Ad hoc On-Demand Distance Vector (AODV) Routing

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AODV enables “dynamic, self-starting, multi-hop routing between mobile nodes wishing to establish and maintain an ad hoc network”[1].

AODV allows for the construction of routes to specific destinations and does not require that nodes keep these routes when they are not in active communication.

AODV avoids the “counting to infinity” problem by using destination sequence numbers. This makes AODV loop-free.
Overview

- AODV defines 3 message types:
  - Route Requests (RREQs)
  - Route Replies (RREPs)
  - Route Errors (RERRs)

- RREQ messages are used to initiate the route finding process.

- RREP messages are used to finalize the routes.

- RERR messages are used to notify the network of a link breakage in an active route.
Overview

• The AODV protocol is only used when two endpoints do not have a valid active route to each other.

• Nodes keep a “precursor list” that contains the IP address for each of its neighbors that are likely to use it for a next hop in their routing table.

• Route table information must be kept for all routes even short-lived routes.
Overview

The routing table fields used by AODV are:
- Destination IP Address
- Destination Sequence Number
- Valid Destination Sequence number flag
- Other state and routing flags
- Network Interface
- Hop Count
- Next Hop
- List of Precursors
- Lifetime
Overview

- The authors point out that the AODV protocol is designed for mobile ad hoc networks of tens to thousands of nodes.

- The protocol was also designed to work in a network where all the nodes trust each other.
Simple Example

- Node A wants to send a message to node E.
- A valid route must be created between A and E.

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A  B  C  D  E
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- Node A generates a RREQ message with initial TTL of 1 and broadcast it to its neighbors. (In this case node B)
- The Message contains among other items node A’s IP address and the IP address of node E.
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Simple Example

- IF node B has an active route to node E then B will send a RREP message back to node A.
  - If A sets a special flag in the RREQ message, node B will also send a “gratuitous” RREP message to node E.
  - This will be necessary if node B will need to send packets back to A, i.e. TCP connection.
  - RREP messages are unicast to the next hop toward the originator or destination if it is a gratuitous RREP.
Simple Example

- If A does not receive a RREP message within a certain time, it will re-broadcast the RREQ message with an incremented TTL value.
- Default increment is 2
- “Reverse” routes to the originator, in this case node A, are created as RREQ messages are forwarded.
- Active route is established when A receives a RREP message.
- This behavior (Incrementing TTL) keeps network utilization down.
Maintaining Sequence Numbers

- The proper maintenance of sequence numbers is crucial to keeping AODV loop-free and thereby avoiding the “counting to infinity” problem.

- Forwarding nodes only update their stored sequence number for a given destination when forwarding RREP messages and only when:
  - The sequence number in the routing table is invalid, or
  - The sequence number in the RREP message is greater than the stored number, or
  - The sequence numbers are identical, but the route is marked as inactive, or
  - The sequence numbers are the same, but the hop count is smaller for the RREP message.
Maintaining Sequence Numbers

- Nodes originating RREQ messages must increment their own sequence number before transmitting the RREQ.

- Destination nodes increment their sequence numbers when the sequence number in the RREQ is equal to their stored number.
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Link Breaks

- Nodes can keep track of connectivity to neighbors using available data link or network layer mechanisms.

- RERR message processing is initiated when:
  - Node detects a link break for the next hop of an active route, or
  - Receives a data packet destined for a node for which it has no (active) route, or
  - Receives a RERR message from a neighbor for at least one active route in its routing table
Link Breaks

- Nodes must **increment** the destination sequence numbers of the routing entries contained in the RERR message before transmitting to nodes in precursor list.

- Nodes receiving RERR messages simply update their sequence numbers with those contained in the RERR message.

- Nodes must also mark these routing entries as invalid regardless of whether they are transmitting and/or receiving.
Link Breaks

- This ensures that no predecessors may reply to a RREQ from a node on their successor path, thus providing loop-freedom.

- RREQ messages are ultimately forwarded back to the originator who may initiate another RREQ message.
Local Repairs

- Nodes detecting a link breakage can choose to repair the link if possible.
- The node simply increments the destination sequence number and broadcasts a RREQ message.
- If it receives a RREP message then the repair was successful.
Security Considerations

• Currently AODV has no security measures built in.

• If the network membership is known, then authentication can be used on the AODV control messages.
References