CHAPTER 3

RELATED WORK

3.1. INTRODUCTION

A mobile ad hoc network (MANET) is a collection of wireless mobile nodes dynamically forming a network topology without the use of any existing network infrastructure or centralized administration. Routing is the process which transmitting the data packets from a source node to a given destination [64]. The main classes of routing protocols are Proactive, Reactive and Hybrid. A Reactive (on demand) routing strategy is a popular routing category for wireless ad hoc routing. In this chapter an attempt has been made to compare the four Reactive (on demand) routing protocols for MANETs: AODV, DSDV, AOMDV and MPRAODV protocol.

3.2. Adhoc on Demand Distance Vector Routing (AODV) Protocol

3.2.1. Introduction

AODV belongs to the class of Distance Vector Routing Protocols (DV). In a Distance Vector Routing Protocol every node knows its neighbours and the costs to reach them. Ad hoc On Demand Distance Vector (AODV) is a reactive routing protocol which initiates a route discovery process only when it has data packets to transmit and it does not have any route path towards the destination node, that is, route discovery in AODV is called as on demand [63][67].

AODV is composed of three mechanisms: Route Discovery process, Route message generation and Route maintenance. The significant feature of AODV is whenever a route is available from source to destination; it does not add any overhead
to the packets. However, route discovery process is only initiated when routes are not used and/or they expired and consequently discarded. This strategy reduces the effects of stale routes as well as the need for route maintenance for unused routes. Another distinguishing feature of AODV is the ability to provide unicast, multicast and broadcast communication. AODV uses a broadcast route discovery algorithm and then the unicast route reply message [64].

3.2.2. Description of Adhoc on Demand Distance Vector Routing (AODV) Protocol

AODV is the on-demand (reactive) topology-based routing protocol in which backward learning procedure is utilized in order to record the previous hop (previous sender) in the routing table. In the backward learning procedure, a broadcast query (RREQ) contains source and destination address, sequence numbers of source and destination address, request ID and message lifespan. The address of the node sending the query will be recorded in the routing table. Recording the specifications of previous sender node into the table enables the destination to send the reply packet (RREP) to the source through the path obtained from backward learning.

A full duplex path is established by flooding query and sending of reply packets. As long as the source uses the path, it will be maintained. Source may trigger to establish another query-response procedure in order to find a new path upon receiving a link failure report (RERR) message which is forwarded recursively to the source [63]. Fig.3.1 represents the route discovery process in AODV protocol.
Counting to infinity Problem

AODV avoids the “counting to infinity” problem from the classical distance vector algorithm by using sequence numbers for every route. The counting to infinity problem is the situation where nodes update each other in a loop. Consider nodes A, B, C and D making up a MANET as illustrated in figure.3.2. A is not updated on the fact
that its route to D via C is broken. This means that A has a registered route, with a metric of 2, to D. C has registered that the link to D is down, so once node B is updated on the link breakage between C and D, it will calculate the shortest path to D to be via A using a metric of 3. C receives information that B can reach D in 3 hops and updates its metric to 4 hops. A then registers an update in hop-count for its route to D via C and updates the metric to 5. And so they continue to increment the metric in a loop [63].

![Diagram of node connections](image)

**Fig.3.2 counting to infinity problem**

**Characteristics of AODV**

- Unicast, Broadcast, and Multicast communication.
- On-demand route establishment with small delay.
- Multicast trees connecting group members maintained for lifetime of multicast.
- Link breakages in active routes efficiently repaired.
- All routes are loop-free through use of sequence numbers.
- Use of Sequence numbers to track accuracy of information.
- Only keeps track of next hop for a route instead of the entire route.
  
  Use of periodic HELLO messages to track neighbours.

**AODV Protocol Design**

AODV defines the following control messages for route maintenance [67].

There are
* Route Request Message (RREQ)
* Route Reply Message (RREP)
* Route Error Message (RERR)
* HELLO Messages.

**Route Request (RREQ)**

A route request packet is flooded through the network when a route is not available for the destination from source. The parameters contained in the route request packet are presented in the following table:

<table>
<thead>
<tr>
<th>Source Address</th>
<th>Request ID Source</th>
<th>Sequence Number</th>
<th>Destination Address</th>
<th>Destination Sequence Number</th>
<th>Hop Count</th>
</tr>
</thead>
</table>

![Fig.3.3 Route Request](image)

A RREQ is identified by the pair source address and request ID, each time when the source node sends a new RREQ and the request ID is incremented. After receiving the request message, each node checks the request ID and source address pair. The new RREQ is discarded if there is already RREQ packet with same pair of parameters. A node that has no route entry for the destination, it rebroadcasts the RREQ with incremented hop count parameter. A route reply (RREP) message is generated and sent back to source if a node has route with sequence number greater than or equal to that of RREQ.
**Route Reply (RREP)**

Once find out the valid route to the destination or if the node is destination, a RREP message is sent to the source by the node. The following parameters are contained in the route reply message:

![Fig.3.4 Route Reply](image)

**Route Error Message (RERR)**

The neighborhood nodes are monitored. When a route that is active is lost, the neighborhood nodes are notified by route error message (RERR) on both sides of link.

**Hello Messages**

The HELLO messages are broadcasted in order to know neighborhood nodes. The neighborhood nodes are directly communicated. In AODV, HELLO messages are broadcasted in order to inform the neighbors about the activation of the link. These messages are not broadcasted because of short time to live (TTL) with a value equal to one.

**Discovery of Route**

When a source node does not have routing information about destination, the process of the discovery of the route starts for a node with which source wants to communicate. The process is initiated by broadcasting of RREQ. On receiving RREP message, the route is established. If multiple RREP messages with different routes are
received then routing information is updated with RREP message of greater sequence number.

**Setup of Reverse Path**

The reverse path to the node is noted by each node during the transmission of RREQ messages. The RREP message travels along this path after the destination node is found. The addresses of the neighbors from which the RREQ packets are received are recorded by each node.

**Setup of Forward Path**

The reverse path is used to send RREP message back to the source but a forward path is setup during transmission of RREP message. This forward path can be called as reverse to the reverse path. The data transmission is started as soon as this forward path is setup. The locally buffered data packets waiting for transmission are transmitted in FIFO (First-in –First Out) -queue.

**Advantages and Disadvantages**

The main advantage of AODV protocol is that routes are established on demand and destination sequence numbers are used to find the latest route to the destination. The connection setup delay is less. The HELLO messages supporting the routes maintenance are range-limited, so they do not cause unnecessary overhead in the network. One of the disadvantages of this protocol is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries. Also multiple Route Reply packets in response to a single Route Request packet can lead to heavy control overhead. Another disadvantage of AODV is that the periodic beaconing leads to unnecessary bandwidth consumption [68].
3.3. Destination-Sequenced Distance-Vector Routing (DSDV) Protocol

3.3.1. Introduction

Destination sequenced distance vector routing (DSDV) is adapted from the conventional Routing Information Protocol (RIP) to ad hoc networks routing. It adds a new attribute, sequence number, to each route table entry of the conventional RIP[65]. Using the newly added sequence number, the mobile nodes can distinguish stale route information from the new and thus prevent the formation of routing loops.

3.3.2. Description of Destination-Sequenced Distance-Vector Routing (DSDV) Protocol

The DSDV (destination-sequenced distance vector) protocol uses the Bellman-Ford algorithm to calculate paths. The cost metric used is the hop count, which is the number of hops it takes for the packet to reach its destination. DSDV is a table-driven proactive protocol, thus it maintains a routing table with entries for all the nodes in the network and not just the neighbors of a node [69]. The changes are propagated through periodic and trigger update mechanisms used by DSDV. Due to these updates, there is a chance of having routing loops within the network [54][60].

To eliminate routing loops, each update from the node is tagged with a sequence number. The sequence number from each node is independently chosen but it must be incremented each time a periodic update is made by a node. The sequence number of normal update must be an even number, since each time a periodic update is made the node increments its sequence number by 2 and adds its update to the routing message it transmits [66].
The node cannot change the sequence number of other nodes. If a node wants to send an update for an expired route to its neighbors, only then it increments the sequence number of the disconnected node by 1. The nodes receiving this update will then look at the sequence number and if it is odd, will remove the corresponding entry from the routing table. Distance Vector Routing Protocol Initialization Phase Cost per hop = 1

Each node:

- Knows its neighbors and the cost to reach them
- Tells its neighbors periodically the distance to every other node in the network

The Table 3.1 shows the routing table for DSDV routing protocol. It shows the routing table for the nodes A, B and C. The nodes A, B and C are communicated with each other based on their routing table.
3.4. Performance Analysis of ADOV & DSDV

In the analysis, performance of AODV and DSDV protocol are compared using following performance metrics:

**Throughput vs. Speed**

In fig 3.6 the throughput of both protocol decreases as speed increases. DSDVs throughput decreases in a steeper and more rapid fashion. This is attributed to excessive channel usage by regular route table updates. Furthermore, as mobility speed increases, more event-triggered updates are generated, resulting in even more
throughput decrease. This problem is not present in AODV since routes are only generated on-demand.

![Throughput of AODV and DSDV vs. speed](image)

**Fig. 3.6 Throughput of AODV and DSDV vs. speed**

**Routing Overhead vs. Speed**

In fig.3.7 the DSDV generates much more routing traffic than AODV. This is due to the fact that DSDV periodically generates routing traffic as opposed to the on-demand nature of AODV. When comparing the number of routing overhead packets sent by each of the protocols, AODV clearly has the lowest overhead.
Fig. 3.7 Overhead for AODV and DSDV vs. speed

Packet Loss Ratio vs. Speed

The graph below, show not much packet loss on AODV side. This is because when a link fails, a routing error is passed back to a transmitting node and the process repeats. For DSDV show the packet loss higher than AODV. But in DSDV, the information on new Routes, broken Links, metric change is immediately propagated to neighbors.

Fig. 3.8 Packet loss ratio of AODV and DSDV vs. speed
3.5. Summary

DSDV routing protocol consumes more bandwidth, because of the frequent broadcasting of routing updates. While the AODV is better than DSDV as it doesn’t maintain any routing tables at nodes which results in less overhead and more bandwidth. From the above analysis, assumed that, DSDV routing protocols works better for smaller networks, but not for larger networks. The experimental result shows that, AODV routing protocol is best suited for general mobile ad-hoc networks as it consumes less bandwidth and lower overhead when compared with DSDV routing protocol.
3.6. Adhoc on Demand Multipath Distance Vector Routing (AOMDV) Protocol

3.6.1. Introduction

A multipath routing scheme called Multipath On-demand routing, in order to minimize the route break recovery overhead. This scheme provides multiple routes on the intermediate nodes on the primary path to destination along with source node [72]. The primary path is the first path received by the source node after initiating the route discovery, which is usually the shortest path. Having multiple routes at the intermediate nodes of the primary path, avoid overhead of additional route discovery attempts, and reduce the route error transmitted during route break recovery [71].

Multipath routing protocols work on the principle that higher performance can be achieved by recording more than one feasible path. When multiple routes are known, even if the primary path fails data forwarding can continue uninterrupted on the alternate available paths without waiting for a new route to be discovered. In this scheme, the single-path AODV has been extended for multipath routing [73]. This scheme is used for infrastructure less networks in which communication failure occurs frequently and designed to calculate node-disjoint paths and fail-safe paths.

3.6.2. Description of Adhoc on Demand Multipath Distance Vector Routing (AOMDV) Protocol

Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV) [48][49] protocol is an extension to the AODV protocol for computing multiple loop-free and link-disjoint paths [52][55]. The routing entries for each destination contain a
list of the next-hops along with the corresponding hop counts. All the next hops have
the same sequence number. This helps in keeping track of a route.

For each destination, a node maintains the advertised hop count, which is
defined as the maximum hop count for all the paths, which is used for sending route
advertisements of the destination. Each duplicate route advertisement received by a
node defines an alternate path to the destination. Loop freedom is assured for a node by
accepting alternate paths to destination if it has a less hop count than the advertised hop
count for that destination[50][51].

Because the maximum hop count is used, the advertised hop count therefore
does not change for the same sequence number. When a route advertisement is
received for a destination with a greater sequence number, the next-hop list and the
advertised hop count are reinitialized. AOMDV can be used to find node-disjoint or
link-disjoint routes. To find node-disjoint routes, each node does not immediately
reject duplicate RREQ [53][56].

Each RREQ arriving via a different neighbor of the source defines a node-
disjoint path. This is because nodes cannot be broadcast duplicate RREQs, so any two
RREQs arriving at an intermediate node via a different neighbor of the source could
not have traversed the same node.

In an attempt to get multiple link-disjoint routes, the destination replies to
duplicate RREQs, the destination only replies to RREQs arriving via unique neighbors.
After the first hop, the RREPs follow the reverse paths, which are node-disjoint and
thus link-disjoint. The trajectories of each RREP may intersect at an intermediate node,
but each takes a different reverse path to the source to ensure link-disjointness.
The advantage of using AOMDV is that it allows intermediate nodes to reply to RREQs, while still selecting disjoint paths. But, AOMDV has more message overheads during route discovery due to increased flooding and since it is a multipath routing protocol, the destination replies to the multiple RREQs those results are in longer overhead.

3.7. Performance Analysis of AODV & AOMDV

The comparison of the AODV and AOMDV Routing Protocols is done by using the NS-allinone-2.34 Simulator. The number of nodes is considered by changing their number as 10, 20, 30, 40, 50, 60, 70 and 80 with same propagation model. The routing protocol AODV and AOMDV are used which routes the packet towards its destination on its call. The mobility model used is static with movement maximum speed is 1.5 m/s and minimum speed is 0.5 m/s. The network type is wireless with 50 packets in interface queue. The constant bit rate is transferring the constant rate of bits for a particular time. The performance of AODV and AOMDV protocols are compared according to the following metrics.

1) Packet delivery Ratio
2) End-to-End delay
3) Packet Loss

Packet delivery Ratio

Fig.3.9 and Fig.3.10 depicts the Xgraph values of both AODV and AOMDV. The X axis represents number of nodes and Y axis represents PDR value \(10^3\). It is clear from the figure that the value for average PDR of AOMDV is higher with respect to the number of nodes, which is increasing from 10 to 80. In figure; AOMDV has a
better value when compared to AODV for each set of connections. This is because in the time waited at a node, AOMDV can find an alternate route if the current link has broken, whereas AODV is rendered useless at that point.

Fig. 3.9 AODV Packet Delivery ratio

Fig. 3.10 AOMDV Packet Delivery ratio
End-to-End Delay

Fig.3.11 and Fig.3.12 depict the Xgraph values of both AODV and AOMDV. The X axis represents the number of nodes and the Y axis represents PDR value ($10^3$). In the graph, AODV has a better average delay than AOMDV due to the fact if a link break occurs in the current topology, AOMDV would try to find an alternate path from among the backup routes between the source and the destination node pairs, resulting in additional delay to the packet delivery time.

In comparison, if a link break occurs in AODV, the packet would not reach the destination due to unavailability of another path from source to destination, since we assume in AODV only singular paths exist between a source and destination node.

![Fig.3.11 AODV Delay](image-url)
Fig. 3.12 AOMDV Delay

Packet Loss

Fig. 3.13 and Fig. 3.14 depict the Xgraph values of both AODV and AOMDV. The X axis represents the number of nodes and the Y axis represents the dropped packet value ($10^3$). The number of packets dropped in AOMDV is more than the number of packets dropped in AODV. While in case of lower mobility, AOMDV performs better than AODV. Theoretically, it should not be the case, i.e., in stable networks, AODV should perform better than AOMDV.

Fig. 3.13. AODV Packet Loss
3.8. Summary

The AOMDV has more routing overhead than AODV for any range of pause time. This is attributed to the different mechanism of AODV and AOMDV. Due to AODV being a unipath routing protocol, once a link breaks, the packet delivery along that route stops. But AOMDV is a multipath routing protocol and it searches for alternate paths if the current route breaks by flooding the network with RREQ packets. Hence AOMDV incurs more routing overhead than AODV.
3.9. Multi Point Relay Adhoc On Demand Distance Vector Routing (MPRAODV)

3.9.1. Introduction

Amiour Med Tahar, Bilami Azeddine et al [42] introduced new protocol MPRAODV protocol. The MPR (Multi Point Relay algorithm) concept is introduced in the AODV protocol [MPRAODV] to reduce the number of messages broadcasted during the flooding phase and enhances the packet delivery performance[2][9].

3.9.2. Description of Multi Point Relay Adhoc on Demand Distance Vector Routing AODV (MPRAODV)

In this Literature an alternative flooding control mechanism, called Multipoint Relay (MPR)[58] is implemented, which was first introduced in the Optimized Link State Routing Protocol (OLSR), a proactive routing protocol[61].

In order to use this optimized mechanism, the nodes must perform a proactive control in order to know their two-hop neighborhood. This can be done via the reception of hello messages generating by the nodes and containing their neighbors list. Since two nodes are neighbors when they can see each other address in their respective hellos, this is a very straightforward procedure [59].

The MPR concept is implemented in AODV protocol to reduce the overhead. MPR is a flooding mechanism used to reduce the number of broadcasted message for the control; in order to limit the flow on the network by selecting a small number of nodes which will be the only ones allowed disseminating messages on the network.
3.9.3. Multi Point Replay Flooding Algorithm

In MANETs, packets can be forwarded on the same interface that it arrived on. Instead of pure flooding where all nodes retransmit all packets, with Multipoint Relays (MPR) packets are forwarded only by the node’s MPRs in order to reduce the number of transmissions that are needed to successfully deliver the packets. A MPR set is a subset of a node’s one-hop neighbors, such that together this subset is able to reach all the two-hop neighbors. In order to calculate the MPR set, the node must have link state information about all one-hop and two-hop neighbors [62][70].

Let N1 (u) denote the set of one-hop neighbors of u, and N2 (u) denote the set of 2nd-hop neighbors of u.

1. Start with an empty MPR set MPR (u).

2. Select those one-hop neighbor nodes in N1(u) as multipoint relays which are the only neighbor of some node in N2(u), then add these one-hop neighbor nodes to the multipoint relay set MPR(u).

3. While there still exist some nodes in N2 (u) which are not covered by the multipoint relay set MPR (u):

   • For each node in N1 (u) not in MPR (u) compute the number of the nodes that it covers among the uncovered nodes in the set N2 (u).

   • Add that node of N1 (u) in MPR (u) for which this number is maximum.

The Multi Point Relay algorithm is implemented in AODV in order to reduce the overhead.
3.10. Performance Analysis of AODV & MPRAODV

3.10.1. Simulation Environment

The simulation experiment is carried out in FEDORA 6. The detailed simulation model is based on network simulator-2 (ver-2.35). The NS2 instructions can be used to define the topology structure of the network and the motion mode of the nodes, to configure the service source and the receiver, to create the statistical data track file and so on.

The studied scenario consists of 25 mobile nodes. The topology is a rectangular area with 800 m length and 500 m width. A rectangular area was chosen in order to force the use of longer routes between nodes than would occur in a square area with equal node density. All simulations are run for 25 seconds of simulated time. All mobile nodes are constant bit rate traffic sources. They are distributed randomly within the mobile ad hoc network. The sources continue sending data until one second before the end of the simulation.

Fig. 3.15 Screenshot for AODV
Fig. 3.16 Screenshot for Creation of MPR Node

Fig. 3.17 Screenshot for MPRAODV
Parameters

The following Table 3.2 shows the General parameters used in the experiments.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission range</td>
<td>250 m</td>
</tr>
<tr>
<td>Simulation time</td>
<td>25s</td>
</tr>
<tr>
<td>Topology size</td>
<td>800m x 500m</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>25</td>
</tr>
<tr>
<td>Number of source</td>
<td>1</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR(Constant Bit Rate)</td>
</tr>
<tr>
<td>Packet rate</td>
<td>5 packets/s</td>
</tr>
<tr>
<td>Packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>20 m/s</td>
</tr>
</tbody>
</table>

3.10.2. Performance Metrics

The performance of MPRAODV protocol is evaluated based on the following metrics.

1. Packet delivery ratio (PDF)

PDF is the ratio between the number of packets originated by the application layer sources and the number of packets received by the sinks at the final destination. In terms of packet delivery ratio, MPRAODV performs well. However its performance declines with increased number of nodes due to more traffic in the network. The performance of AODV is better at the beginning and decreases slightly with increase in number of nodes. The performance of MPRAODV protocol is better when compared to AODV protocol.
2. Average Delay

For average end-to-end delay, the performance of MPRAODV decreases and varies with the number of nodes. However, the performance of AODV is degrading due to increase in the number of nodes. The performance of MPRAODV decreases and remains constant as the number of nodes increases.

Fig.3.18 PDR between AODV and MPRAODV

Fig.3.19 Average Delay between AODV and MPRAODV
3. Throughput

Another important quality of communication networks is the throughput. It is defined as the total useful data received per unit of time. Figure 3.19 illustrate the comparison of throughput for MPRAODV and AODV, 25 nodes in specific area spaces. In this metric, the throughput of the protocol in terms of number of messages delivered per one second (Mbps) is analyzed. In figure 9 the MPRAODV provides highest throughput than AODV. More routing packets are generated and delivered by MPRAODV than AODV.

![Graph showing Throughput between AODV and MPRAODV](image)

**Fig.3.20 Throughput between AODV and MPRAODV**

4. Packet Loss

It is the number of data packets that are not successfully sent to the destination. In terms of dropped packets, AODV’s performance is the worst. The performance degrades with the increase in the number of nodes. As the number of nodes increases
the number of packets dropped increases which means that number of packets not successfully reaching the destination has also increased. MPRAODV performs consistently well with increase in the number of nodes. The number of packets dropped is negligible which means that almost all packets reach the destination successfully. The packets dropped are much less compared to performance of AODV.

![Packet Loss between AODV and MPRAODV](image)

Fig.3.21 Packet Loss between AODV and MPRAODV

5. Energy

Energy Consumption is defined as the ratio between the sums of energy increased by each node to the total number of data packets delivered. Figure 3.21 shows the total transmission and receiving energy. The energy consumed mainly due to receiving process. When number of nodes is low, the transmitting energy is more. When number of nodes is high, all traffic type consumed similar amount of energy.
3.11. Summary

An improvement of the AODV routing protocol for MANETs is based on MPR mechanism. Compared to the performance of AODV, MPRAODV performs much better performance than AODV in case of high density networks. Considering great speeds, MPRAODV operates better than AODV. This research finds that the current AODV protocol has major control overhead which is caused by “Route Query” flood packets. The AODV routing protocol is improved by reducing routing overhead using an efficient flooding technique multipoint relay. This technique selects the dominated nodes through out the entire network to forward route query flood packets. From the results of the simulations, the MPR technique optimized the original AODV protocol.