THE CONCEPT OF FLOODING

How well does it work in a wireless network?

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Data Delivery Using Flooding

- Sender S broadcasts data packet P to all its neighbors
- Each node receiving P forwards P to its neighbors
  - Sequence numbers used to avoid the possibility of forwarding the same packet more than once
- Packet P reaches destination D provided that D is reachable from sender S
- Node D does not forward the packet

What can go wrong?

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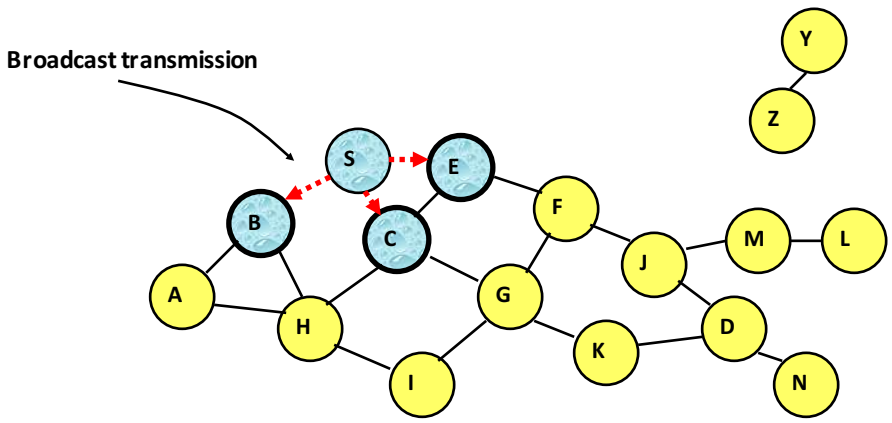
Flooding Example



Represents a node that receives packet P for the first time

Represents transmission of packet P

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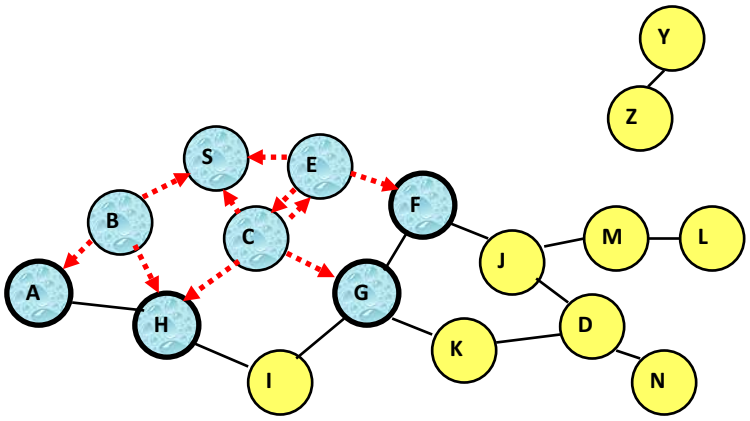
Flooding Example



- Node H receives packet P from two neighbors: potential for collision

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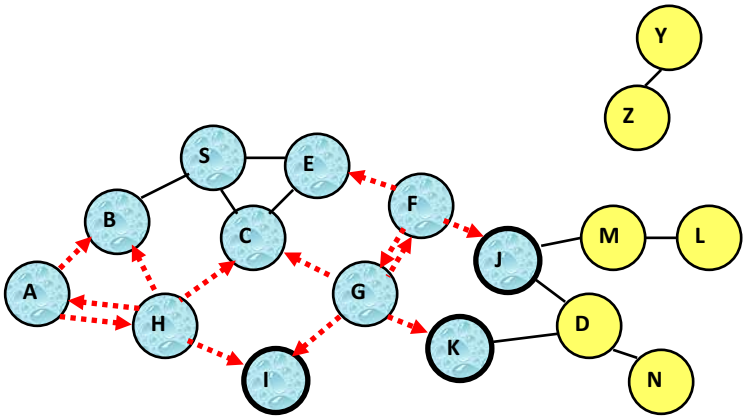
Flooding Example



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

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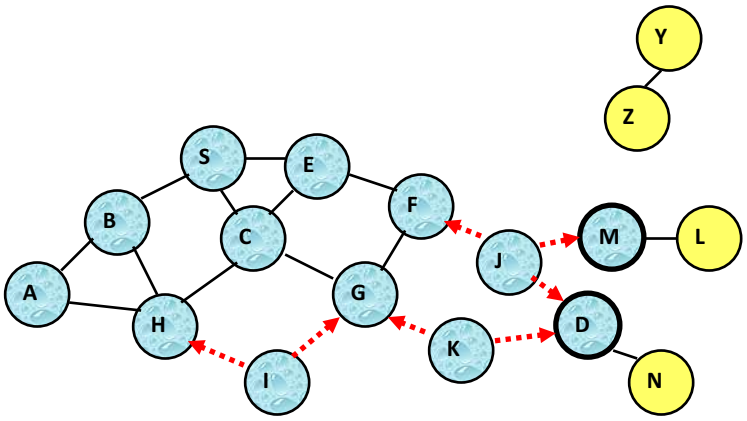
Flooding Example



- Nodes J and K both broadcast packet P to node D
- Since nodes J and K are hidden from each other, their transmissions may collide
  => Packet P may not be delivered to node D at all, despite the use of flooding

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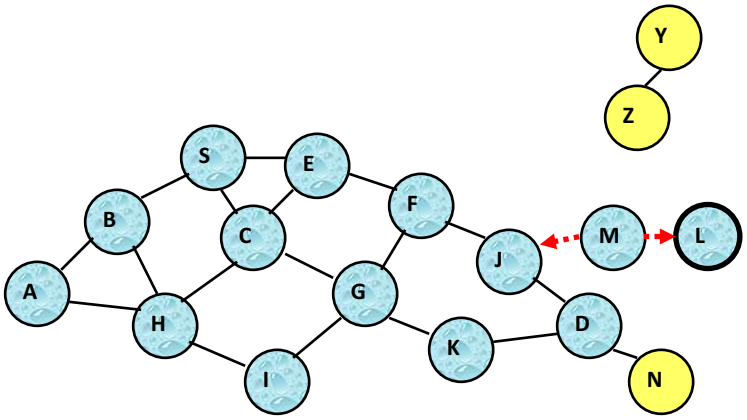
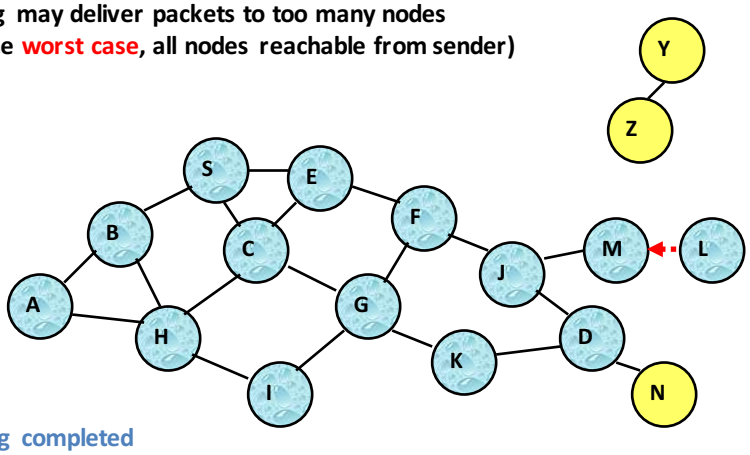
Flooding Example



- Node D does not forward packet P,
  because node D is the intended destination of packet P

Flooding Example

- Flooding may deliver packets to too many nodes
  (in the worst case, all nodes reachable from sender)



- Flooding completed
- Nodes unreachable from S do not receive packet P (e.g., node Z)
- Nodes for which all paths from S go through the destination D
  also do not receive packet P (example: node N)

Flooding for Data Delivery

- Advantages:
  - Simplicity
  - May be more efficient if infrequent communication
    - Route setup / maintenance not worth it
    - Especially, when changing topology / mobility
  - Potentially higher robustness to path failure
    - Because of multi-path redundancy
- Disadvantages:
  - Potentially, very high overhead
    - Packets delivered to too many nodes who don't need them
  - Potentially lower reliability of data delivery
    - Reliable broadcast is difficult
    - Hidden terminal because no channel reservation

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Flooding as a Building Block

- Many protocols perform (potentially *limited*) flooding of control packets, instead of data packets
  - The control packets are used to discover routes
  - Discovered routes are subsequently used to send data packet(s)
- Overhead of control packet flooding is amortized over data packets transmitted between consecutive control packet floods

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DYNAMIC SOURCE ROUTING (DSR)

(Johnson 96)

A Reactive Protocol

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Route Discovery in 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"
- Route Discovery:
  - Source node S floods Route Request (RREQ)
  - Each node appends own identifier when forwarding RREQ

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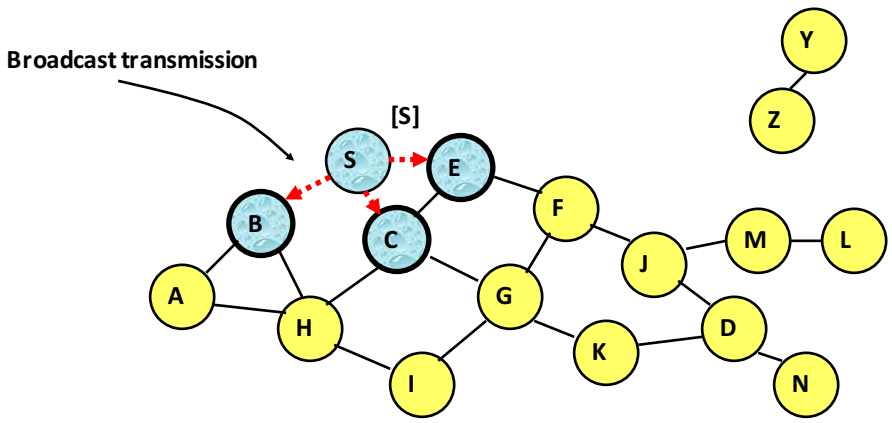
Route Discovery in DSR



Represents transmission of RREQ

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

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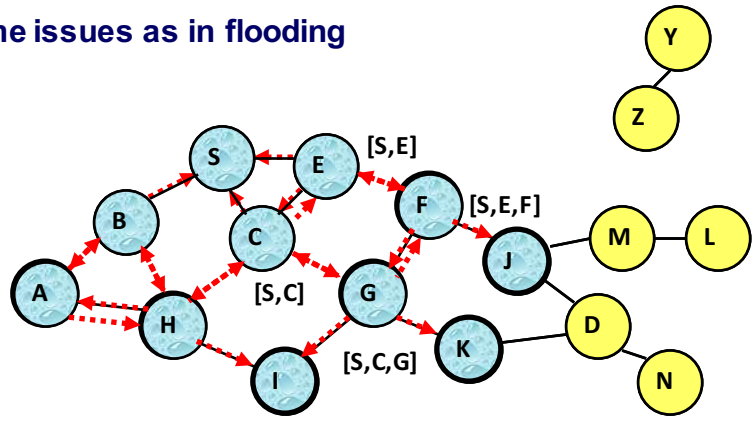
Route Discovery in DSR

- Same issues as in flooding



- Node H receives packet RREQ from two neighbors: potential for collision
- Node C receives RREQ from G and H, but does not forward it again
  - Because node C has already forwarded RREQ once

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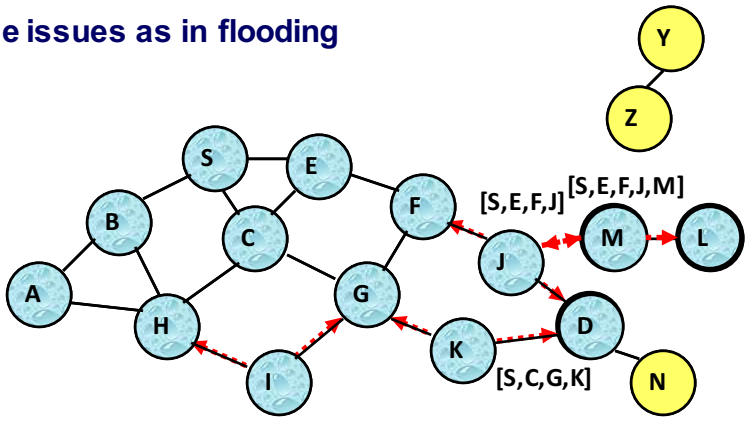
Route Discovery in DSR

- Same issues as in flooding



- Nodes J and K both broadcast RREQ to node D
  - Since J and K are hidden from each other, their transmissions may collide
- Node D does not forward RREQ
  - Because it is the intended target of route discovery

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Route Discovery: Route Reply

- Route Reply:
  - 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
- Route reversal => links need to be bi-directional
  - If unidirectional (asymmetric) links are allowed
    - Then RREP may need a route discovery for S from node D
  - 802.11 links always bi-directional (since ACK is used)

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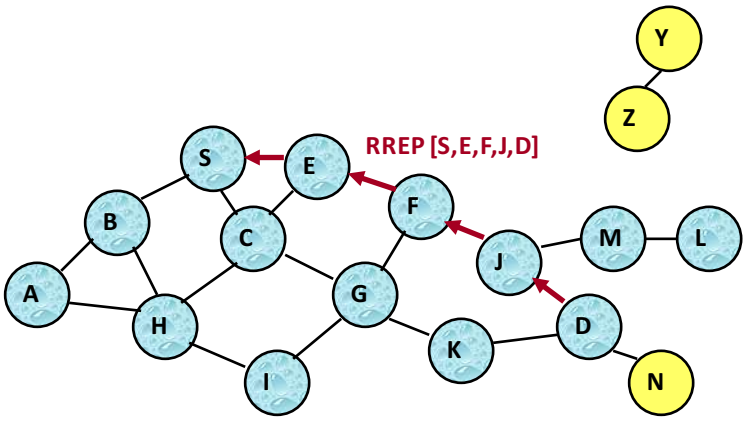
Route Reply in DSR



Represents RREP control message

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Data Delivery in DSR

- Node S on receiving RREP
  - Caches the route included in the RREP
- When node S sends a data packet to D
  - The entire route is included in the packet header
    - Hence the name source routing
  - Packet header grows with route length
- Intermediate nodes use the source route in packet
  - To determine to whom a packet should be forwarded

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DSR Optimization: Route Caching

- Caches a new route it learns by *any means*
- When node S finds route [S,E,F,J,D] to node D
  - Node S also learns route [S,E,F] to node F
- When node K receives Route Request [S,C,G] destined for node D,
  - Node K learns route [K,G,C,S] to node S
- When node F forwards Route Reply RREP [S,E,F,J,D],
  - Node F learns route [F,J,D] to node D
- When node E forwards Data [S,E,F,J,D]
  - It learns by overhearing Data packets

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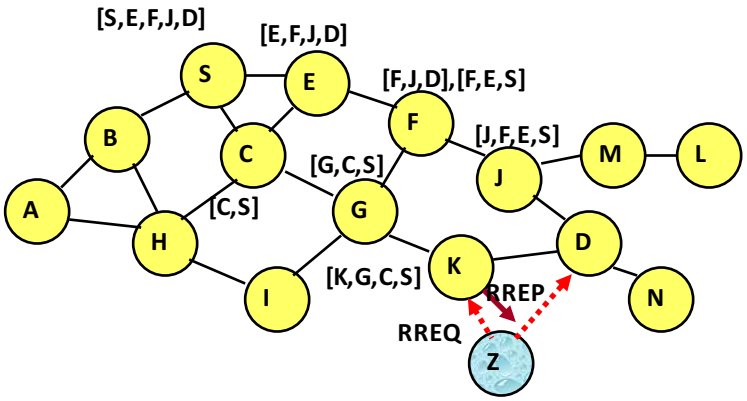
Route Caching: Speed up Discovery



When node Z sends a route request for node C,
node K sends back a route reply [Z,K,G,C] to node Z using its local cache

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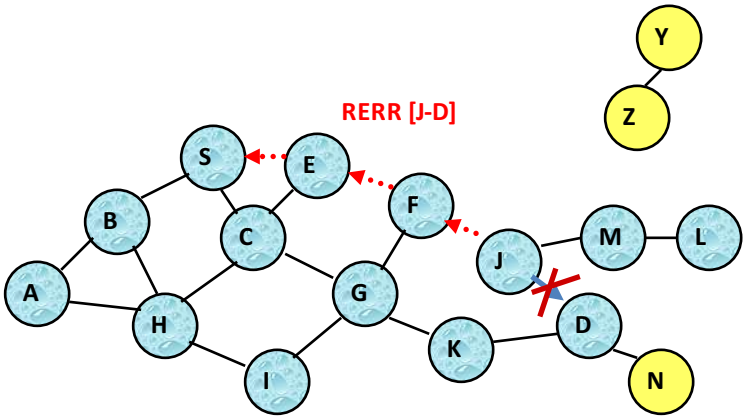
Route Error (RERR)



J sends a route error to S along route J-F-E-S when its attempt to forward the data packet S (with route SEFJD) on J-D fails

Nodes hearing RERR update their route cache to remove link J-D

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Route Caching: Beware!

- With passage of time and host mobility, cached routes may become invalid
- Stale caches can adversely affect performance
  - Local caching by other nodes may result in stale routes
    - Even on multiple tries by sender host
  - May require several trials before finding a good route

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Query Localization

- Path locality heuristic:
  - Look for a new path that contains at most *k* nodes that were *not* present in the previously known route
- Old route is piggybacked on a Route Request
- Route Request is forwarded only if:
  - Accumulated route in the RREQ contains *at most k* new nodes that were absent in the old route
- ☺: Limits propagation of the route request

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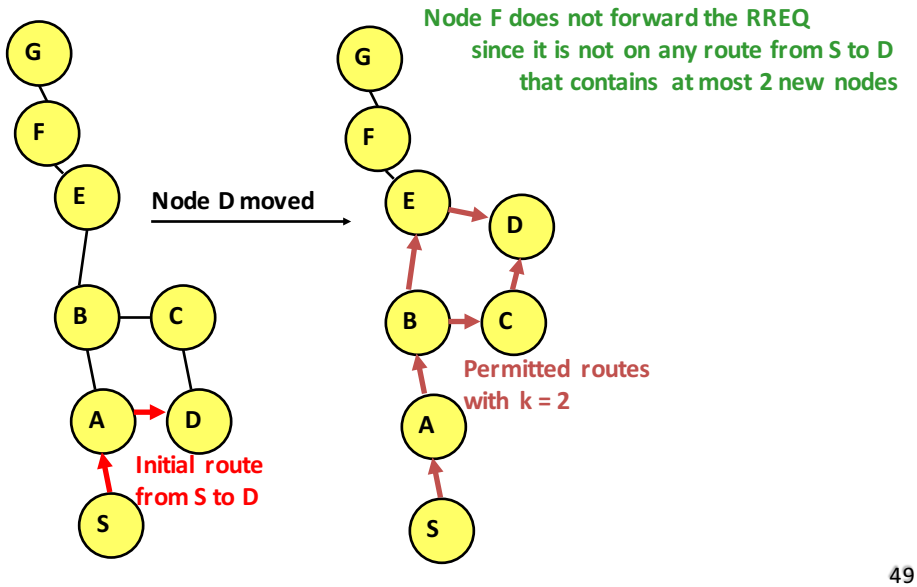
Query Localization: Example



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DSR: Advantages

- Routes maintained reactively
  - Reduces overhead of maintenance
- Route caching can reduce route discovery overhead
- Discovery of multiple routes at D

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DSR: Disadvantages

- Packet header size grows with route length
- Flood of RREQs may potentially reach all nodes
- Care must be taken to avoid collisions between route requests propagated by neighboring nodes
  - Insertion of random delays before forwarding RREQ
- Increased contention if too many RREPs come back
  - Due to nodes replying using their local cache
  - Route Reply *Storm* problem
    - May be eased by preventing a node from sending RREP
      - If it hears another RREP with a shorter route
- An intermediate node may RREP using a stale cache
  - Thus polluting other caches
  - Can be eased by purging invalid cached routes [Hu00]

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AD-HOC ON-DEMAND DISTANCE VECTOR ROUTING

(Perkins 99)

Distance Vector Derivative

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AODV Routing: Intro

- DSR includes source routes in packet headers
  - Resulting large headers can degrade performance
    - Particularly when data contents of a packet are small
- AODV attempts to improve on DSR
  - By maintaining routing tables at the nodes
  - Data packets do not contain long routes
- AODV is also reactive

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AODV: Basic Operation

- Route Requests (RREQ) forwarded like DSR
- When intermediate node re-broadcasts RREQ
  - It sets up a reverse path pointing towards previous node
  - AODV assumes symmetric (bi-directional) links
- Destination replies by sending a Route Reply
- Intermediate nodes forward RREP up the reverse path
  - They also remember the downstream path in local cache

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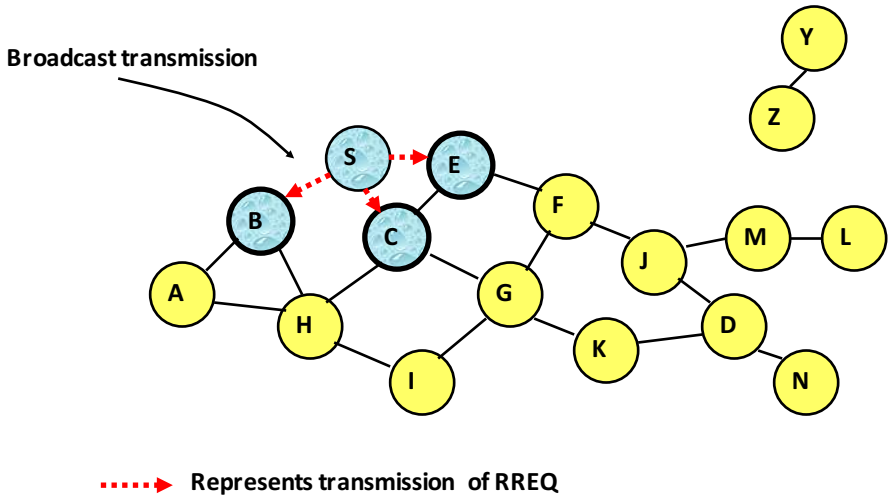
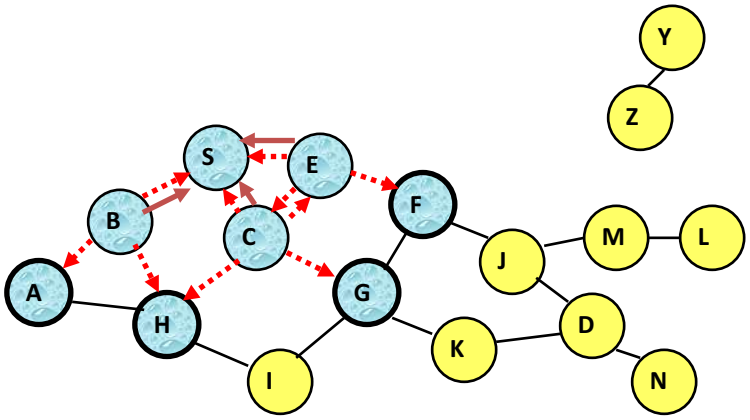
Route Requests in AODV



55

Route Requests in AODV



Represents links on Reverse Path

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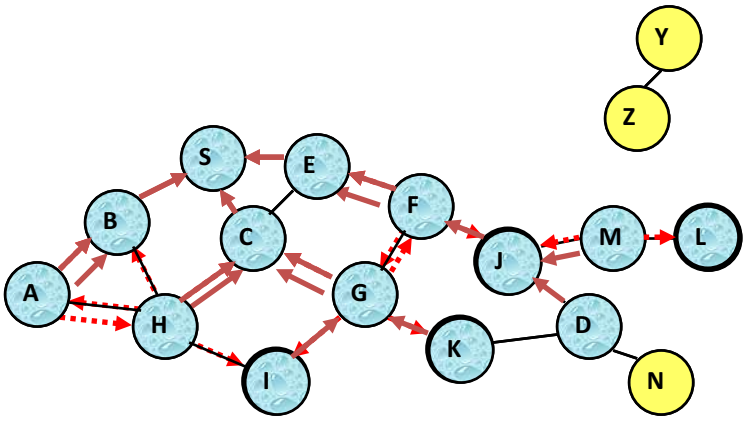
Reverse Path Setup in AODV



- Node C receives RREQ from G and H, but does not forward it again, because node C has already forwarded RREQ once
- Node D does not forward RREQ, because it is the intended target of the RREQ

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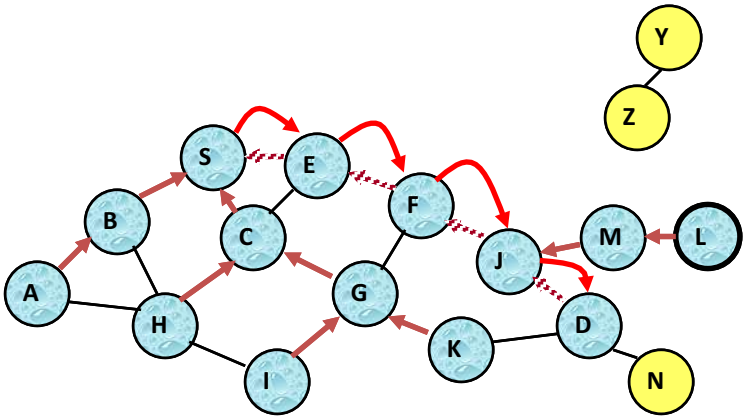
Route Reply in AODV



Represents links on path taken by RREP

Forward links are setup when RREP travels along the reverse path

Represents a link on the forward path

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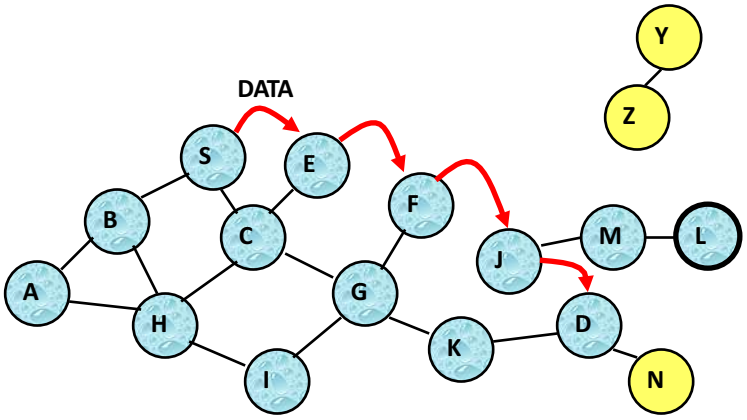
Data Delivery in AODV



Routing table entries used to forward data packet.

Route is *not* included in packet header.

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Route Reply in AODV

- An intermediate node may also send a RREP
  - If it knows a more recent path than the one previously known to sender S
- To determine whether the intermediate node's path is more recent
  - *Destination sequence numbers* are used
- The likelihood that an intermediate node will send a RREP when using AODV not as high as DSR
  - A new RREQ by node S for a destination is assigned a higher destination sequence number
    - An intermediate node which knows a route, but with a smaller sequence number, cannot send RREP

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Timeouts

- A routing table entry maintaining a reverse path is purged after a timeout interval
  - Timeout should be enough to allow RREP to come back
- A routing table entry maintaining a forward path is purged if *not used* for a *active_route_timeout* interval
  - If no is data being sent, routing entry will be deleted
    - Even if the route may actually still be valid
- Link Failure Reporting
  - Neighbor X is considered "active for a routing table entry" if it sent a packet, within *active_route_timeout*, which was forwarded using that entry
    - When the next hop link in a routing table entry breaks, all corresponding active neighbors are informed (using RREQ)

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Route Error

- When X is unable to forward a packet (from S to D) on link (X,Y), it generates an RERR message
  - X increments the cached destination seq number for D
  - The incremented seq number *N* is included in the RERR
- When node S receives the RERR
  - It initiates a new route discovery for D
  - Using destination sequence number > *N*
- When node D receives the RREQ with destination sequence number N,
  - D will set its seq number to N, unless it is already larger

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Link Failure Detection

- *Hello* messages:
  - Neighboring nodes periodically exchange hello message
  - Absence of hello message is used as an indication of link failure
- Alternatively, failure to receive several MAC-level acknowledgement may be used as an indication of link failure

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Summary: AODV

- Routes need not be included in packet headers
- Nodes maintain routing tables – contain entries only for routes that are in active use
- At most one next-hop per destination maintained at each node
  - DSR may maintain several routes for a single destination
- Unused routes expire even if topology does not change

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