Improving Fault Tolerance in AODV

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Why AODV?

- Proactive vs. Reactive
  - Reactive protocols have been shown to perform better in most simulated scenarios. [Broch98]
- DSR vs. AODV
  - Very similar, but AODV's next-hop paradigm is easier to implement and integrate in existing systems.
  - Potentially better scalability. AODV header size on data packets is consistent rather than a function of path lengths.
- Thus we feel it is likely that AODV (or a similar protocol) would become the most widely used ad hoc routing protocol.

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Problem Statement

- In AODV, only one route is maintained per destination
  - DSR makes use of multiple paths
  - This is a major weakness of AODV [Das00]
- Whenever a path breaks, AODV has to perform a route discovery
  - The source broadcasts a route request packet
  - Increases contention, significant overhead
- We want to avoid frequent route discoveries

Proposed Solutions

- Basic Idea
  - Maintain multiple paths learned from a route discovery
  - When a path breaks, try to use an alternate path instead of initiating a new route discovery
- Two approaches
  - Maintain multiple paths at the source (AODVM)
  - Maintain multiple routes at the intermediate nodes (AODVM-R)

AODVM – Motivation

- IDEA: Data source is responsible for maintaining alternate routes to a sink.
  - Scalable with the number of flows per source
  - Intermediate nodes only maintain at most one forwarding table entry per flow
  - Gives source more flexibility upon reception of an error. In addition to stopping the flow and doing a broadcast route discovery, the source may have the option of trying an alternate path.

AODVM – Protocol Description (1)

- Add path information to control packets. Data packet routing is not changed.
- Destination can reply to up to *k* route requests to allow the source to learn of more alternate routes (*k* = 3).
- Source caches all learned routes (subject to AODV's freshness policy). Initially, uses the shortest one.

AODVM – Protocol Description (2)

- When a source detects an error, it removes all cached routes which have the broken link. If an alternate path exists, a *probe* packet is sent to the destination and includes the desired path.
- The *probe* packet is “source routed” to the destination. The destination sends a route reply back along the path.

AODVM – Performance Evaluation (1)

varying network load

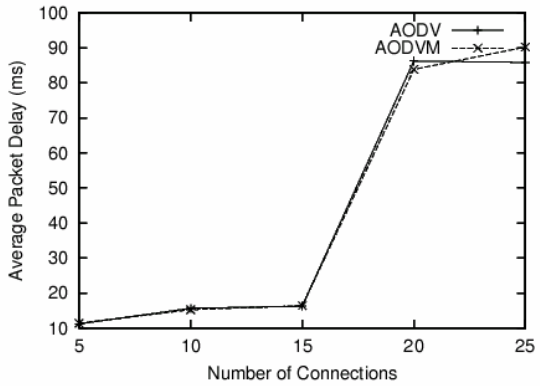

Figure 1: Packet Delay vs. the Number of Connections

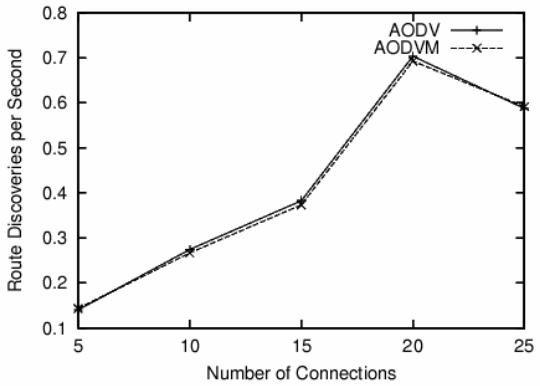

Figure 3: Route Discoveries per Second vs. the Number of Connections

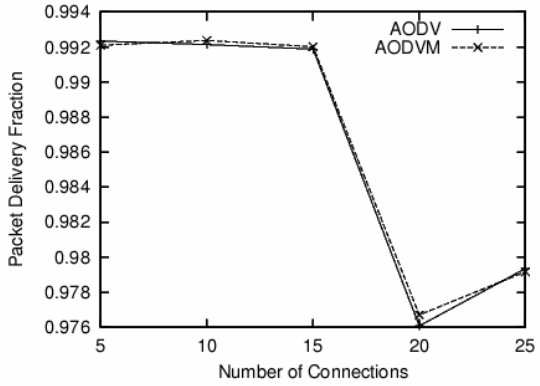

Figure 2: Packet Delivery Ratio vs. the Number of Connections

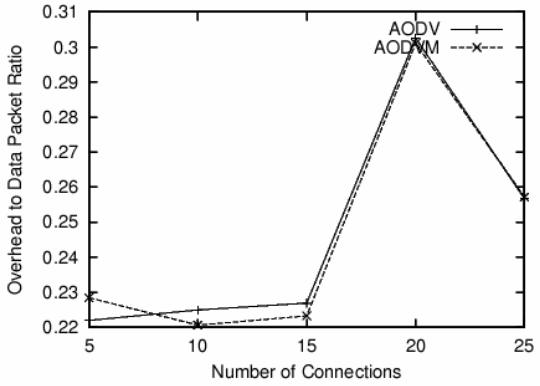

Figure 4: Overhead to Data Ratio vs. the Number of Connections

AODVM – Performance Evaluation (2)

varying mobility

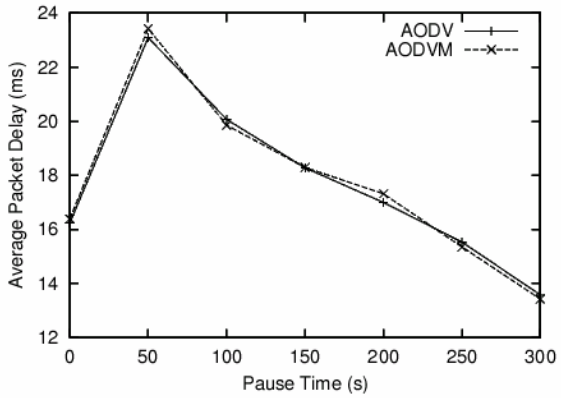

Figure 5: Packet Delay vs. Pause Time

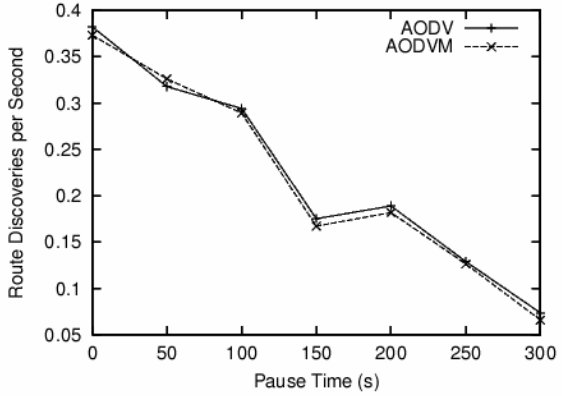

Figure 7: Route Discoveries per Second vs. Pause Time

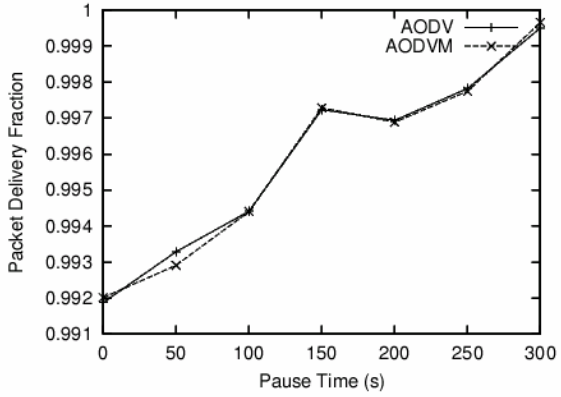

Figure 6: Packet Delivery Ratio vs. Pause Time

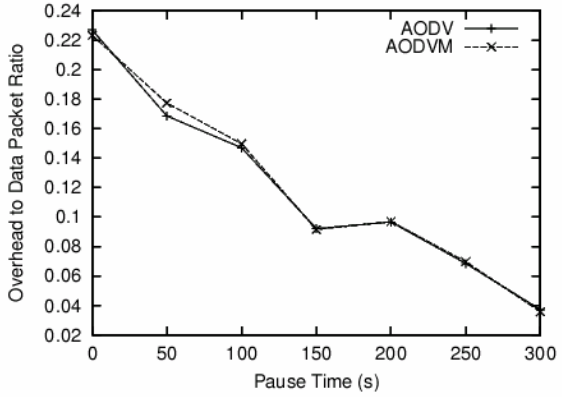

Figure 8: Overhead to Data Ratio vs. Pause Time

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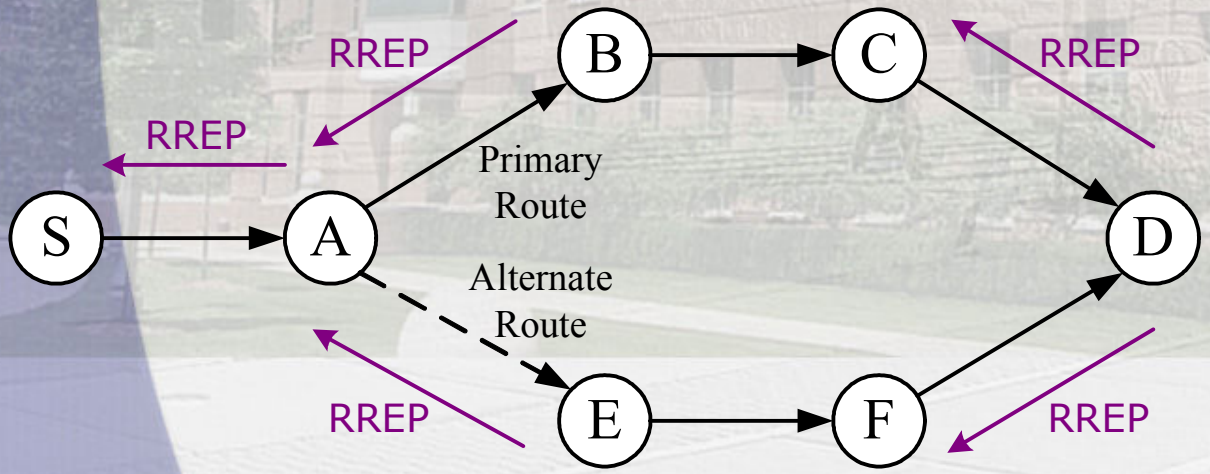
AODVM – Conclusion

- Does not change the performance of AODV significantly and hence is not worth the extra implementation complexity.
- Major problem: there is not enough opportunity to use alternate paths. The number of route discoveries dominates the number of *probe* packets in simulations.
- If the number of alternate paths used could become more significant, the protocol should outperform AODV when mobility is low.

AODVM-R – Protocol Description (1)

- Route Discovery
  - Maintain multiple routes at each node
  - To ensure loop freedom
    - The RREQ packet includes path information (path from the source to the router)
    - Primary and secondary routes must have the same sequence numbers

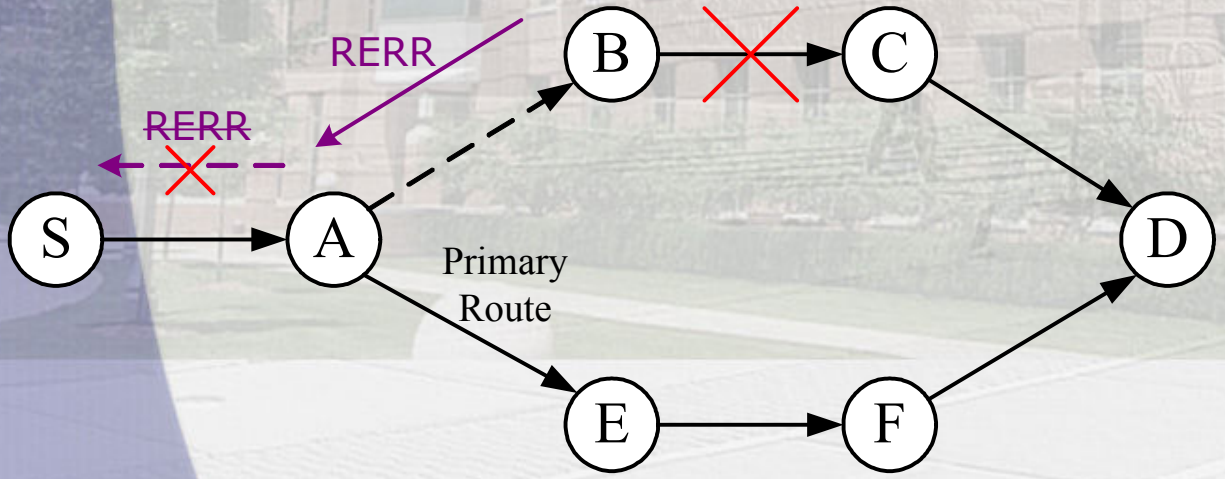


Routing Table of A

dst	next	seq	prime
D	B	8	P
D	E	8	S
S	S	4	P

AODVM-R – Protocol Description (2)

- Link Repair
  - When a link breaks, a node tries to repair the route using alternate paths
  - If still there is an unreachable destination, the node sends an RERR message to its neighbors

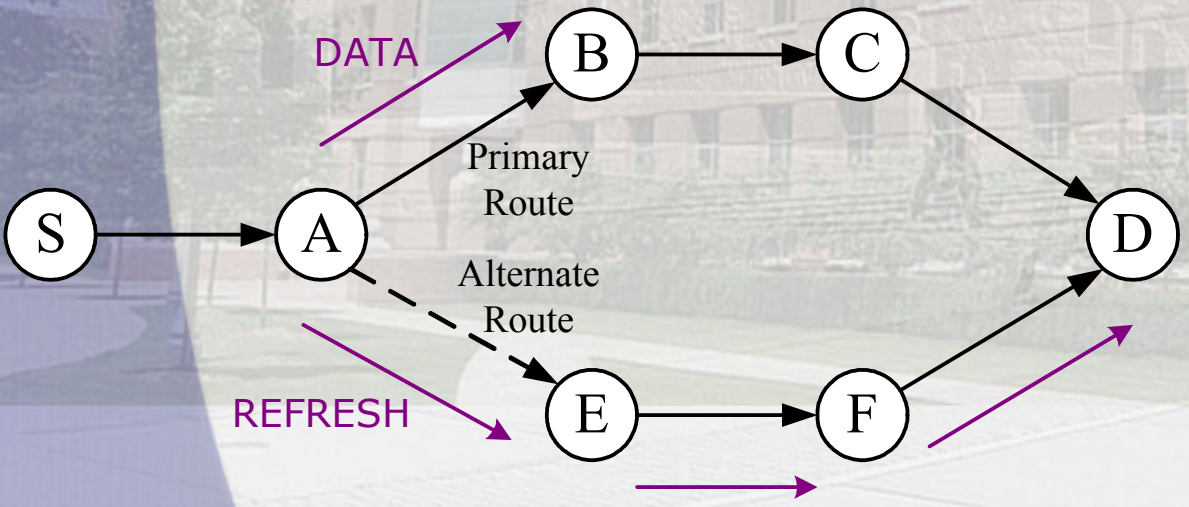


Routing Table of A

dst	next	seq	prime
D	E	8	S
S	S	4	P

AODVM-R – Protocol Description (3)

- Refresh alternate routes
  - If the primary route works for a long time, alternate paths might timeout because they are not used
  - While the primary route is being used, send REFRESH message to the alternate routes occasionally to refresh them



- The REFRESH packet is sent every *active_route_timeout / 2* seconds.
- The REFRESH packet is forwarded to the destination, refreshing the routes on the way.
- If an alternate route is detected to be broken, it is simply discarded from the route table

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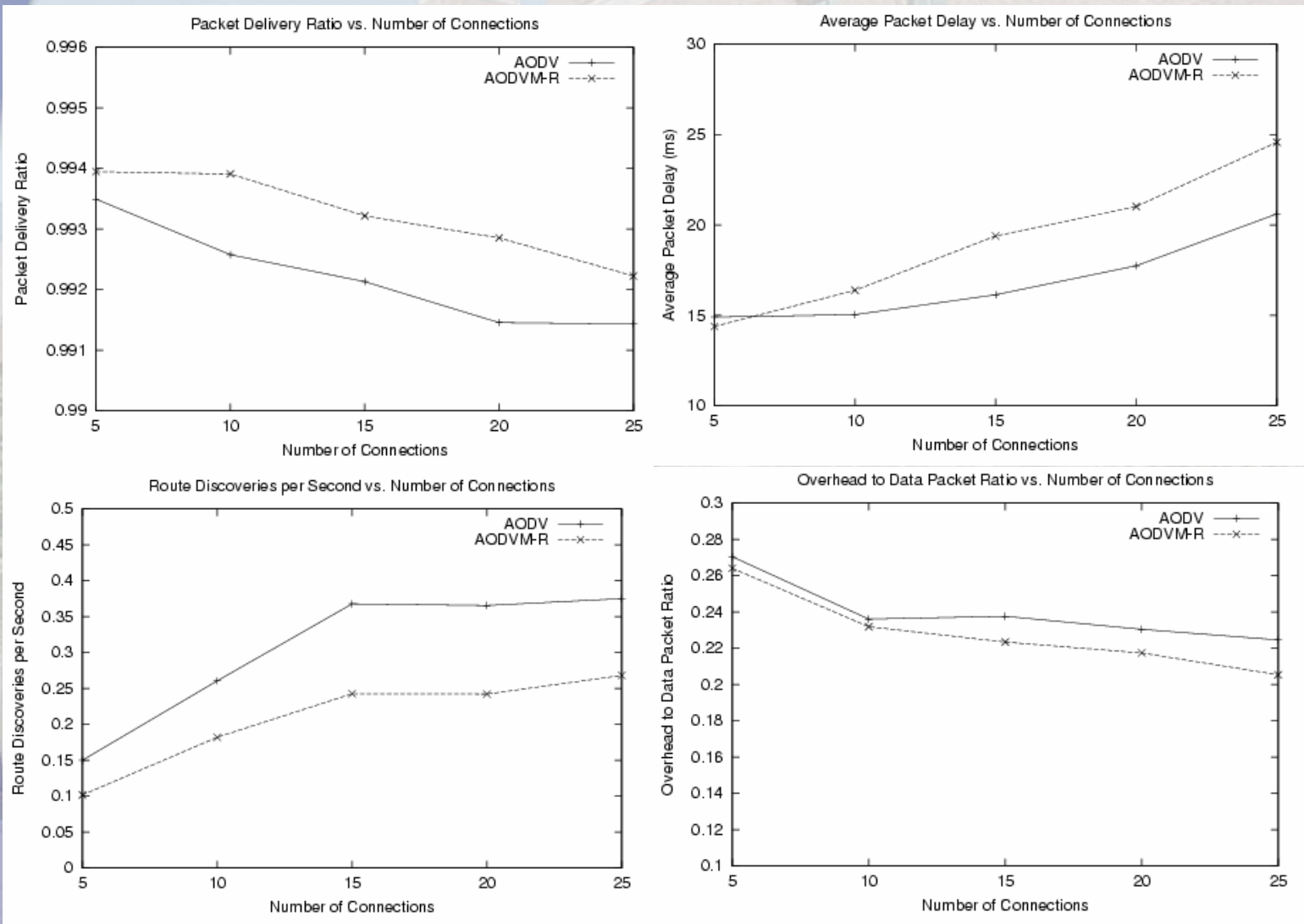
AODVM-R *varying network load*



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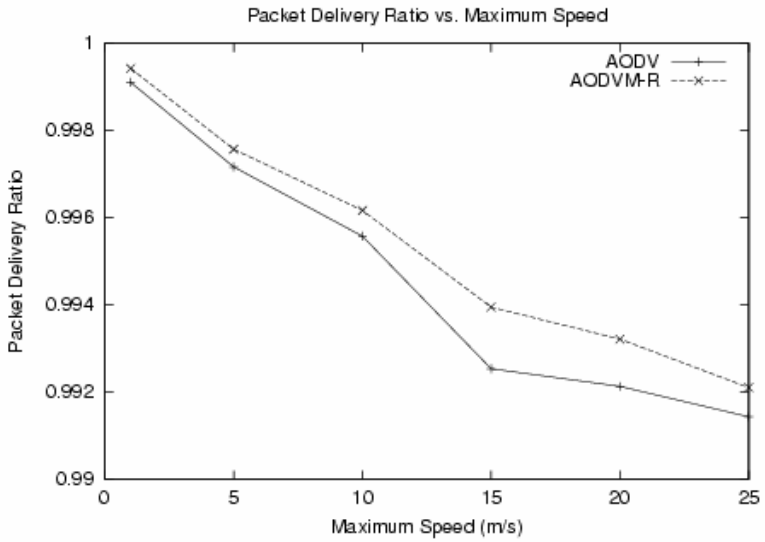
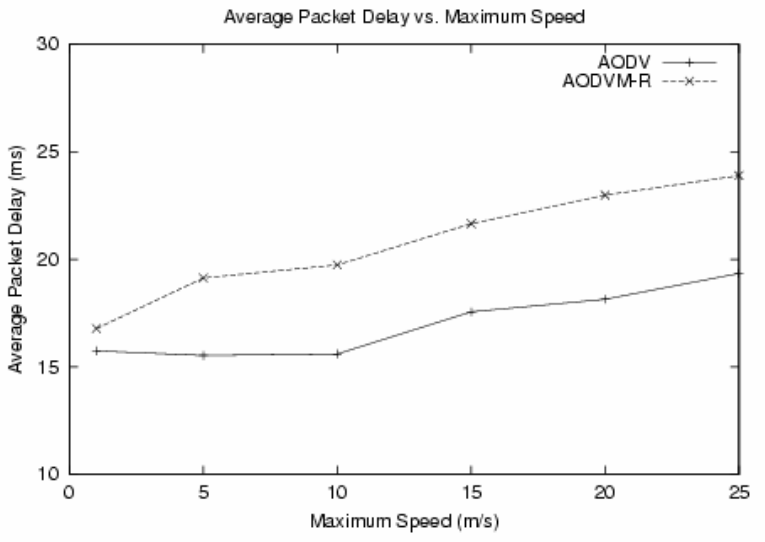
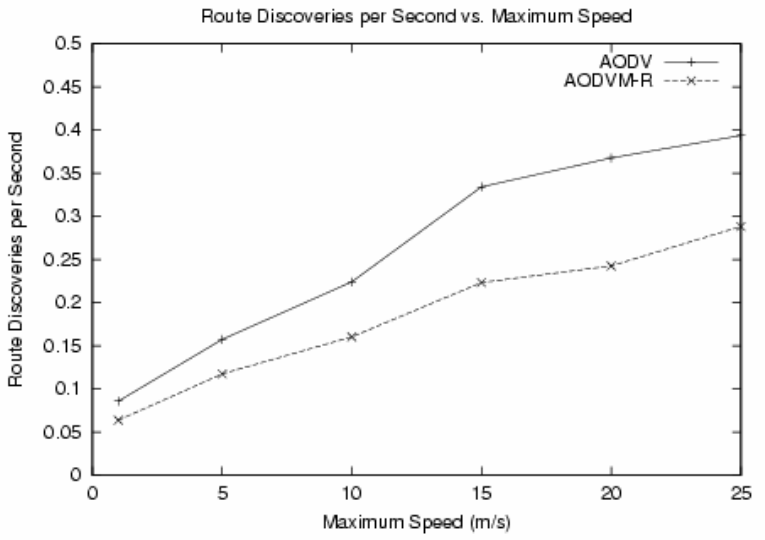
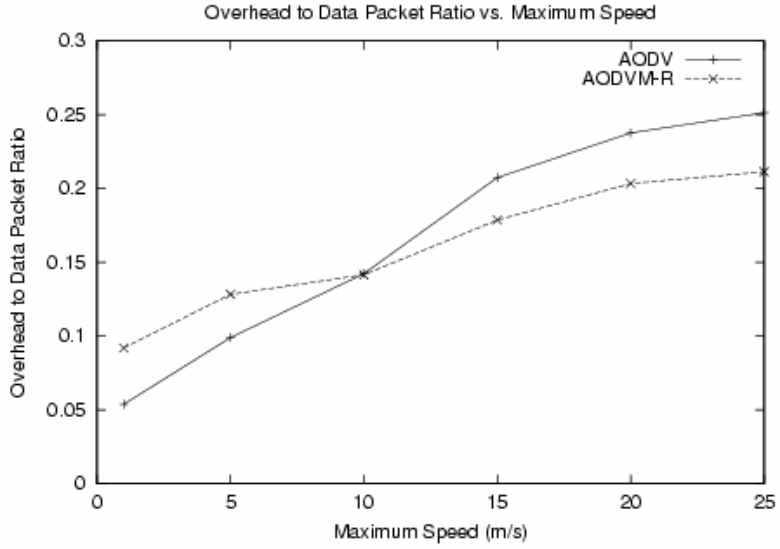
AODVM-R *varying mobility*









AODVM-R – Conclusion

- AODVM-R reduces number of route discoveries, but the total overhead is not significantly reduced because of refresh message overhead
  - Refresh message period can be carefully tuned to reduce overhead
- The packet delay is higher in AODVM-R, because repaired routes tend to have longer hop distance than optimal routes
- AODVM-R performs slightly better than AODV in terms of packet delivery ratio, but the improvement is minimal
  - The benefit gained from reducing number of route discoveries is diminished by longer average hop count and refresh message overhead