AD-HOC ON-DEMAND DISTANCE VECTOR ROUTING

(Perkins 99)

Distance Vector Derivative

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

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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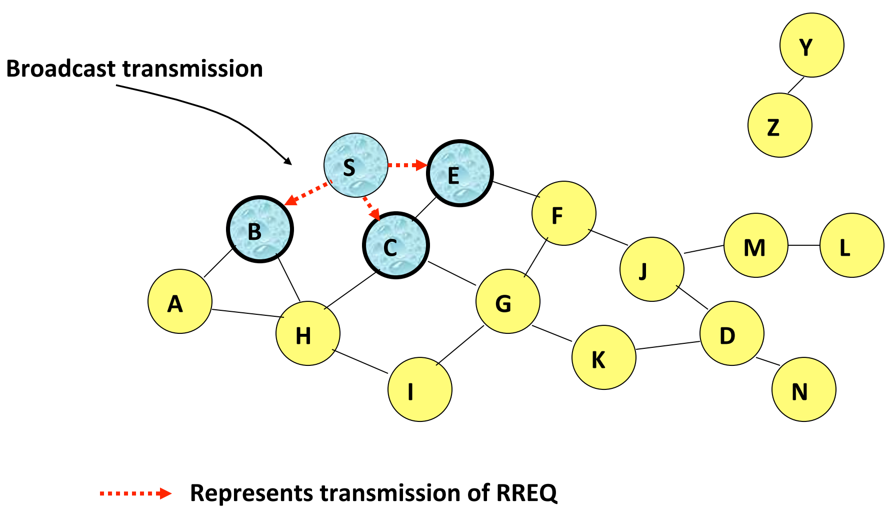
Route Requests in AODV



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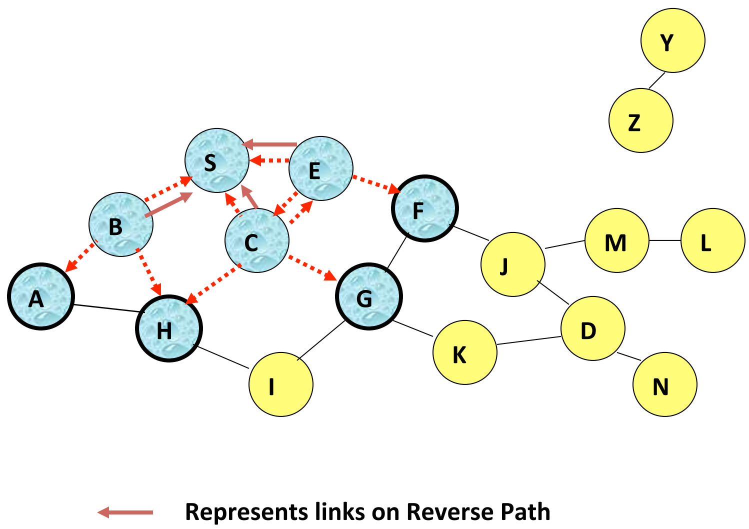
Route Requests in AODV



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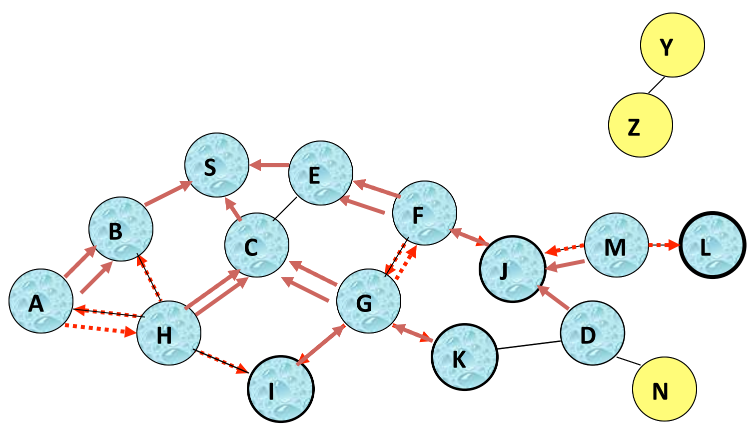
Reverse Path Setup in AODV



- 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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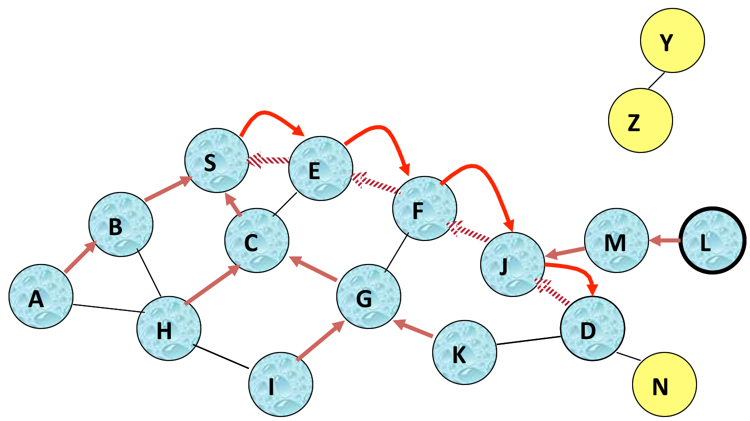
Route Reply in AODV



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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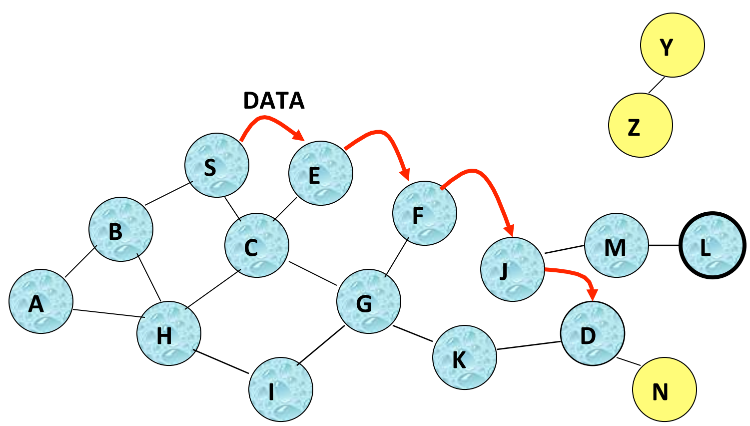
Data Delivery in AODV



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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LOCATION AWARE ROUTING

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Location-Aided Routing (LAR)

- Exploits location information to limit scope of RREQ
  - Location information may be obtained using GPS
- *Expected Zone* is determined as a region that includes the current location of destination
  - Expected region determined based on:
    - Potentially old location information
    - Knowledge of the destination's speed
- Route requests limited to a *Request Zone*
  - Such that Expected Zone contained in Request Zone

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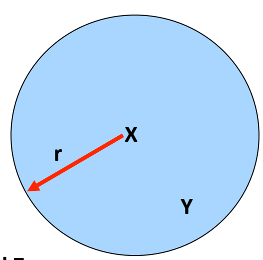
Expected Zone in LAR

X = last known location of node D, at time t_0

Y = location of node D at current time t_1, unknown to node S

r = $(t_1 - t_0)$ * estimate of D's speed



Expected Zone

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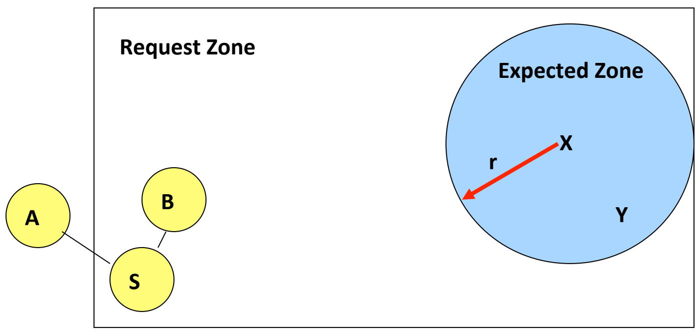
LAR

- Only nodes within the request zone forward RREQ
  - Node A does not forward RREQ, but node B does
- Request zone explicitly specified in the route request
  - Each node must know its physical location to determine whether it is within the request zone



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LAR: Request Zone Size

- Only nodes within the request zone forward route requests
- If route discovery using the smaller request zone fails
  - Initiate new discovery with large zone
  - Perhaps large zone = entire network
- Rest of route discovery protocol similar to DSR

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Location Aided Routing (LAR)

- Advantages
  - Reduces the scope of route request flood
  - Reduces overhead of route discovery
- Disadvantages
  - Does not take into account possible existence of obstructions for radio transmissions
  - Assumes that destination's location information is not too stale

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PROACTIVE APPROACHES

Link State, Fish Eye, LANMAR, …

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Link State Routing: Recap

- Each node periodically floods status of its links
  - Each node re-broadcasts link state information received from its neighbor
- Each node keeps track of link state information received from other nodes
- Each node uses above information to determine next hop to each destination

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Fish Eye Routing

- Overhead of LSR too much
  - Every node sends its own link states periodically
- Instead, adapt the periodicity and TTL of updates
  - Transmit updates frequently with low TTL
  - Transmit updates infrequently with high TTL
- Fish Eye: Clarity of vision degrades with distance
- Routing packets can be sent to approx direction
  - Micro-level course correction as destination approaches

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Landmark Routing (LANMAR)

- Designed for MANETs with "group mobility" [Pei00]
  - A *landmark* node is elected for a group of nodes that are likely to move together
  - A *scope* is defined such that each node would typically be within the scope of its landmark node
- Each node propagates:
  - *Link state* information only to nodes within its *scope*
  - *Distance-vector* information for all *landmark* nodes
- Combination of link-state and distance-vector
  - Distance-vector used for landmark nodes outside scope
  - No state info for non-landmark nodes outside scope

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POWER & ROUTING

Power Control, Power-Aware Routing

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Power Control

- So far: protocols find a route provided it exists
  - On a *given* network topology
- Some protocols attempt to ensure that a route exists
  - *Control* topology by transmission power control
    - To yield desirable network properties [Ramanathan00]
- Some provide a distributed power control mechanism:
  - That allows for local decisions, but guarantees global connectivity [Wattwnhofer00]
  - Each node uses a power level that ensures that the node has at least one neighbor in each *cone* with angle $2\pi/3$
- Such approaches can significantly impact performance at several layers of protocol stack

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Power-Aware Routing

- Define optimization criteria as a function of energy consumption
  - [Singh98-Mobicom], [Chang00-Infocom]
- Examples:
  - Minimize energy consumed per packet
  - Minimize time to network partition due to energy depletion
  - Maximize duration before a node fails due to energy depletion
- Assign an appropriate weight to each link
  - Prefer a route with smallest aggregate weight

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