receives information from Y about a route to Z
  - –Let destination sequence number for Z at X be S(X), S(Y) is sent from Y



  - – If S(X) > S(Y), then X ignores the routing information received from Y
  - – If S(X) = S(Y), and cost of going through Y is smaller than the route known to X, then X sets Y as the next hop to Z
  - – If S(X) < S(Y), then X sets Y as the next hop to Z, and S(X) is updated to equal S(Y)

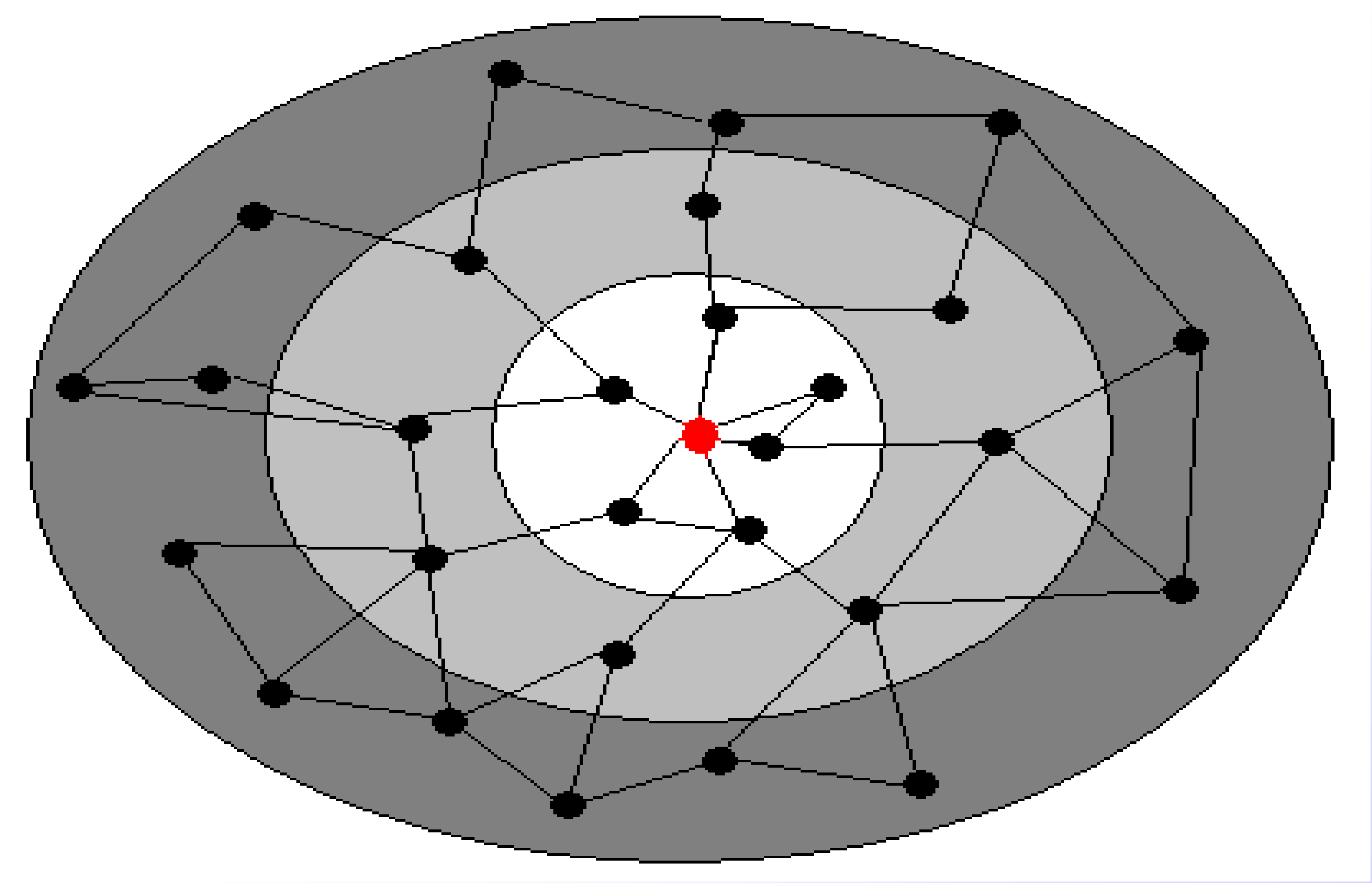
1b) Wireless Routing Protocol (WRP)

- Each node maintains four separate tables to exchange routing information
  - a distance table
  - a routing table
  - a link-cost table
  - a message retransmission list (MRL)
- Predecessor and Successor information helps in avoiding loops
- Nodes send HELLO message to each other when idle to announce presence

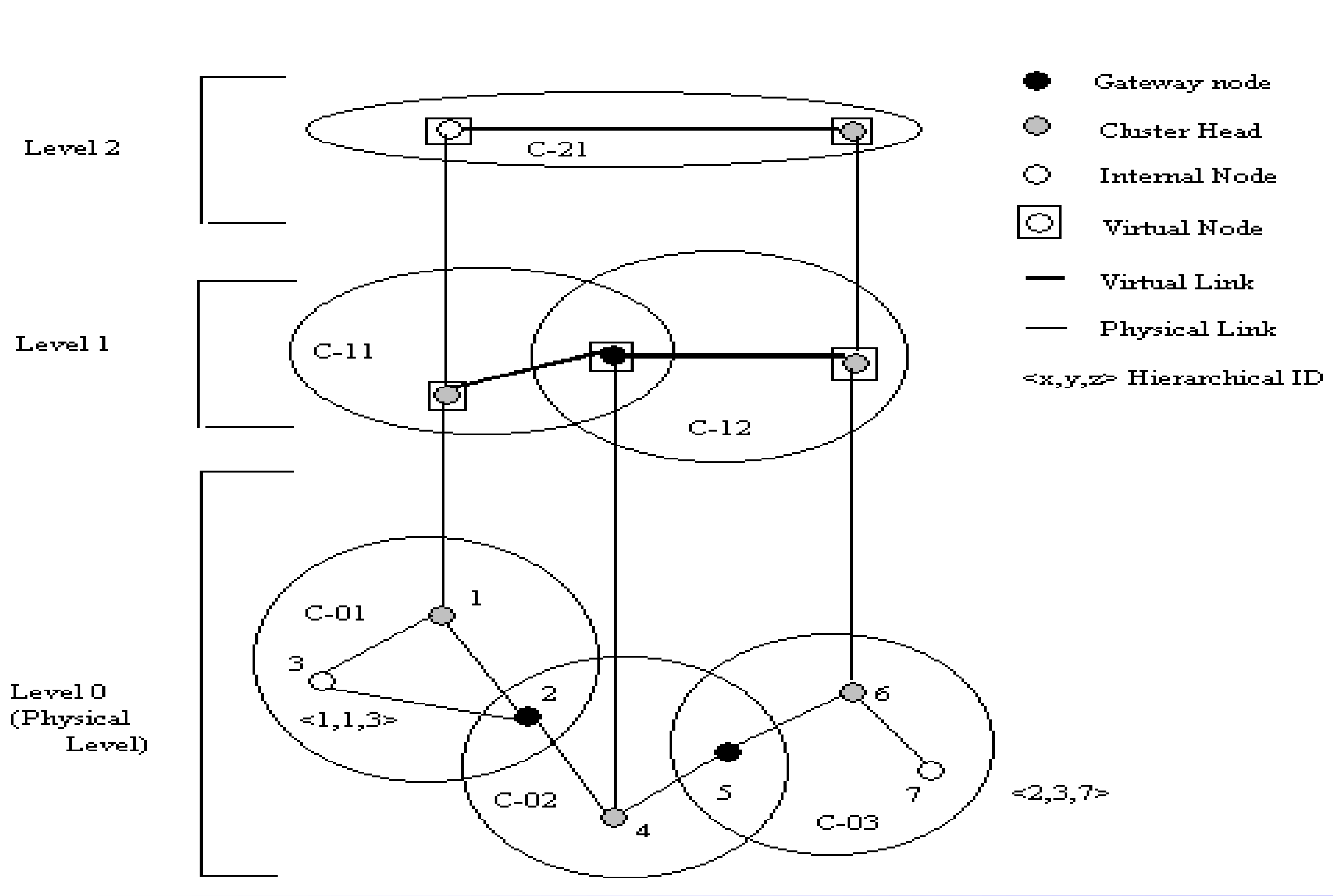
1c) GLOBAL STATE ROUTING (GSR)

- Uses link state Routing Scheme
- Each node maintains four tables
  - Neighbor list
  - Topology table
  - Next hop table
  - Distance table
- All tables are updated on link change

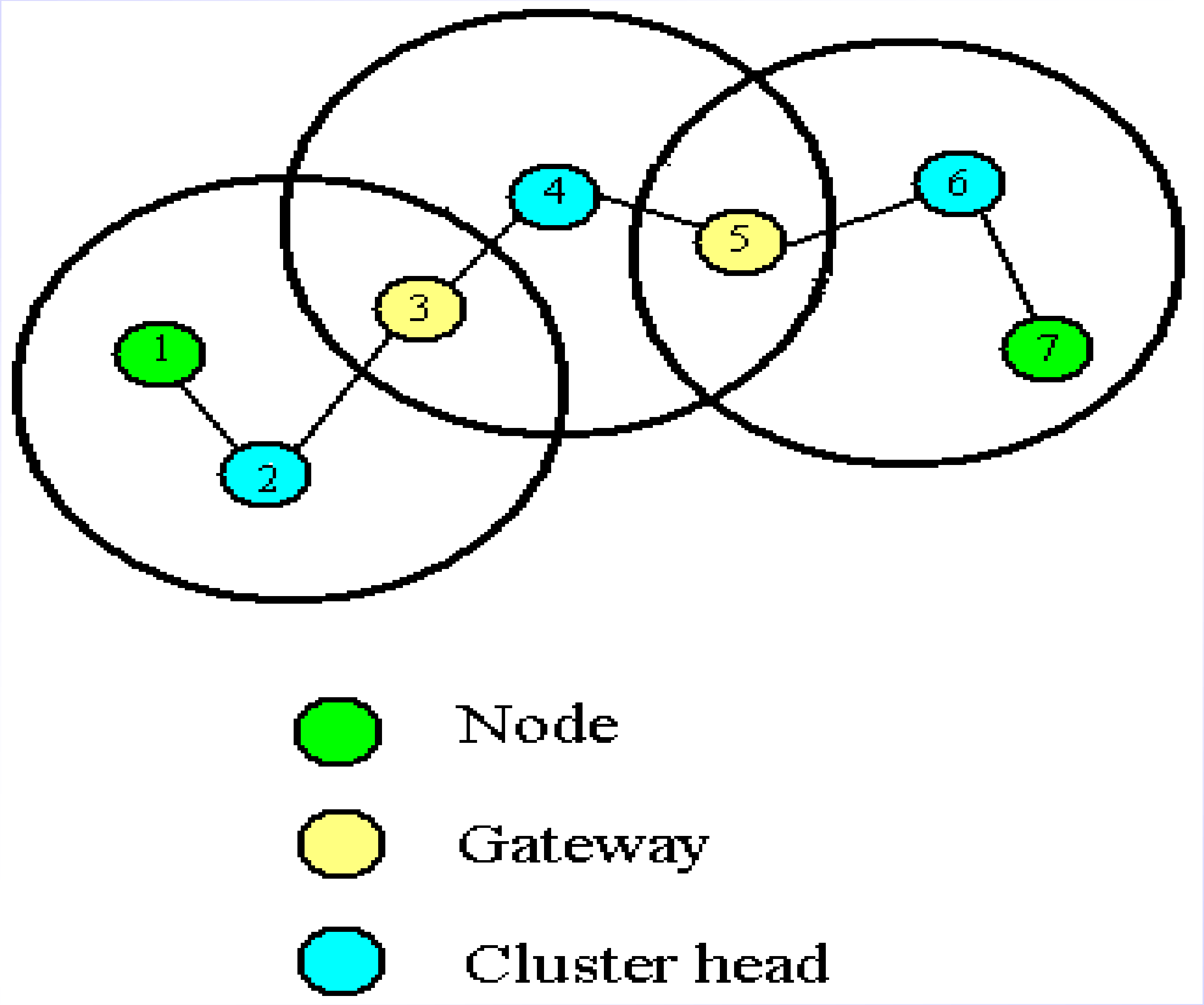
1d) Fisheye State Routing (FSR)



1e) Hierarchical State Routing (HSR)



1f) Clusterhead Gateway Switching Routing (CGSR)



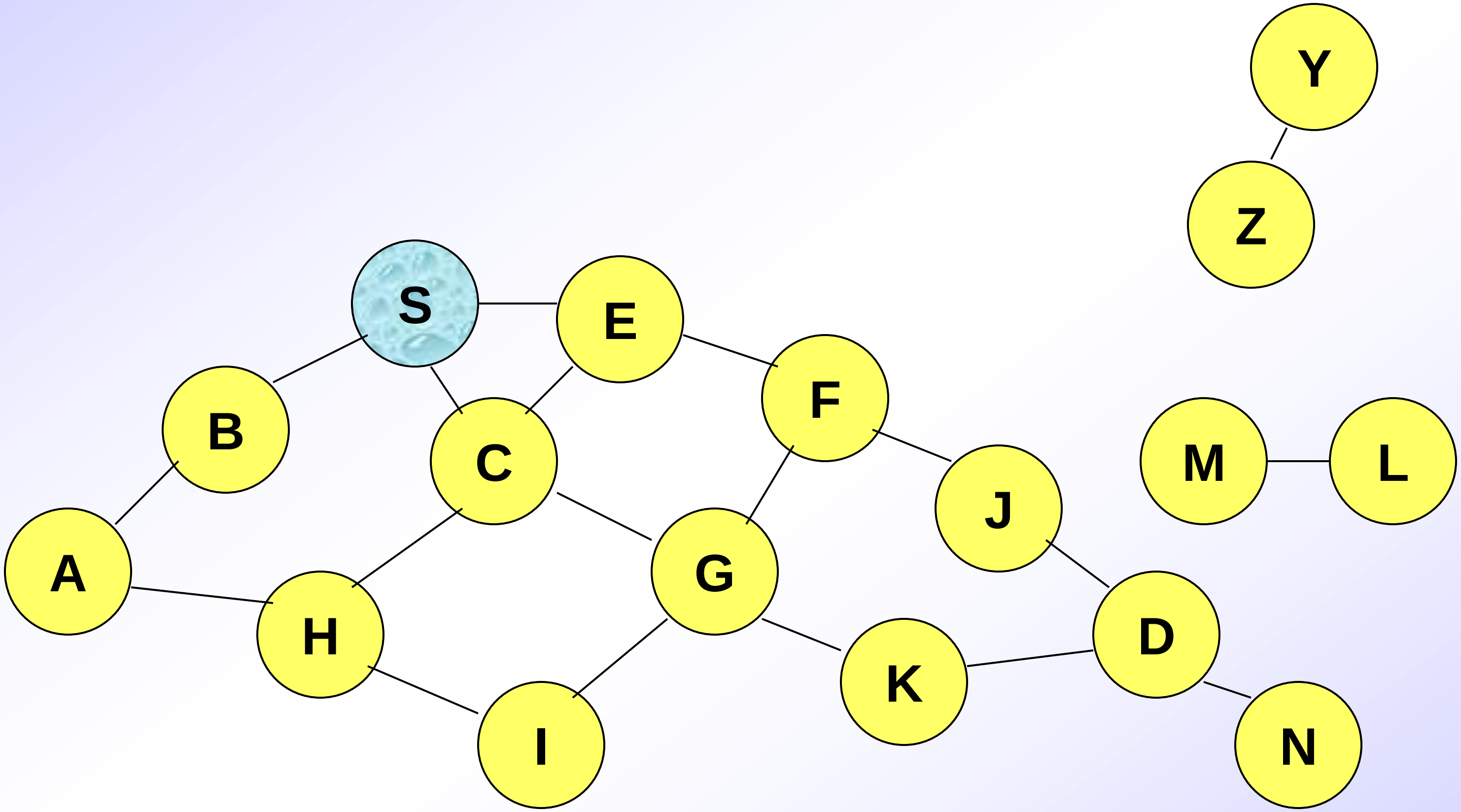
II) REACTIVE PROTOCOLS (DEMAND BASED)

- Dynamic Source Routing (DSR)
- Ad hoc On Demand distance Vector Routing (AODV)
- Associativity Based Routing (ABR)
- Signal Stability Algorithm (SSA)
- Temporally Ordered Routing Algorithm (TORA)

2a) Dynamic Source Routing (DSR)

- 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)
- Each node *appends own identifier* when forwarding RREQ

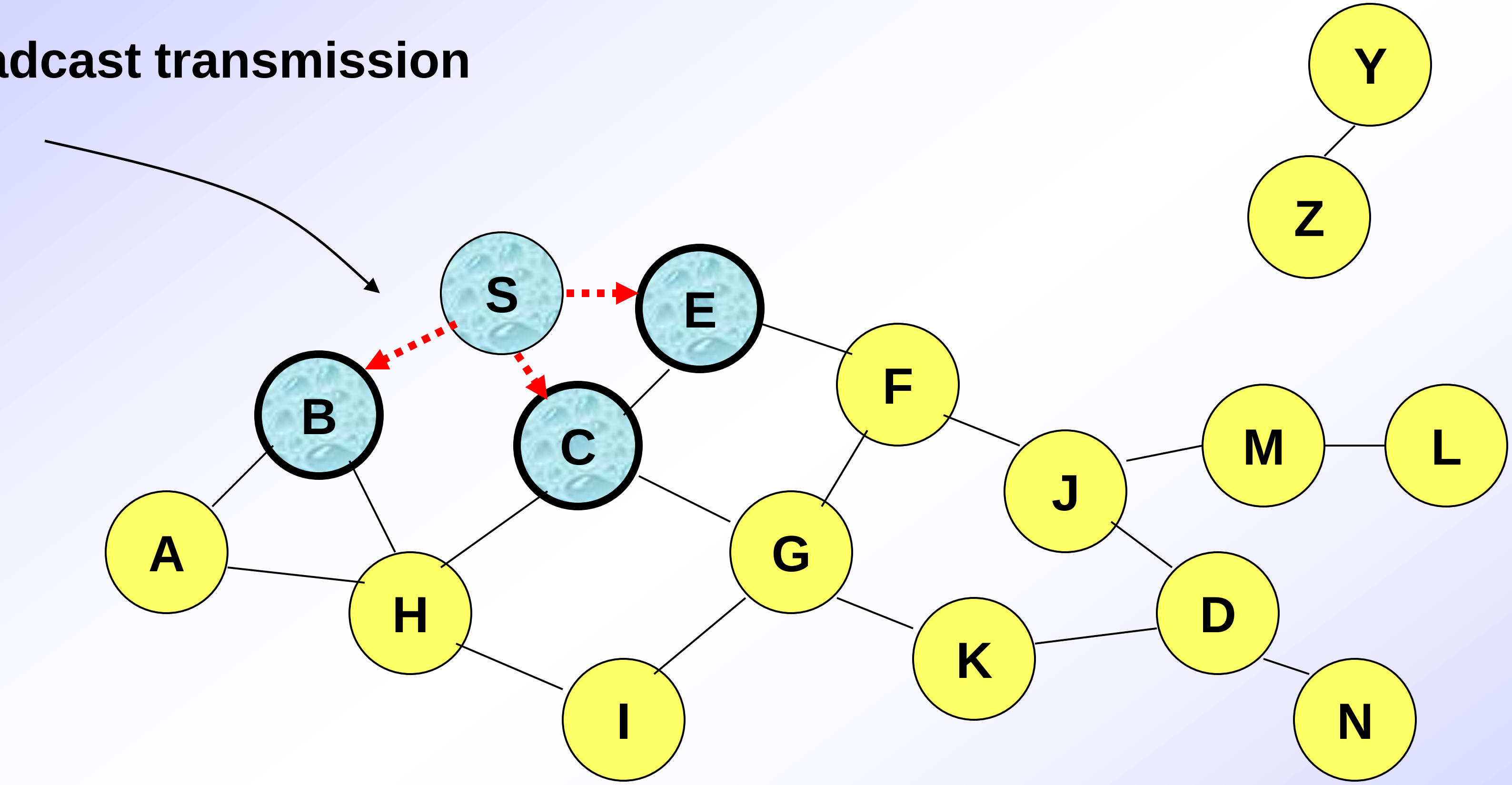
Route Discovery in DSR



Represents a node that has received RREQ for D from S

Route Discovery in DSR

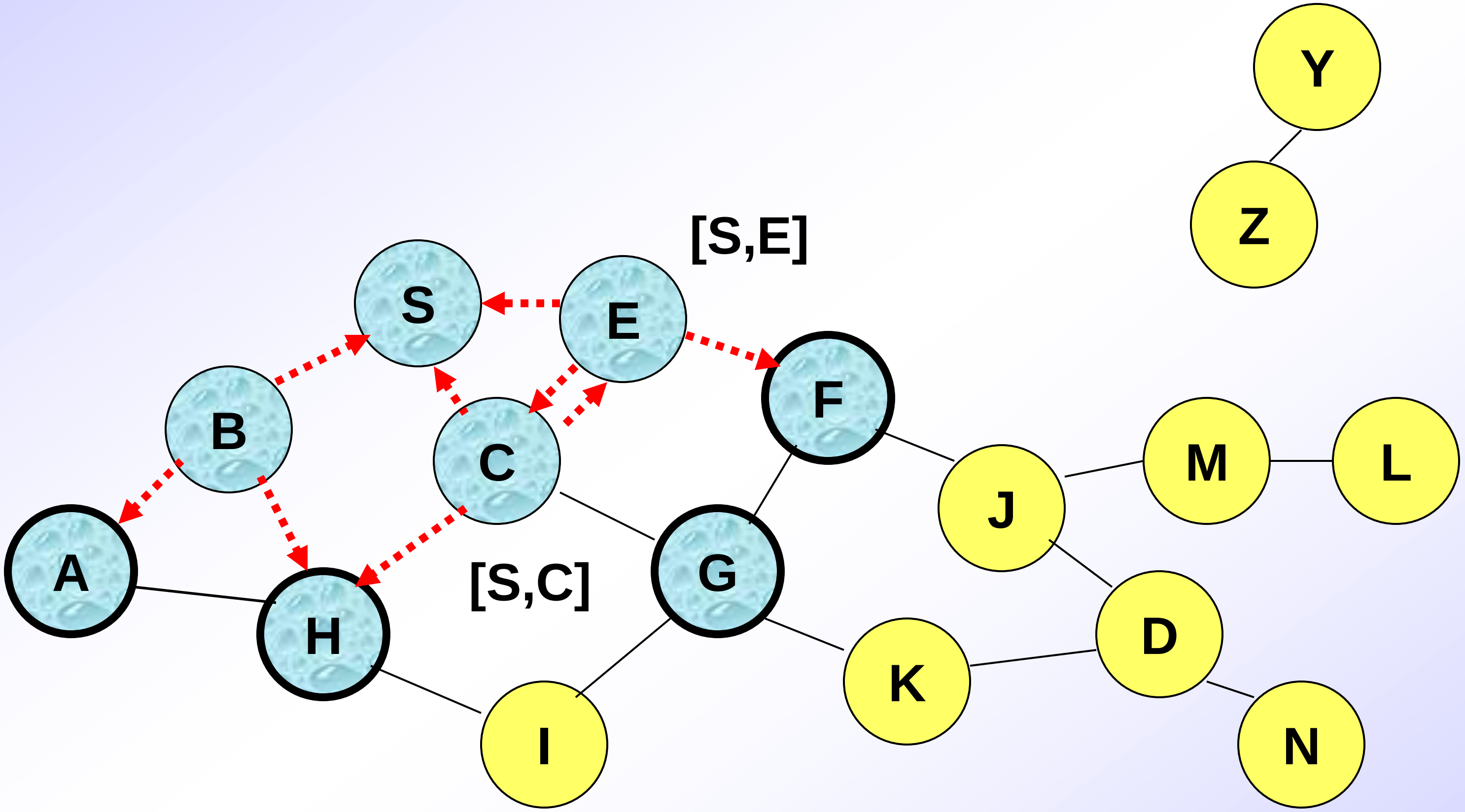
Broadcast transmission



Represents transmission of RREQ

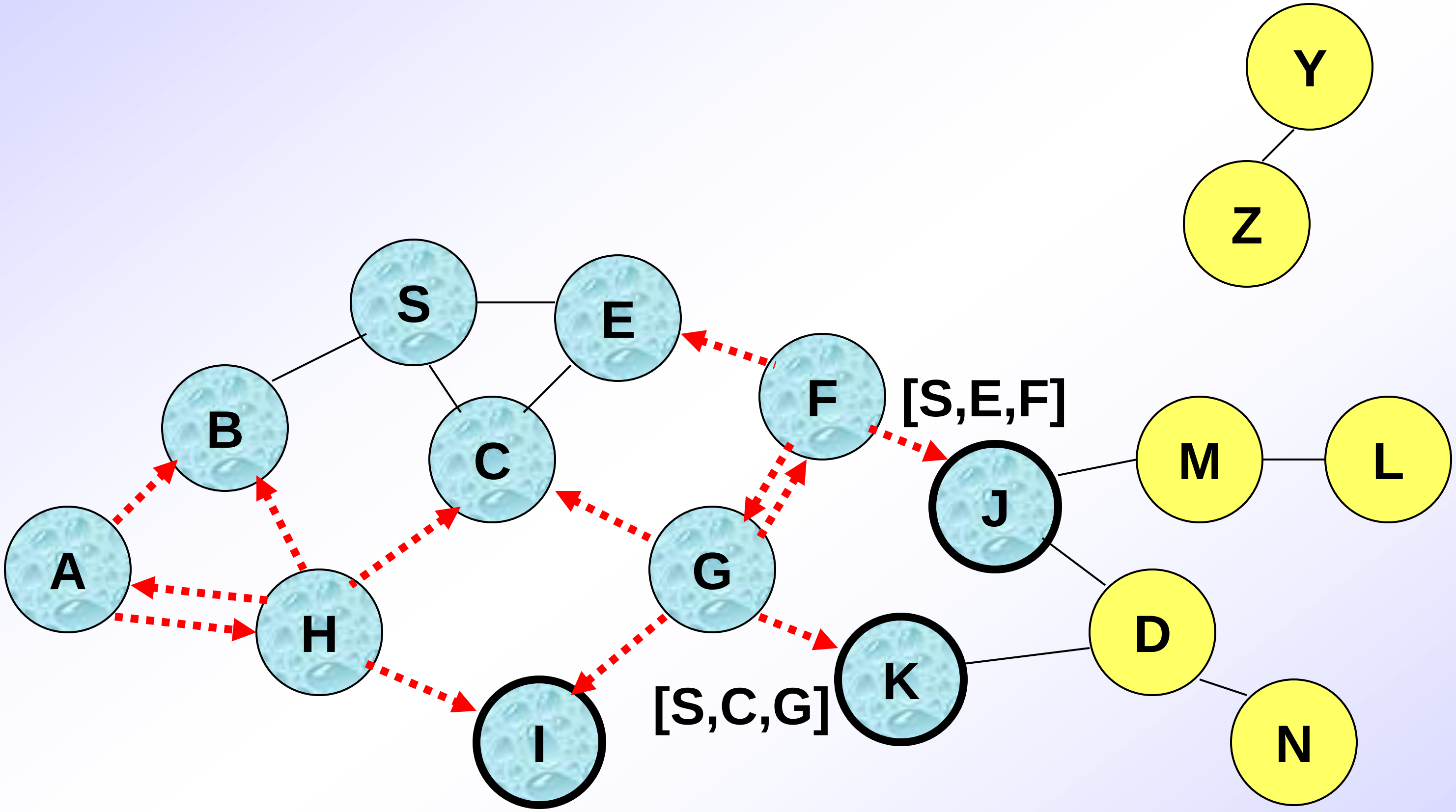
[X,Y] **Represents list of identifiers appended to RREQ**

Route Discovery in DSR



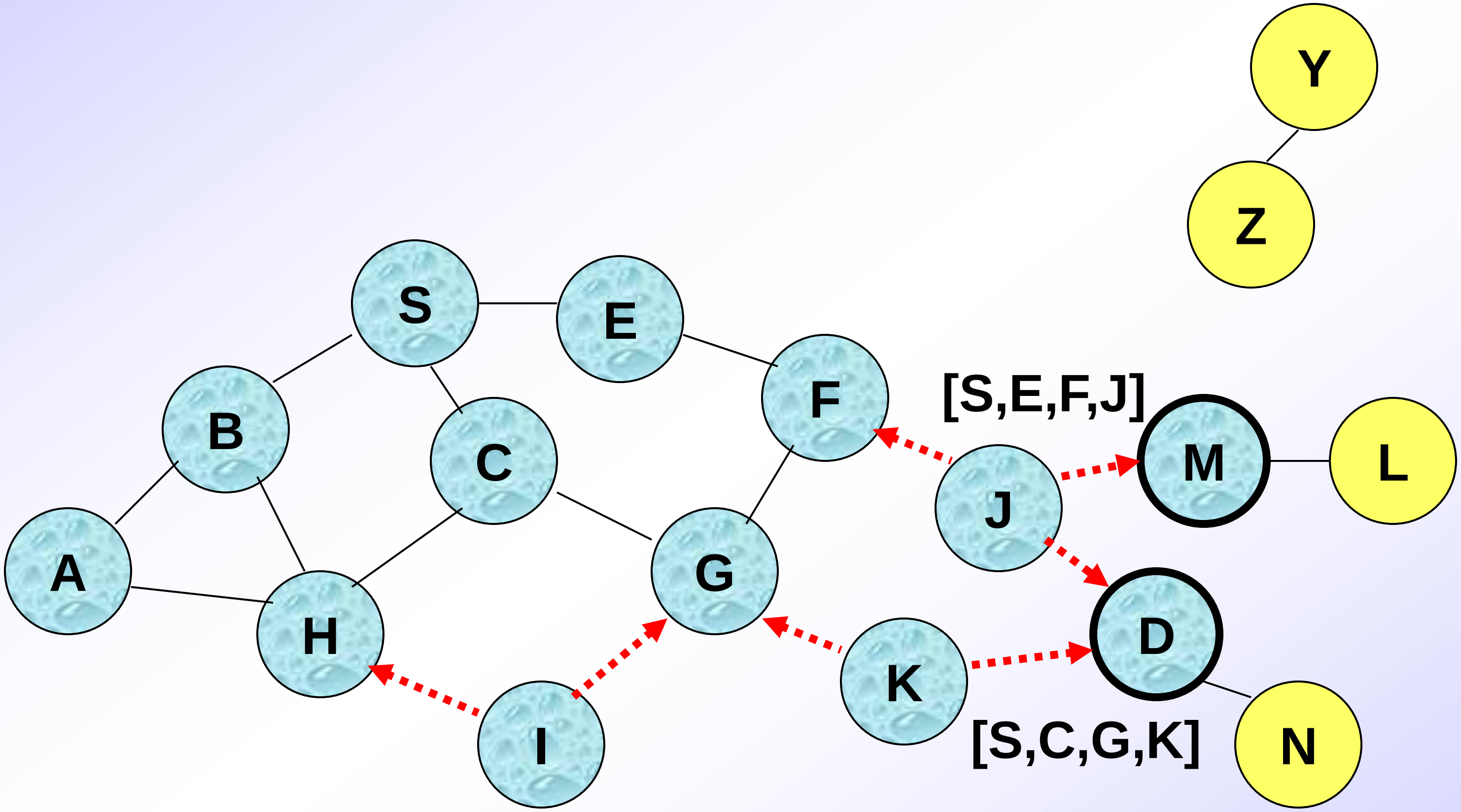
• **Node H receives packet RREQ from two neighbors: potential for collision**

Route Discovery in DSR



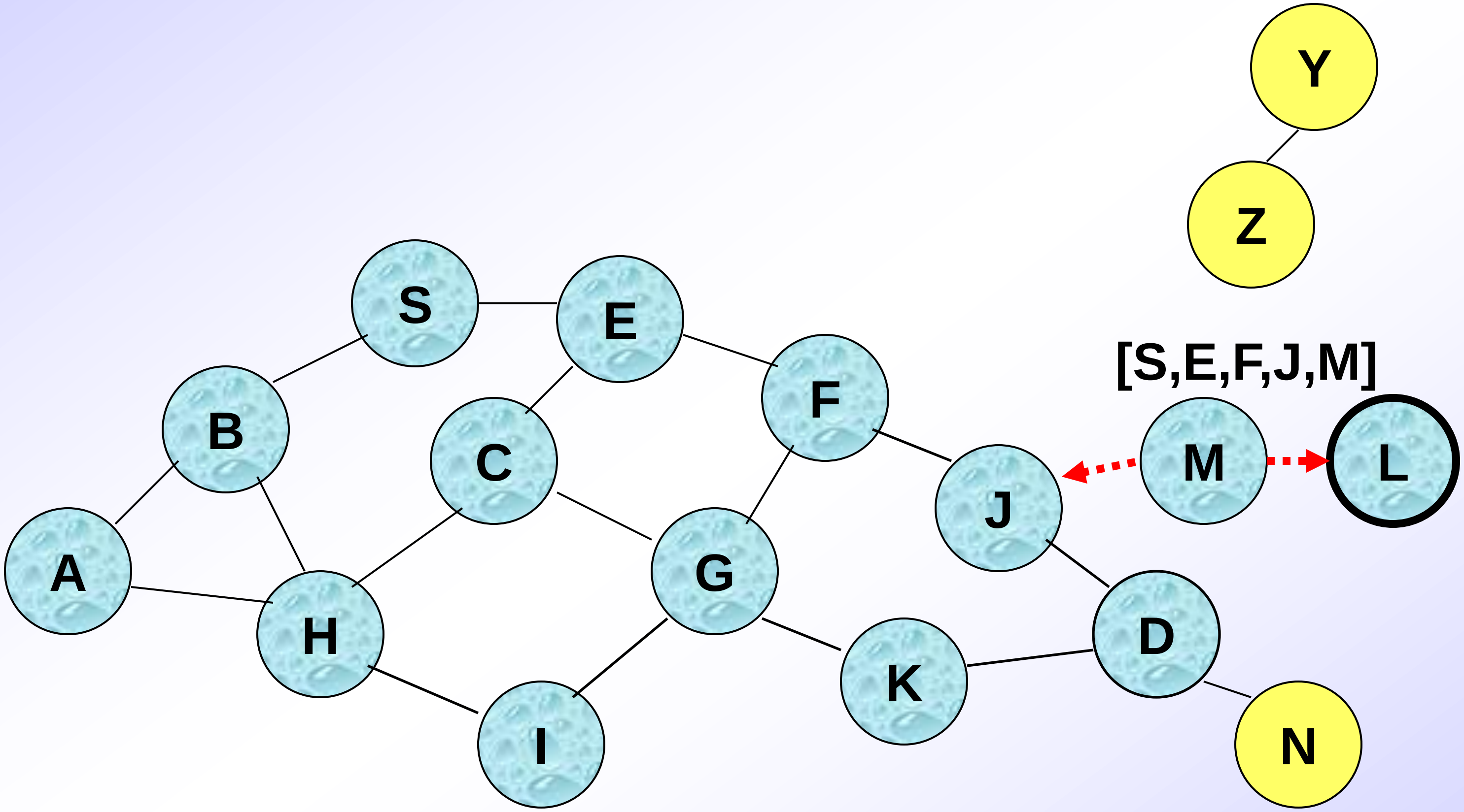
- Node C receives RREQ from G and H, but does not forward it again, because node C has already forwarded RREQ once

Route Discovery in DSR



- 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



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

Route Discovery in DSR

- Destination D on receiving the first RREQ, sends a Route Reply (RREP)
- RREP is sent on a route obtained by reversing the route appended to received RREQ
- RREP includes the route from S to D on which RREQ was received by node D

Ad Hoc On-Demand Distance Vector Routing (AODV)

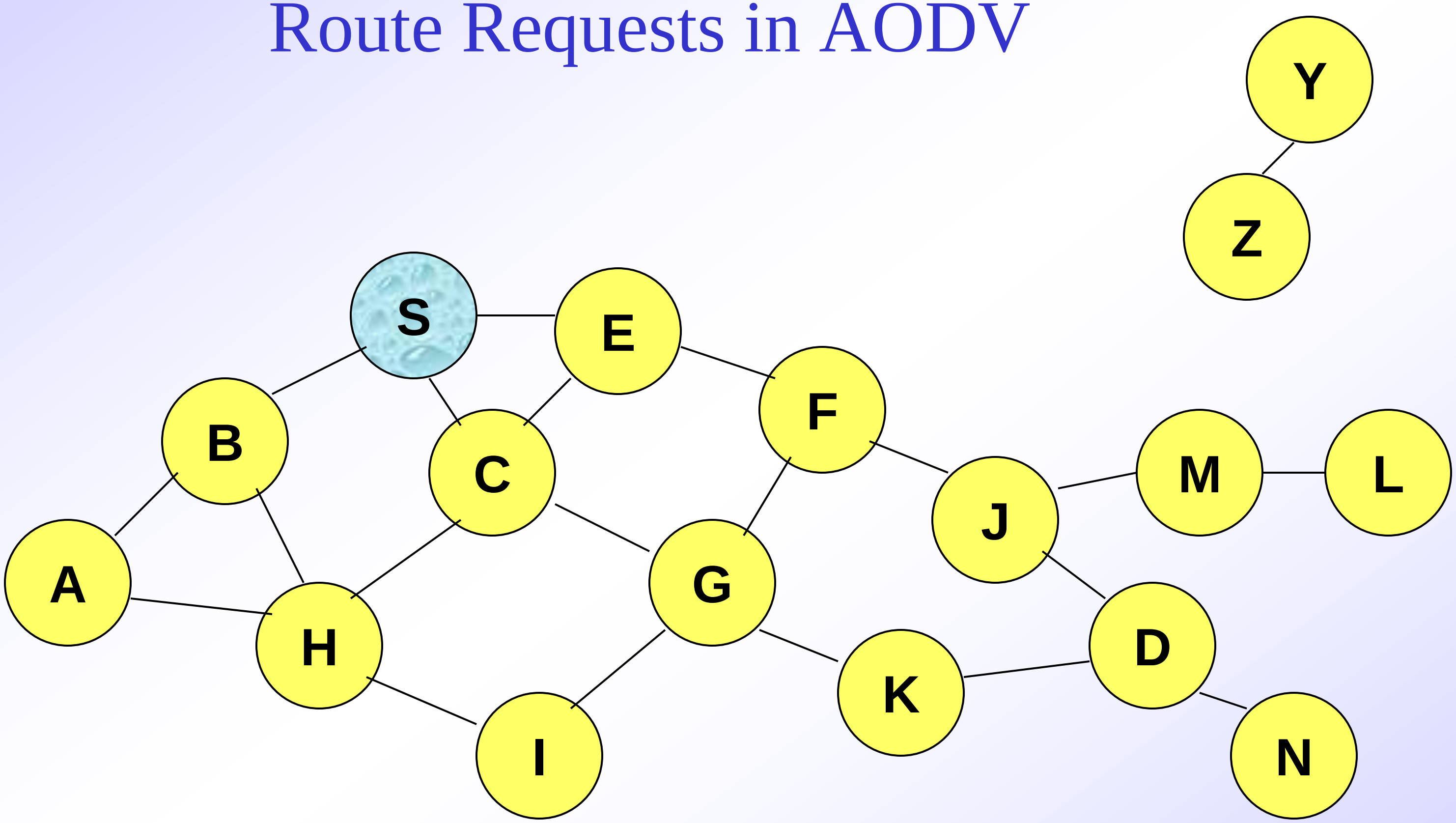
- Route Requests (RREQ) are forwarded in a manner similar to DSR

- When a node re-broadcasts a Route Request, it sets up a reverse path pointing towards the source
  - AODV assumes symmetric (bi-directional) links

- When the intended destination receives a Route Request, it replies by sending a Route Reply (RREP)

- Route Reply travels along the reverse path set-up when Route Request is forwarded

Route Requests in AODV



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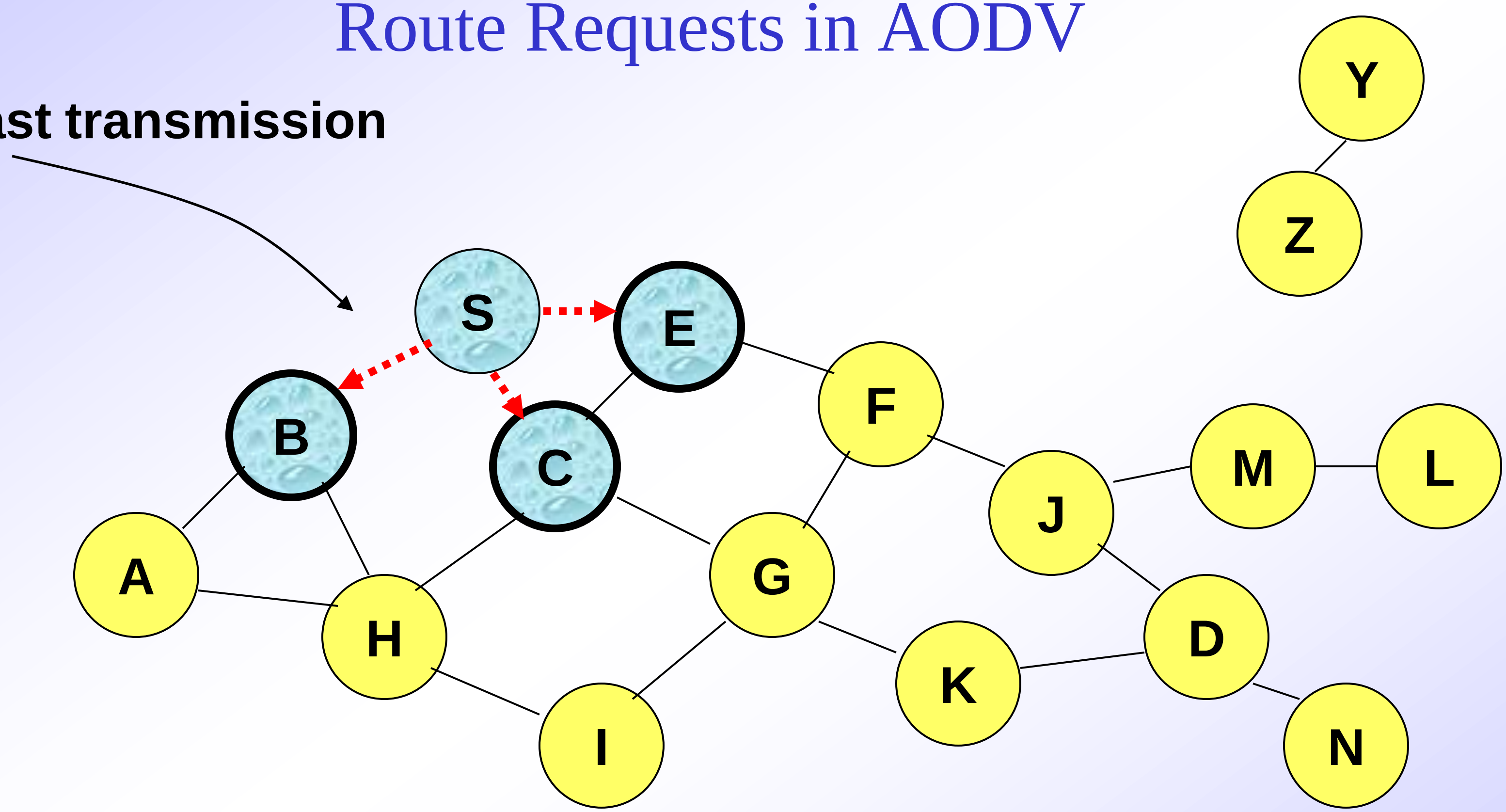
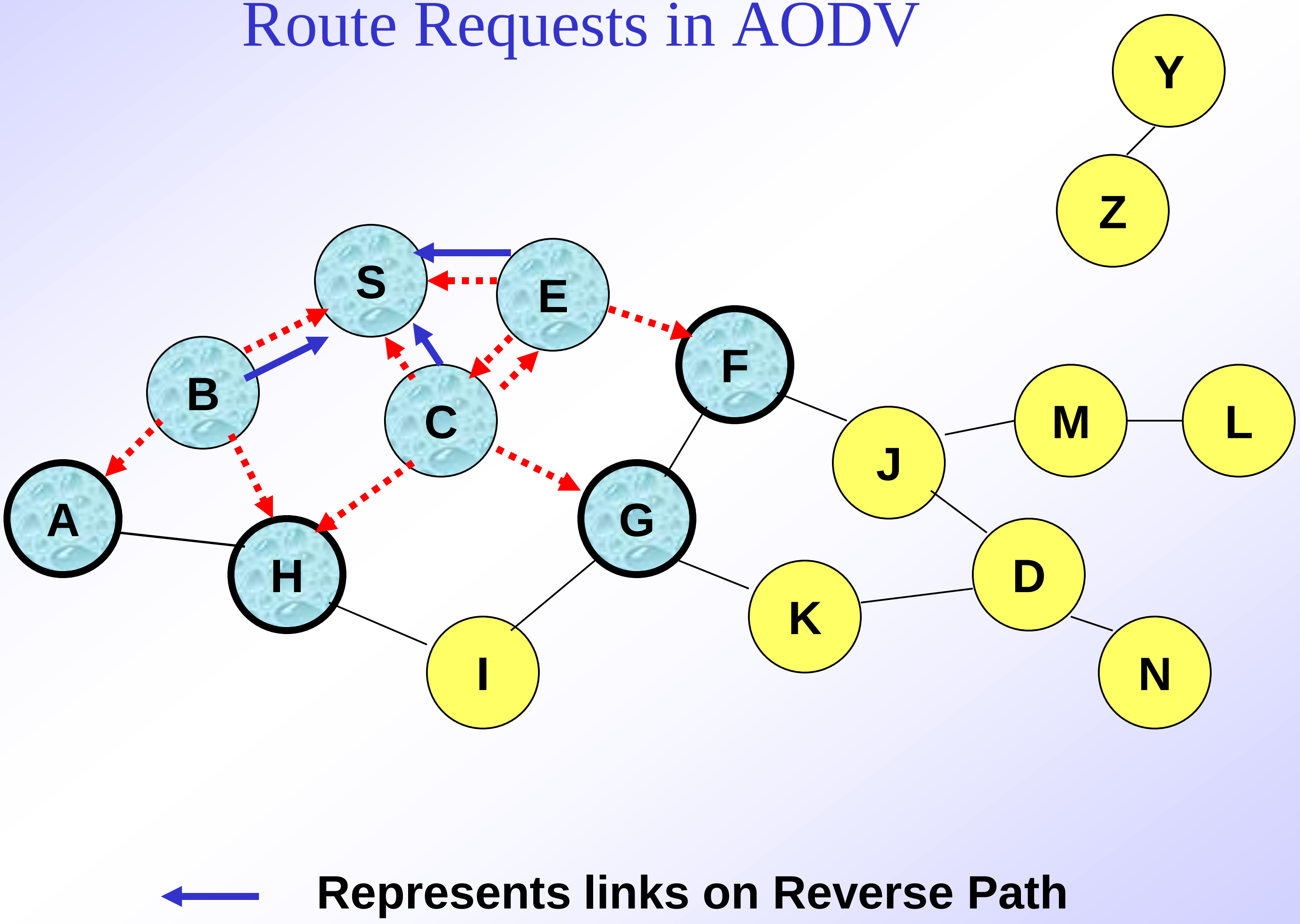
Route Requests in AODV

Broadcast transmission

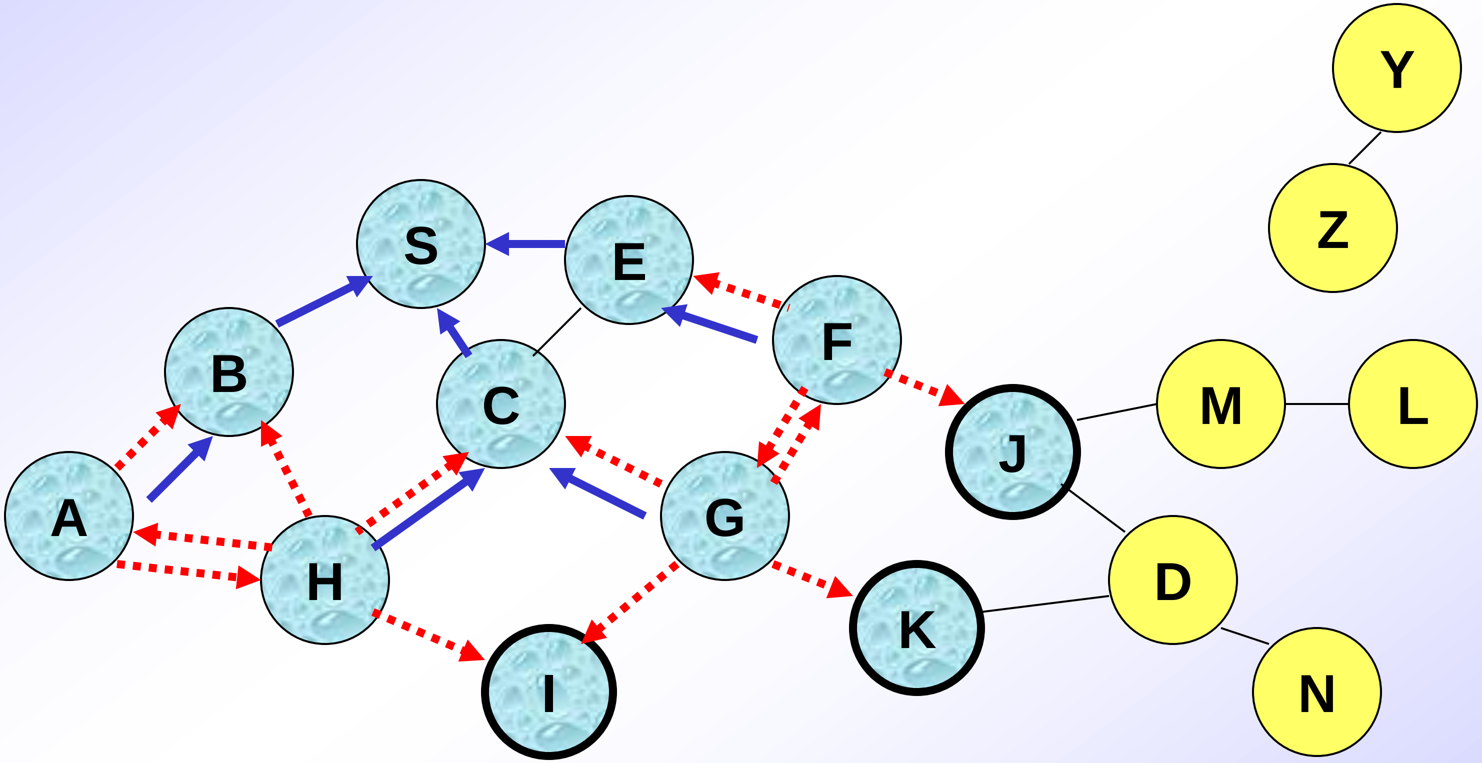


Represents transmission of RREQ

Route Requests in AODV



Route Requests in AODV



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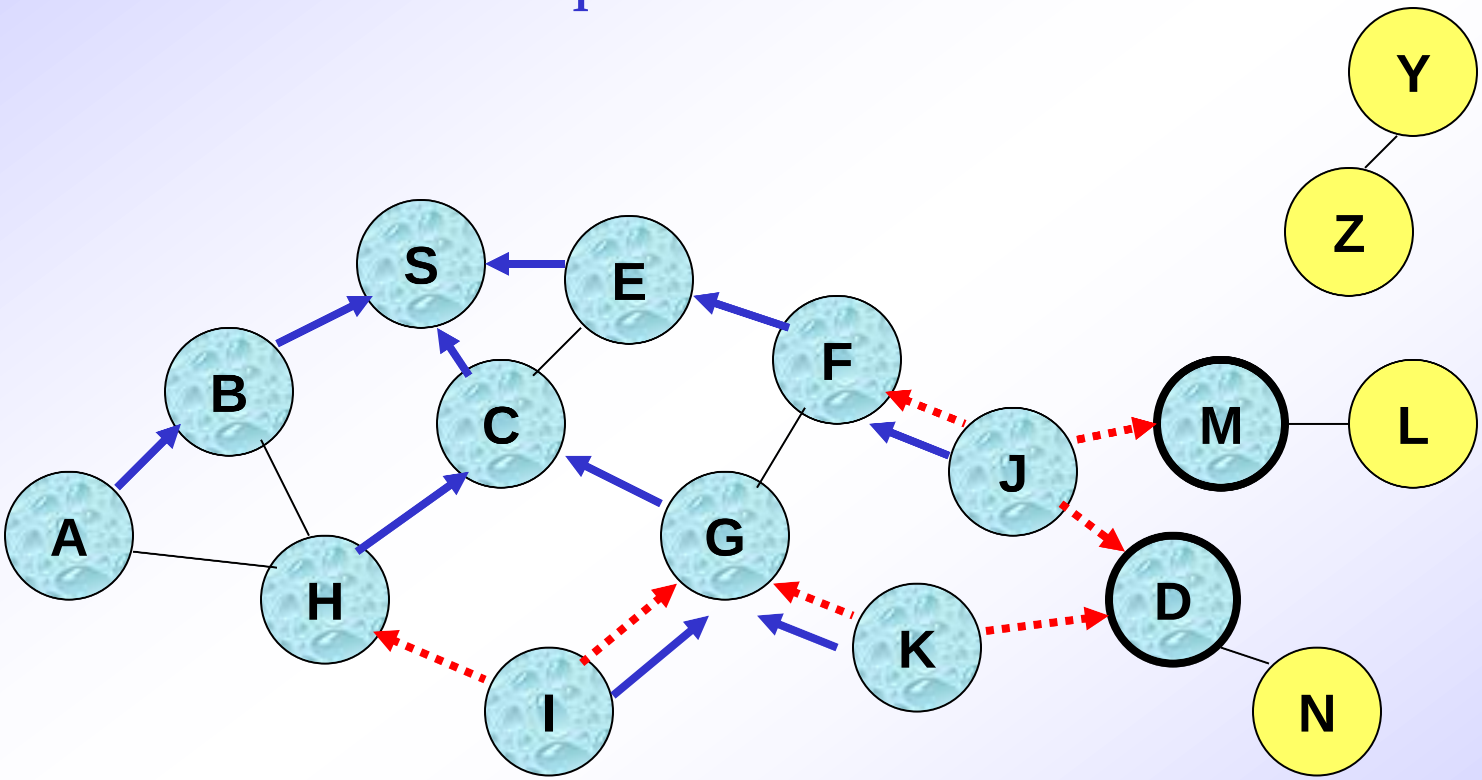
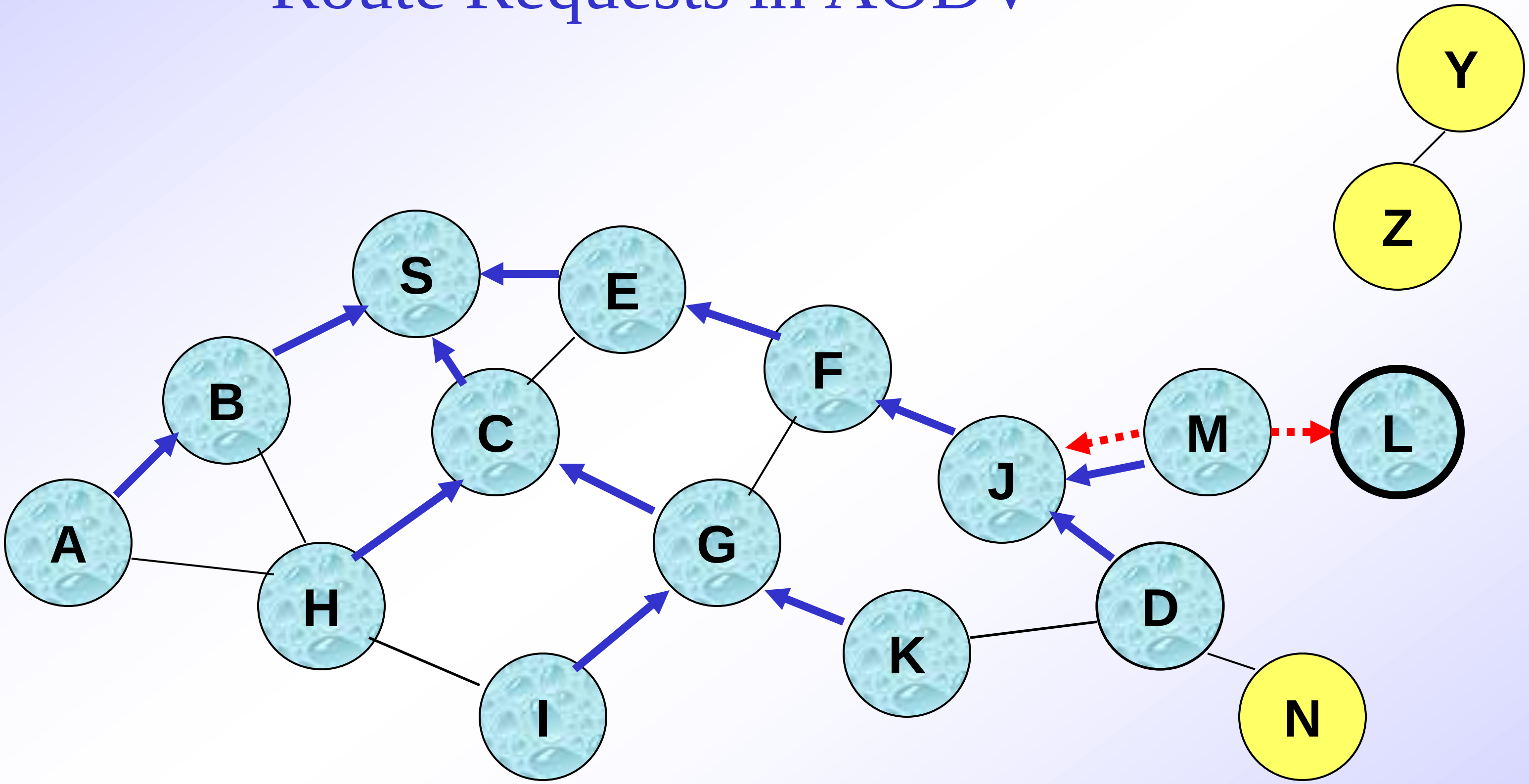
Route Requests in AODV



Route Requests in AODV



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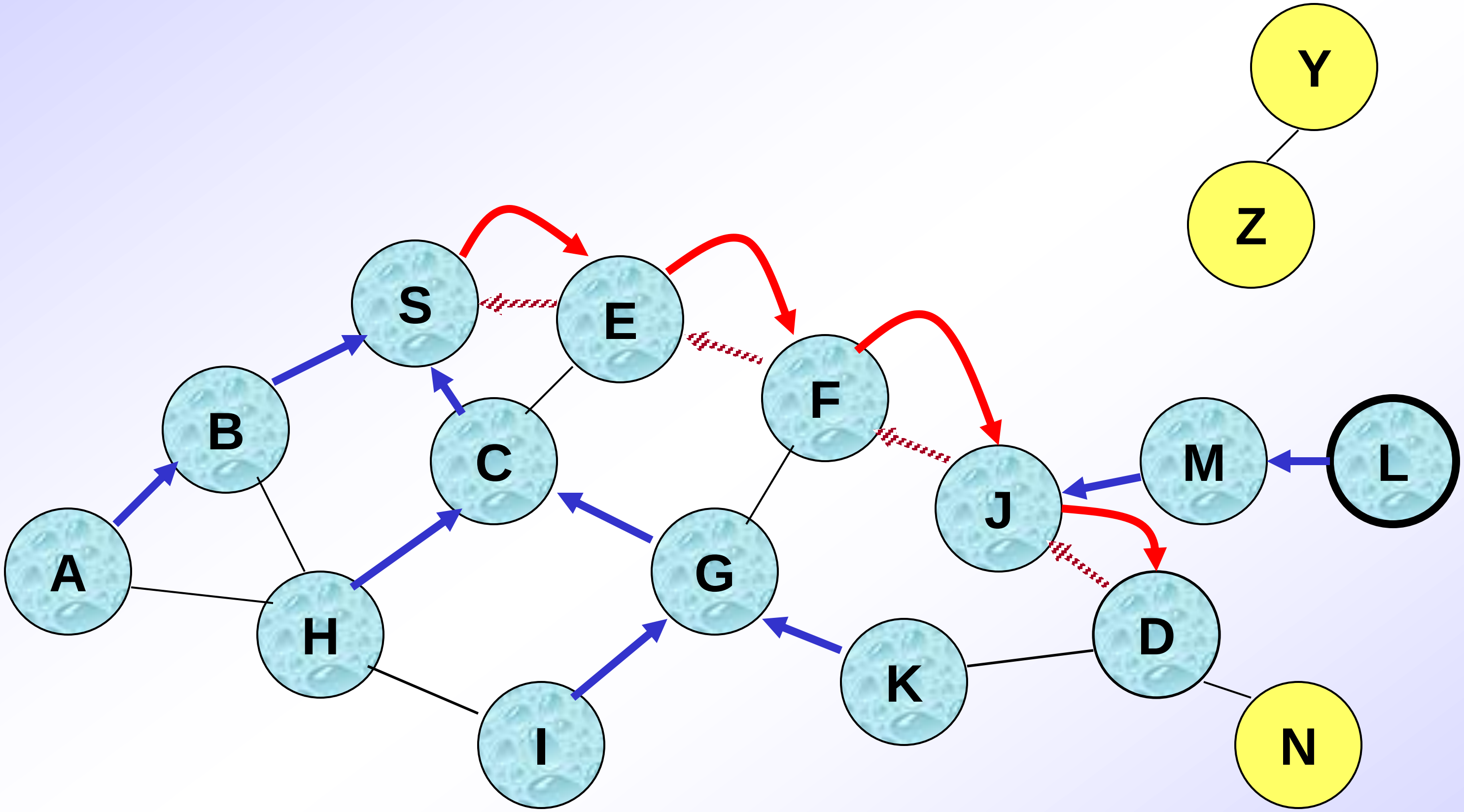
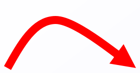
Route Requests in AODV



Forward links are setup when RREP travels along the reverse path



Represents a link on the forward path

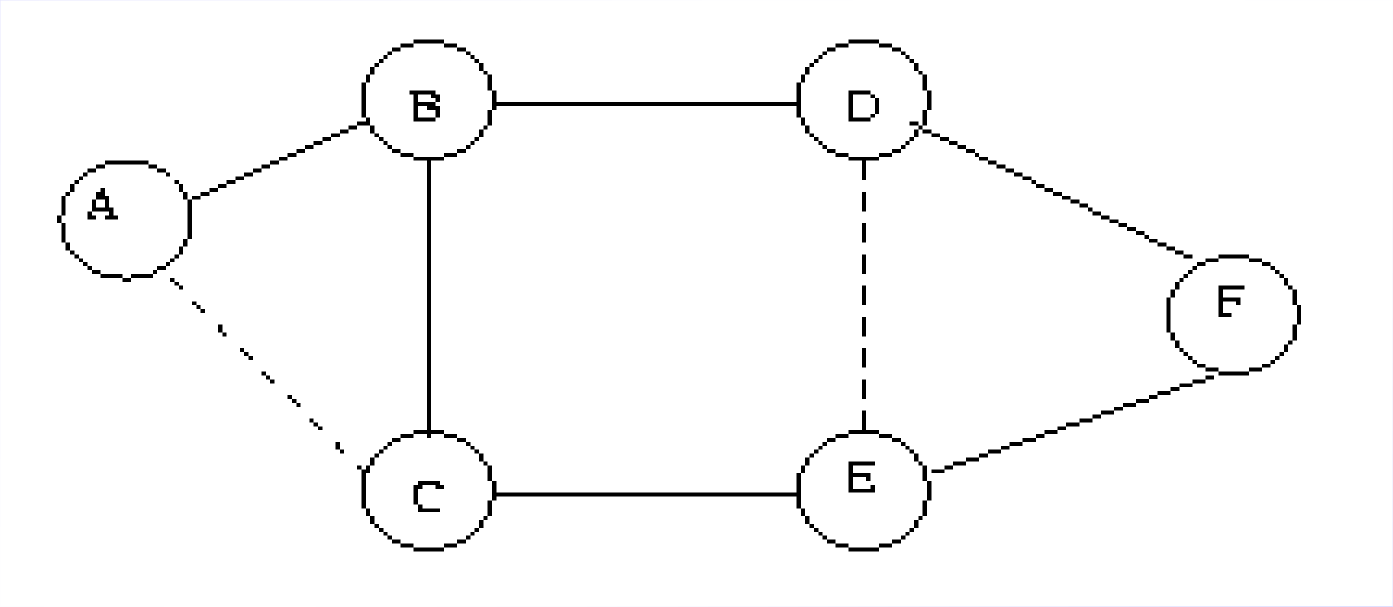
2c) Associativity Based Routing (ABR)

- Based on degree of association of stability
- All nodes generate beacons to announce their presence
- Node updates its associativity tick when it receives beacon from others
- High associativity tick implies stable node
- Destination chooses best route by examining the associativity tick of multiple routes taken by the packet (threshold associativity)

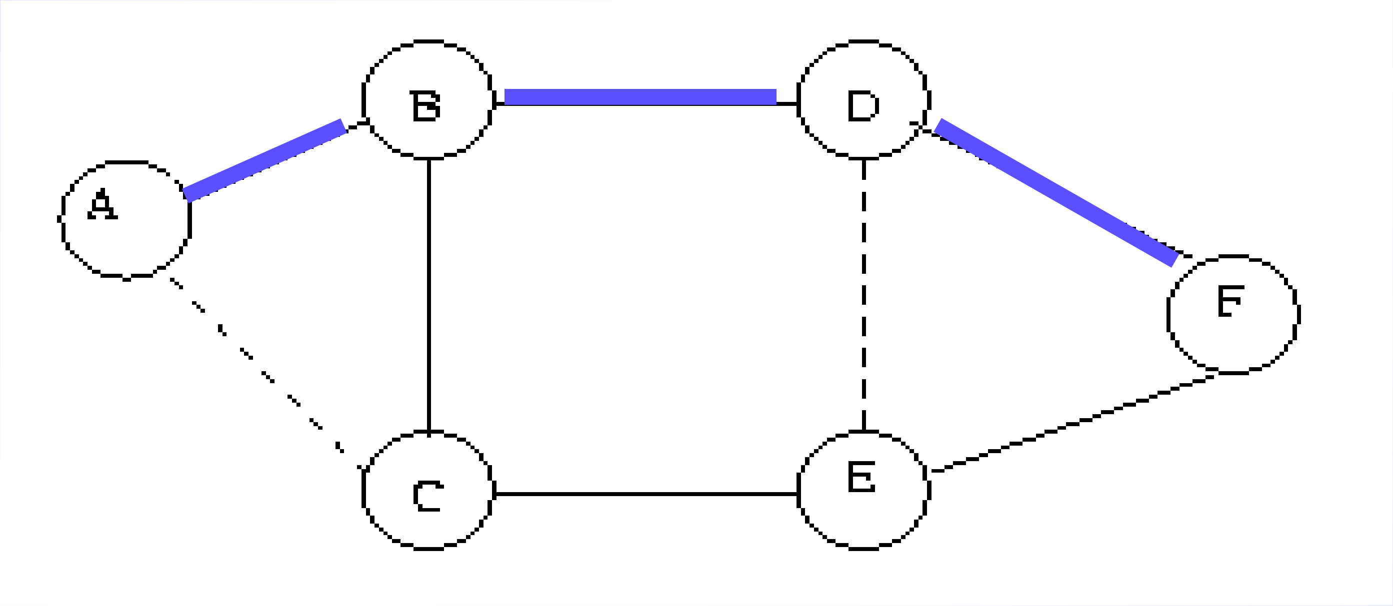
2c) Signal Stability Algorithm (SSA)

- Channel strength based on beacon signal
- Route discovery attempted through strong channel first
- Destination knows that route is along the strongest channels available

Signal Stability Routing (SSA)



Signal Stability Routing (SSA)



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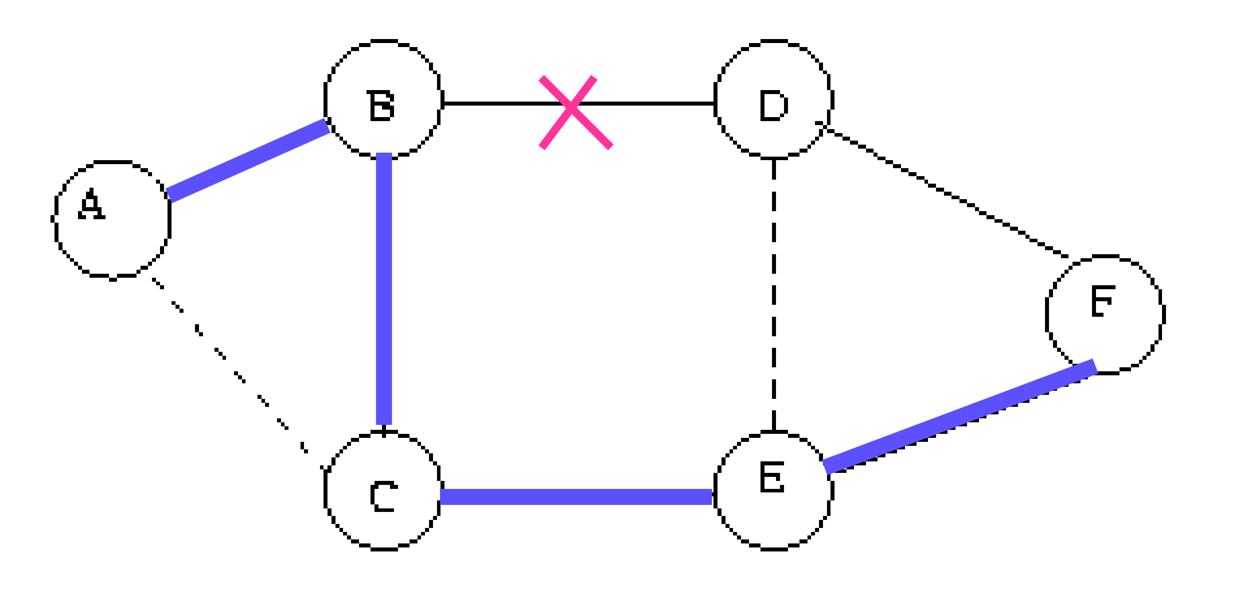


2e) Temporally-Ordered Routing Algorithm (TORA)

- Route optimality is considered of secondary importance; longer routes may be used

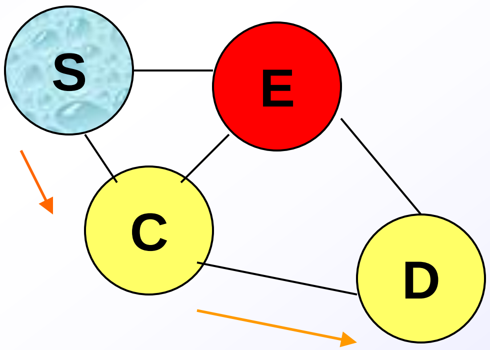
- At each node, a logically separate copy of TORA is run for each destination, that computes the height of the node with respect to the destination
- Height captures number of hops and next hop
- Route discovery is by using query and update packets

- TORA modifies the partial link reversal method to be able to detect partitions
- When a partition is detected, all nodes in the partition are informed, and link reversals in that partition cease

Power Aware Routing Protocol

– Modify DSR to incorporate weights and prefer a route with the smallest aggregate weight

– Assign a weight to each link: function of energy consumed when transmitting a packet on that link, as well as the residual energy level



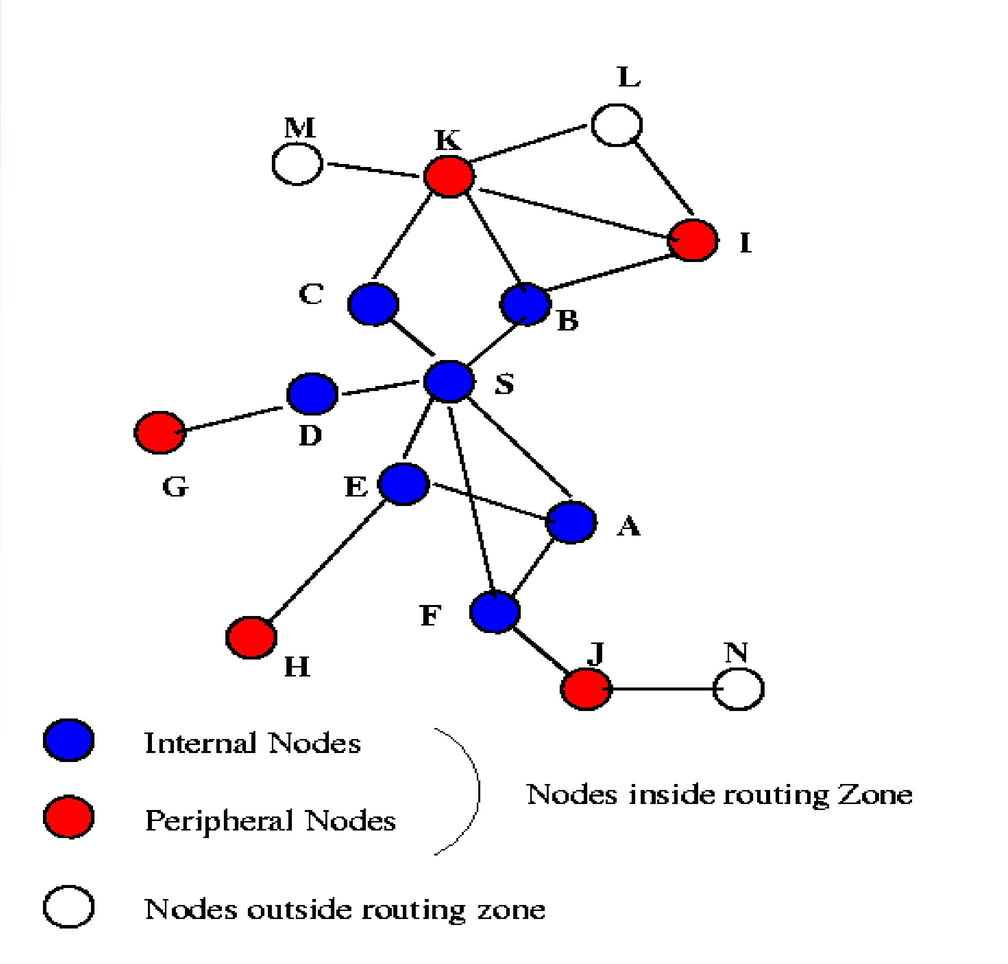
3a) Zone Routing Protocol (ZRP)

- ZRP combines proactive and reactive approaches

- All nodes within hop distance at most *d* from a node X are said to be in the routing zone of node X
- All nodes at hop distance exactly *d* are said to be peripheral nodes of node X's routing zone

- Intra-zone routing: Proactively maintain routes to all nodes within the source node's own zone.
- Inter-zone routing: Use an on-demand protocol (similar to DSR or AODV) to determine routes to outside zone.

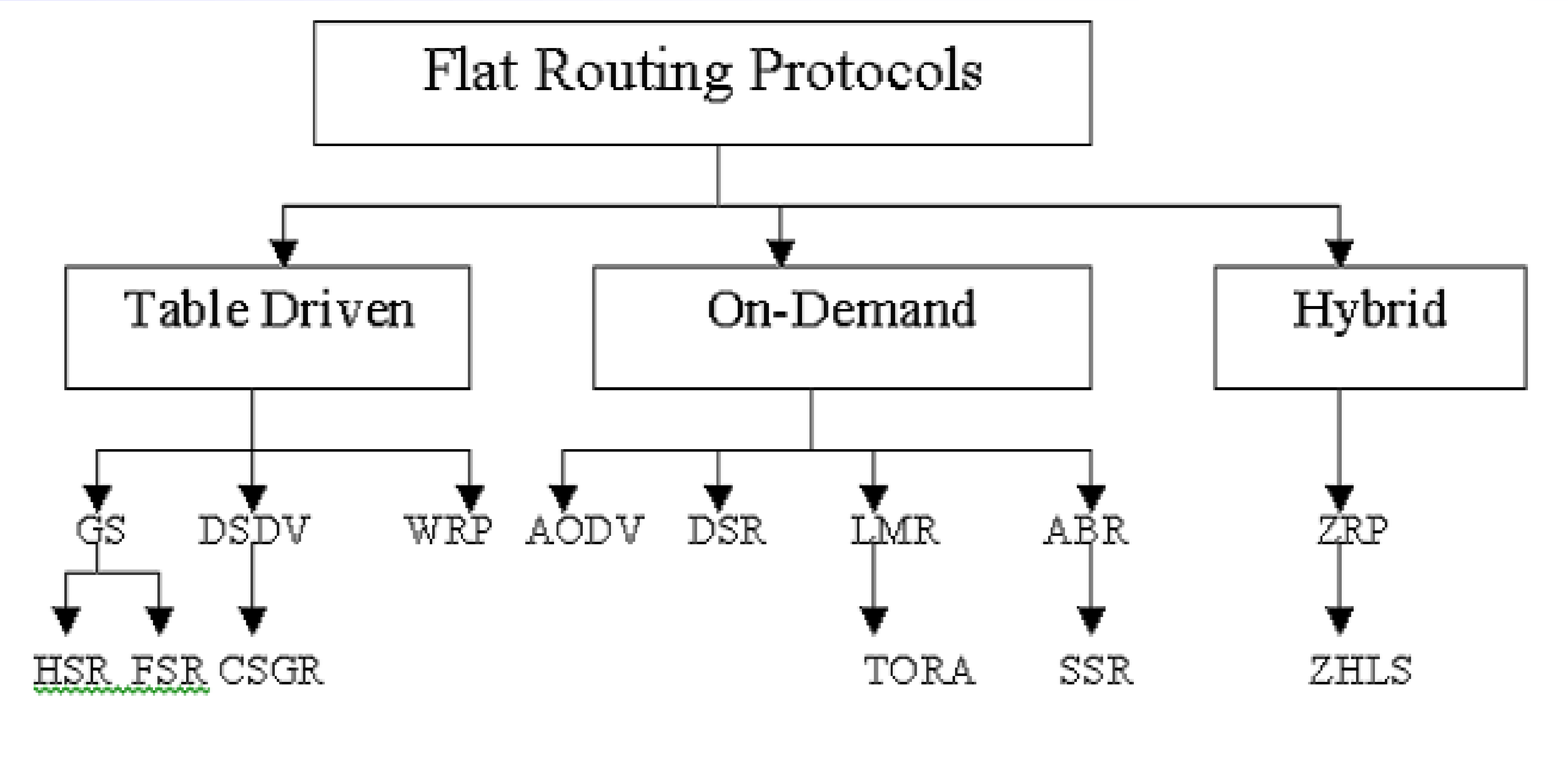
Zone Routing Protocol (ZRP)



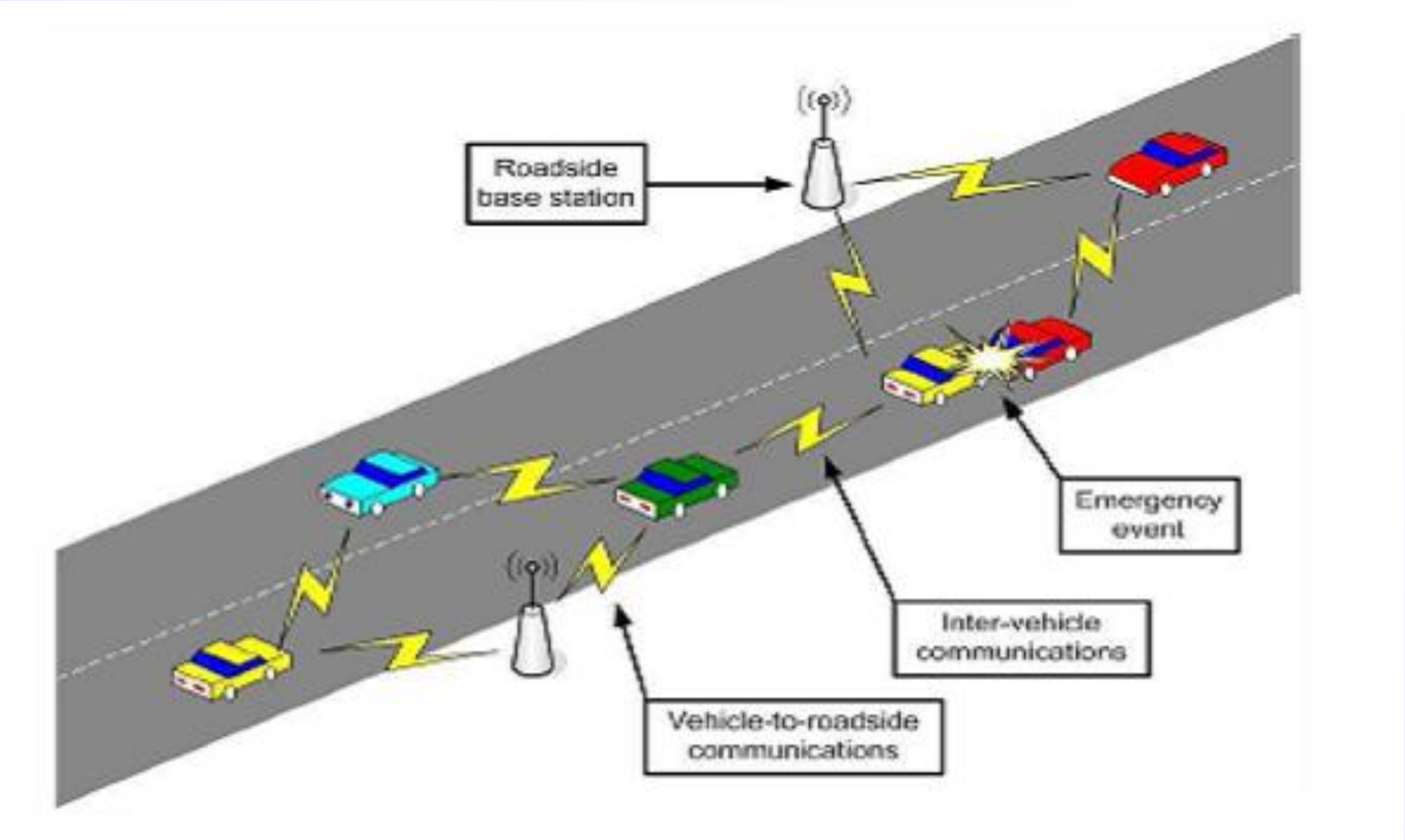
Radius of routing zone = 2

(w.r.t. node S)

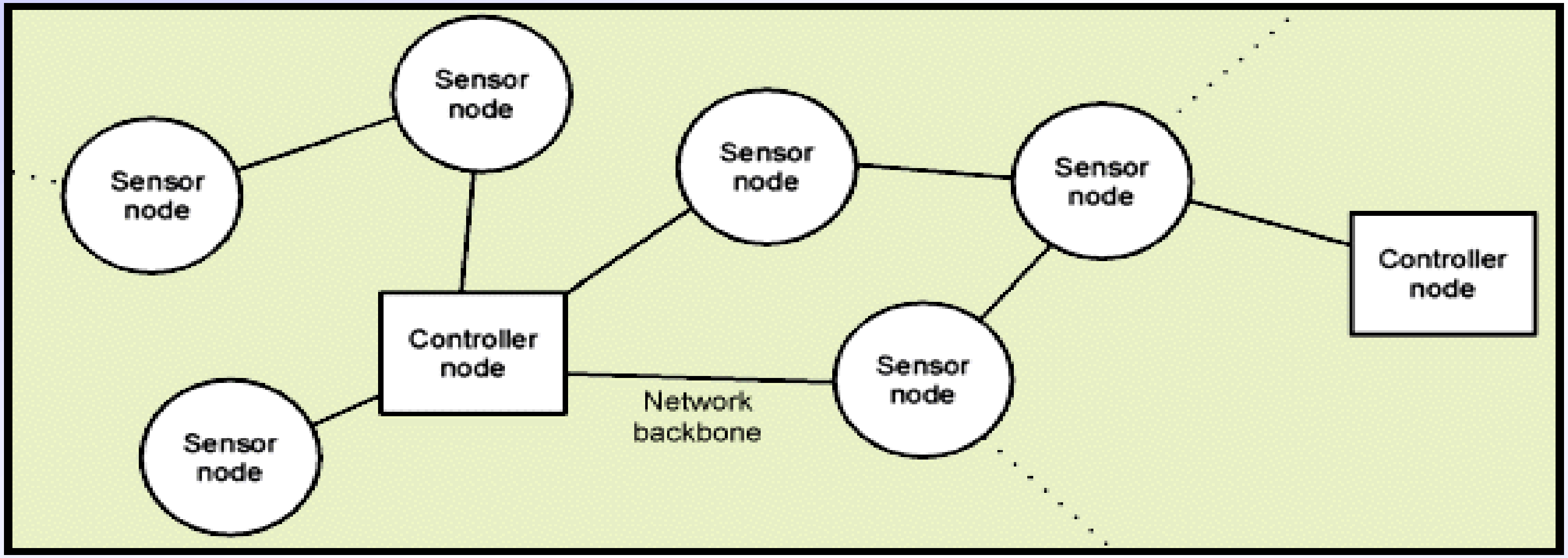
Classification of Routing Protocols in MANET



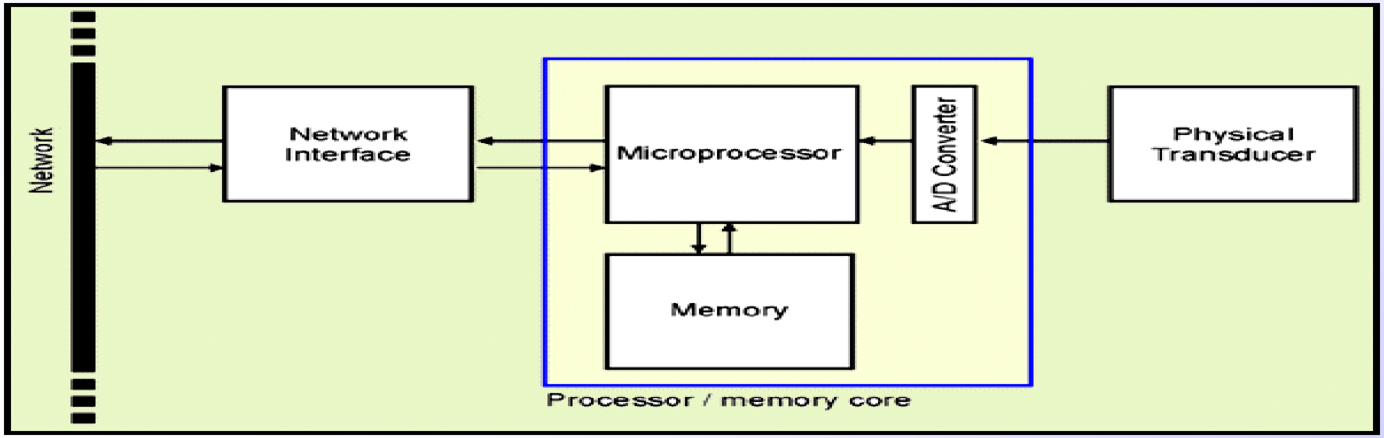
VANETs


Roadside
base station
Emergency
event
Inter-vehicle
communications
Vehicle-to-roadside
communications

Sensor Networks

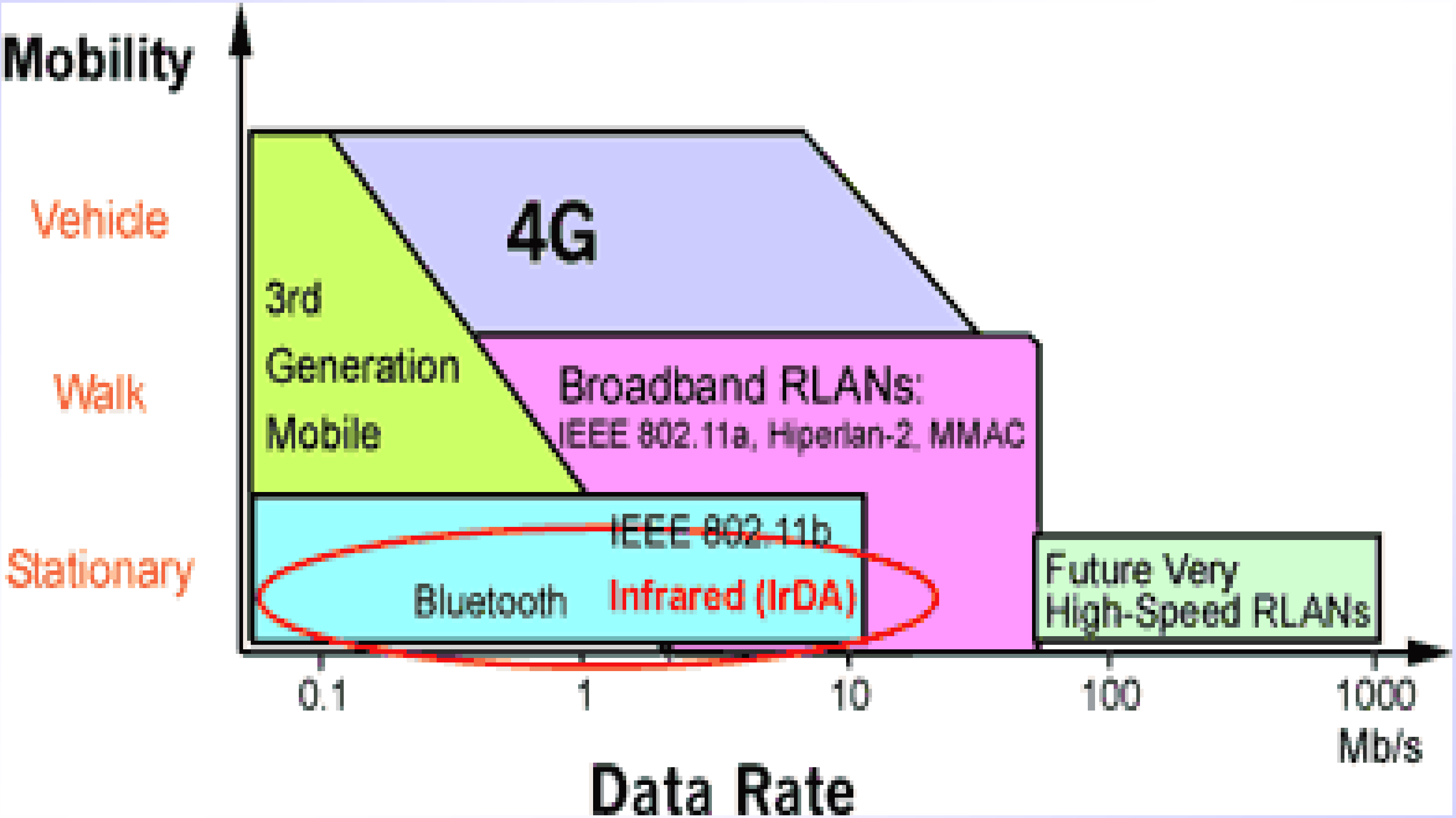


A Sensor System



Sensor Node

MOBILE COMMUNICATION STANDARDS



Data Rate Vs. Mobility (source: www.zurich.ibm.com)

MOBILE COMMUNICATION STANDARDS

1. **Bluetooth**
2. **Code Division Multiple Access (CDMA)**
3. **Digital Enhanced Cordless Telecommunications (DECT)**
4. **Frequency Division Multiple Access (FDMA)**
5. **General Packet Radio Services (GPRS)**
6. **Global System for Mobile Communication (GSM)**
7. **GSM/EDGE Radio Access Network (GERAN)**
8. **I-Mode***
9. **Mobile Station Application Execution Environment (MExE)**
10. **Synchronization Markup Language (SyncML)**
11. **Time Division Multiple Access (TDMA)**
12. **Universal Mobile Telecommunication Services (UMTS)**
13. **Wireless Application Protocol (WAP)**

THANK YOU

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Thank You!!