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## Mobility and Direction Aware Ad-hoc On Demand Distance Vector routing protocol

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### Abstract

Mobile Ad hoc Network (MANET) is a rapidly growing wireless technology with wide range of applications. MANET routing faces challenges due to their Ad hoc nature, and many routing algorithms have been proposed. Reactive routing protocols are preferred due to less control overhead and scalability, but they suffer from frequent link breakages due to the high-mobility of the nodes. To reduce the link breakages and get a stable route, a new reactive routing protocol is proposed that is tree-based mobility-aware. The proposed Mobility and Direction Aware Ad-hoc On Demand Distance Vector routing protocol (MDA-AODV) aims to handle the mobility and direction factors in ad-hoc networks. MDA-AODV guides the route discovery and route reply depending on the speed of the participating nodes and their directions. Qualnet simulator version 7.1, using two offered load simulations (packet-rate and CBR connections), was used to investigate the effect and the advantages of MDA-AODV over AODV protocol. The simulation results show that the proposed scheme decreases control overhead by (4.6 ÷ 5.2 %). It also accomplishes (37 ÷ 41 %) lower route losses compared to AODV. The delivery ratio is increased by (29 ÷ 47 %). The consumed energy and end-to-end delay of the proposed protocol is also compared to that of AODV.

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### 1. Introduction

Mobile Ad hoc network<sup>1</sup> is constructed and built without knowledge of the surrounding environment. The routing process is one of the most challenging aspects in MANET because of its limited resources, dynamic topology, frequent link breakages and distributed features. The famous classification of ad hoc networks routing protocols divides them into proactive and reactive classes based on the way the route information is determined, maintained

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and stored. The Destination-Sequenced Distance Vector (DSDV) protocol<sup>2</sup> is an example of proactive routing protocol. Ad hoc On-demand Distance Vector (AODV) is an example of reactive routing protocol<sup>3</sup>. Reactive protocols are more scalable and generate less traffic as they discover routes only when needed<sup>4</sup>. The routing process in these protocols floods the network with control packets that consumes the network resources, causes the broadcast storm problem<sup>5</sup> and control overhead.

In this paper, we focus to design a new scheme for Ad hoc routing protocols that deal with high mobility networks. It is called Mobility and Direction Aware Ad hoc On Demand Distance Vector routing protocol (MDA-AODV), it is proposed to find a more stable and reliable route between the source/destination pairs which leads to avoid any invalid route as a result of the continuity and high dynamic mobility, and also to avoid any unpredictable interrupt in the data transmission.

MDA-AODV prevents high mobility nodes (their speeds are more than a specific threshold) from participating in the route discovery process. In the route reply process, once the route request packet reaches the destination or any intermediate has an active route toward the destination. Then the new scheme will apply an algorithm to select the best path from different paths, through which requests were received, depending on the speed and the direction for the participating nodes in the routing process.

The rest of this paper is organized as follows. Section 2 presents some of the related work. In Section 3, we discuss the main idea and the operation details of the MDA-AODV scheme. Section 4 presents the simulation environment and experimental results. In Section 5, we present conclusions and future work.

## 2. Related Work

Literature review revealed many different schemes. They enhance the performance of the dynamic mobility Ad hoc networks by taking into account some needs depend on requirements of specific environment or application such as mobility, position, energy, QoS or even broadcast aware routing schemes.

### 2.1 Mobility-based Scheme

These schemes have three parameters: position, direction and speed where only one of these parameters is considered to select the next hop during the route discovery process. Khalaf et al. (2015)<sup>6</sup> aims to control the route discovery phase of AODV protocol especially for high-mobility nodes. It depends on the velocity-vector probability to discover stable routes in ad hoc networks. Two new velocity-aware probabilistic models are proposed. They are called Simple Velocity Aware Probabilistic (SVAP), and Advanced Velocity Aware Probabilistic (AVAP). These models are designed to reduce the number of link breakages and to ensure that all selected links are mostly stable.

### 2.2 Link Quality and Energy Aware-based Scheme

Huang et al. (2014)<sup>7</sup> aims to select a stable and reliable route. It lets only the low-mobility nodes to forward the RREQ packet and delays the forwarding according to node's degree of busy (delay of time depends on the communication status of the node and the network density). This technique reduces control overhead, delay time and collision problems. Routing selection is based on residual energy and link stability of the nodes.

### 2.3 Position Aware-based Scheme

Muthusenthil and Murugavalli (2014)<sup>8</sup> proposed a position based routing protocol. It uses the node's position instead of routing based on the conventional topology is proposed. It supposes that the source node has position information of itself, the destination node and its neighbors.

### 2.4 QoS Aware-based Scheme

Cherif et al. (2014)<sup>9</sup> proposed an improvement for Ad hoc On demand Multipath Distance Vector (AOMDV) protocol called Link Quality and MAC-Overhead aware Predictive Preemptive AOMDV (LO-PPAOMDV). This protocol is based on a new metric combine's two routing metrics (MAC Overhead and Link Quality) between every node and next hop neighbor.

### 3. The Main Idea of MDA-AODV

Our proposed scheme is built on top of the conventional AODV protocol. It assumes that all nodes in Ad hoc network enable GPS and they have omnidirectional antennas for connecting each other. Therefore, each node uses the GPS device to get its geographical coordinates. According to the coordinates for every node over the elapsed time, each node can calculate its speed easily.

#### 3.1 HELLO Message Procedure

To meet our requirements, we will modify the HELLO message that is transferred periodically to the neighbors of the node for maintaining the node Routing Table. Two new fields are added to the HELLO message. They are used for broadcasting **the current position and the current speed** of that node. The position contains the node coordinate parameters (longitude, Altitude and height). The height of the node is zero if we consider the terrain of Ad hoc network is a flat area. Once the node broadcasts the message among neighbors, its neighbors will receive the HELLO message and every neighbor will get these parameters used to fill direction flag (*Dir.Flag*) and *Speed of neighbor* fields in its Routing Table. This scenario is repeated in each node in the network.

In Fig. 1, we note that node B has four neighbors (C, D, E and F). Every node of these neighbors will send its current position and its current speed to node B because they are located in the same transmission range for node B. According to the position of neighbors, the *Dir.Flag* field for each neighbor is updated in the Routing Table. The speed field for each neighbor is, as well updated. In such a way, the Routing Table in each node is updated.

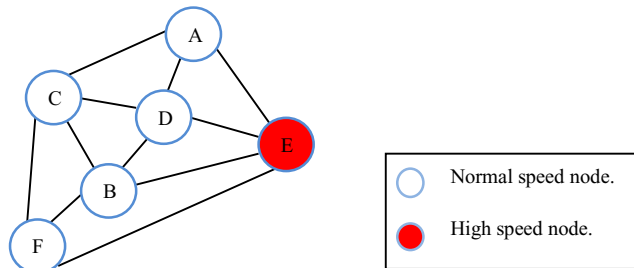


Fig. 1. Ad hoc Network.

Based on the information contained in two successive HELLO messages from a neighbor, using the Euclidian distance formula the node can determine whether the distance between the node and this neighbor is decreasing, increasing or still constant.

According to the results of the above procedure, the distance between the node and its neighbor could be increasing, decreasing or constant. *Dir.Flag* values of 1, -1, 0 are assigned respectively. For example, if the distance between node B and its neighbor node D at time  $t_1$  ( $dist-t_1$ ) is larger than the distance at time  $t_2$  ( $dist-t_2$ ) ( $dist-t_1 > dist-t_2$ ). Therefore, node B concludes that node D is converging towards it. If ( $dist-t_1 < dist-t_2$ ) node D is going away from node B. If ( $dist-t_1 = dist-t_2$ ) so the distance between node B and node D is constant. In the Routing Table for node B (see Table 1) we observe that the last updated speed for node D is 11 m/s and *Dir.Flag* is 1, so node D is diverging from node B with speed equals to 11 m/s.

#### 3.2 Route Discovery Phase

In the AODV routing protocol, the Seen Table consists of *the source-Address* that initiates the request, and the *flooding-ID* for that request. These two fields are used to prevent any intermediate node from rebroadcasting the request if that request came from the same source with the same request ID more than once.

Fig. 2 shows when the intermediate node receives the first RREQ packet. If it does not have an active route to the destination, then a RREQ packet will be forwarded only if its speed is less than a specific threshold. The threshold value is an adaptive value. It is chosen based on the network density and the maximum allowable speed in that network. It should be chosen carefully to resolve the tradeoff between reachability and broadcast storm problem. The proposed scheme utilizes the speed of the nodes to reduce the effects of the broadcast storm problem. MDA-AODV

avoids routing through high speeds to discover more stable routes. In MDA-AODV, the intermediate node will insert in its Seen Table all neighbors (previous hop nodes) through which the request was received, as shown in Fig. 2.

For example, if a RREQ with *Flooding ID* = 0 comes from the source node A to node B as shown in Fig. 1, four possible paths for the RREQ packet may occur ACB, ADB, AEB and ACFB. Node E will not forward RREQ packet because its speed is larger than a threshold value (i.e. 70 m/s, it is estimated by experiment). As a result of that, node B will not receive any request from node E. Therefore, node B can save the reverse paths for this request in *Neighbor.Addr* field. i.e. nodes C, D and F will be stored in its Seen Table, node B has not received a RREQ packet from node E (see Table 2).

Table 1. The Routing Table of Node B

| Destination Address | Next hop | Dir.Flag | Speed of neighbor (m/s) |
|---------------------|----------|----------|-------------------------|
| E                   | E        | -1       | 80                      |
| A                   | D        | -        | -                       |
| D                   | D        | 1        | 11                      |
| C                   | C        | -1       | 4                       |
| F                   | F        | -1       | 25                      |

Table 2. The Seen Table of Node B in MDA-AODV

| Source Addr | Flooding-ID | Neighbor.Addr |
|-------------|-------------|---------------|
| A           | 0           | C             |
| A           | 0           | D             |
| E           | 1           | E             |
| D           | 0           | D             |
| F           | 2           | F             |
| A           | 0           | F             |
| A           | 1           | D             |

```

STEP 1: Extract SourceAddr, Flooding ID from RREQ packet
STEP 2: Search for the same SourceAddr and Flooding ID in the Seen Table
STEP 3: IF SourceAddr and Flooding ID are not matched in the Seen Table THEN
    STEP 3.1: Copy SourceAddr, Flooding ID to the Seen Table
    STEP 3.2: Copy NeighborAddr from which route request appears to the corresponding SourceAddr and Flooding ID
    STEP 3.3: IF speed of the node < threshold THEN
        STEP 3.3.1: Forward RREQ
        ELSE
        STEP 3.3.2: Discard RREQ
        END IF
    END IF
STEP 4: IF SourceAddr and Flooding ID are matched in the Seen Table THEN
    STEP 4.1: Copy NeighborAddr to the corresponding SourceAddr and Flooding ID
    STEP 4.2: Discard RREQ
    END IF
  
```

Fig. 2 Action Taken when a Node has handled The RREQ and Looking for Updating the Seen Table and Forwarding RREQ in MDA-AODV Protocol.

### 3.3 Route Reply Phase

In the AODV protocol, once the request message reaches the intended destination or any intermediate node knows the route toward the destination, it will initiate a RREP packet and forward it through the shortest path regardless of mobility of the intermediate node itself or even the mobility of the neighbor through which the request was received.

Fig. 3 shows how action taken when a node has handled the RREQ and looking for initiating a RREP packet in MDA-AODV protocol. MDA-AODV takes into account the speed of the nodes that the request appears in addition to their directions. This technique will decrease the link breakage, which may be occurred, by preventing high mobility nodes in the route reply process. The average speed is used as a standard to discriminate between low mobility nodes whose speed, located below average speed, and high mobility nodes whose speed above the average speed value.

For example, let node A in Fig. 1 be the source and wants to send data to the destination node F. If we suppose that node B (an intermediate node) has handled the first coming RREQ packet from its neighbor node D, and it has a route toward the destination node F. Therefore, before node B initiates a RREP packet to the source. Firstly, it will check its speed and the speed of node D, the speed of node B (i.e. 32 m/s) and the speed of node D (11 m/s). By looking in the Routing Table for node B we see that the average speed of all its neighbors is  $(80+11+4+25)/4 = 30$  m/s (see table 1). So, the RREP packet will not be initiated because the speed of node B (32 m/s) is more than the average speed of all neighbors of node B (30 m/s).

In contrast to the AODV protocol, the new scheme MDA-AODV protocol does not select the shortest path (the reverse path) from the source to the destination. In MDA-AODV routing protocol, the RREP packet will be **relayed** only to one of the neighbors that the request has come through them. Choosing this neighbor depends on an algorithm that is discussed in Fig 4.

```

STEP 1: Get the speed of NeighborAddr, through which the request was received, from the node Routing Table
STEP 2: Calculate the average speed of all neighbors (Avg) of the node from its Routing Table
STEP 3: IF the node = destination node THEN
    STEP 3.1: IF (speed of NeighborAddr < Avg) THEN
        STEP 3.1.1: Discard RREQ
        STEP 3.1.2: Initiate RREP
    ELSE
        STEP 3.1.3: Discard RREQ
    END IF
ELSE
    STEP 3.2: IF the node = intermediate node has an active route THEN
        STEP 3.2.1: IF (speed of NeighborAddr < Avg AND the speed of the node < Avg) THEN
            STEP 3.2.1.1: Discard RREQ
            STEP 3.2.1.2: Initiate RREP
        ELSE
            STEP 3.2.1.3: Discard RREQ
        END IF
    END IF
END IF

```

Fig. 3 Action Taken when a Node has handled The RREQ and Looking for Initiating RREP in MDA-AODV Protocol.

```

STEP 1: Extract SourceAddr and Flooding ID from RREP packet
STEP 2: Calculate the average speed of all neighbors (Avg) of the node from its Routing Table
STEP 3: Look for the same entry of (SourceAddr and Flooding ID) in the Seen Table of the node
STEP 4: Get the status of all PreviousHops that match the same entry from the node's Routing Table
STEP 4.1: IF # of Constant PreviousHops ≥ 1 THEN
    Select any of them to relay the RREP
STEP 4.2: ELSE IF # of converging PreviousHops ≥ 1 THEN
    STEP 4.2.1: FOR all converging PreviousHops
        STEP 4.2.1.1 IF (Speed of converging PreviousHops < Avg) THEN
            Select the converging PreviousHop that has lower speed to relay the RREP
        END IF
    END FOR
STEP 4.3: ELSE IF # of diverging PreviousHops ≥ 1 THEN
    STEP 4.3.1: FOR all diverging PreviousHops
        STEP 4.3.1.1 IF (Speed of diverging PreviousHops < ½ Avg) THEN
            Select the diverging PreviousHop that has lower speed to relay the RREP
        END IF
    END FOR
STEP 4.4: ELSE
    STEP 4.4.1: Discard RREP
END IF

```

Fig. 4 Action Taken when a Node has handled The RREP Packet in MDA-AODV Protocol.

The format of the RREP packet in the MDA-AODV protocol is upgraded by adding a **Flooding-ID** that used with the **Source-address** to select the best-relayed neighbor as the next hop from the Routing Table (see Fig. 5).

| Source Address | Flooding-ID | Destination Address | Dest.seq# | Life time |
|----------------|-------------|---------------------|-----------|-----------|
|----------------|-------------|---------------------|-----------|-----------|

Fig. 5. The RREP Packet Format.

MDA-AODV's methodology prefers the next hop, which has the least mobility and moves in away close to the sending node as much as possible. Therefore, it will decrease the probability of link breakages by excluding neighbors that are moving away.

For example, let node A in Fig. 1 be the source and wants to send data to the destination node F. Node A will broadcast a RREQ packet with  **Flooding\_ID**  = 0 to its neighbors. Three available paths reach node F are ACF, AEF and ADBF. If node E suffers from high mobility then the MDA-AODV protocol will prevent node E of participating in the route discovery process, so the RREQ request will reach node F just through paths ACF and ADBF.

When node F initiates a RREP packet, node B will handle that packet. By looking in the Seen Table of node B two neighbors in the  **Neighbor.Addr**  field for the same entry [ **Source-Address**  (A) with  **Flooding-ID**  (0)] are C and D neighbors (not including node F because it is the destination in this example). By looking at the Routing Table for node B we see that the average speed for all its neighbors is  $(80+11+4+25)/4 = 30$  m/s. The best neighbor, which node B will select to relay RREP packet, is node C because it is converging with node B and its speed (4 m/s) less than the average speed for all neighbors of node B (30 m/s). When the RREP packet reaches node C, node C will relay RREP directly to the source (node A) because node A locates in the transmission range of node C. If the source does not locate in the transmission range of the intermediate node, the same procedure will be applied for choosing its best neighbor until reaching the source.

#### 4. Simulation Results and Analysis

The simulation is conducted using Qualnet simulator (version 7.1)<sup>10</sup> to simulate and study the behaviors of MDA-AODV scheme. We use the well-known AODV protocol<sup>11</sup> as a reference to prove that MDA-AODV achieves better performance than the original reactive protocols. AODV is chosen as it is a popular protocol in Ad hoc networks, and it has shown better performance results relative to other protocols<sup>12, 13</sup>.

##### 4.1 Simulation Environment Setup

The main scope for this paper is to study the behaviors of the protocols in high dynamic and high offered load environments. Therefore, the packet-rates and the number of CBR connections are varied. Other parameters such as bandwidth, traffic type, data packet size, etc... are constant. To obtain fair results, all protocols are simulated under identical mobility traffic scenarios. Many runs are made with different seeds to change the random simulator parameters. Table 3 summarizes the simulation parameters.

##### 4.2 Performance Metrics

The following are the metrics that are used to evaluate and assess the performance of the simulated routing protocols:

- Packet Delivery Ratio (PDR).
- Routing overhead: it includes RREQ, RREP, RERR and HELLO messages.
- Number of route losses: it indicates that a link broke has occurred.
- Consumed energy: it measures the total energy that is consumed in transmit, receive and idle modes.
- Total end-to-end delay.

Table 3. Simulation Parameters

| Parameter               | Value                     | Parameter              | Value                        |
|-------------------------|---------------------------|------------------------|------------------------------|
| Simulator               | Qualnet (version 7.1)     | Minimum speed          | 0 m/s                        |
| Simulated protocols     | MDA-AODV and AODV         | Maximum speed          | 90 m/s                       |
| Network density         | 30 nodes                  | Pause time             | 0s                           |
| Simulation time         | 300 seconds               | Traffic type           | CBR                          |
| Simulation area         | 1500 X 1500 m             | Data packet size       | 512 byte                     |
| Node placement          | Randomly                  | HELLO interval         | 300 milli-seconds            |
| Radio propagation model | Two-ray ground reflection | Interface queue length | 150000 bytes per priority    |
| Bandwidth               | 2Mbps                     | Radio range            | 340m for 802.11b radio type. |
| Mobility model          | Random waypoint           | Threshold value        | i.e. 80 m/s.                 |

##### 4.3 Packet-rate Simulation

Fig.6 shows different packet-rates 4, 8, 12, 16 and 20 packets/second are applied on 30 mobile nodes. Fig.6 (a) shows that increasing of the packet rates brings less delivery packets because the congestion level is increased. It also takes longer time to transmit and more collisions due to longer data-packet rates. Fig. 6 (a) also shows that MDA-AODV generates more packet delivery ratio and increases it to 46.93% compared to AODV, because MDA-AODV reduces the number of unpredictable link breakages that increase the amount of data packet loss, and it also reduces the overall control overhead that uses large amount of nodes bandwidth. The number of route losses in MDA-AODV is

reduced to 40.43% as shown in Fig.6 (b) because only the stable neighbors are inserted into the routing table as next hop nodes toward the destination.

Fig.6 (c) shows that MDA-AODV generates less control overhead to 5.19% compared with AODV. MDA-AODV decreases the number of RREQ and RREP packets, in opposite of AODV that allows blind broadcasting and floods the network with more RERR messages. Fig.6 (d) shows that MDA-AODV generates less delay to 19.5% compared with AODV, although AODV uses the shortest path to forward data. MDA-AODV reduces the reinitiating of RREQ packets as a result of reducing the route losses. So, the total delay is eventually decreased.

Consumed Energy for MDA-AODV is reduced by 0.342% compared with the AODV. This relate to reducing the number of control packets and frequently routing switch, which in turn leads to preserve the node's energy as shown in Fig. 6 (e). Saving the node's energy leads to prolong the lifetime for each node, it ensures the mobile nodes will still alive as much as possible in MANET networks.

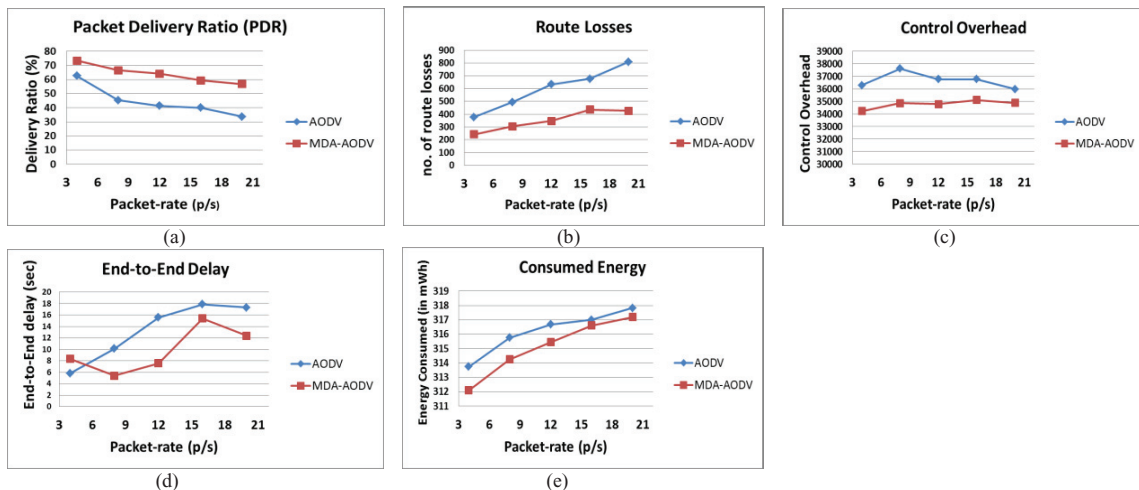


Fig. 6. Packet-rate Simulation Results at 90 mps Maximum Speed and 20 CBR Connections.

#### 4.4 CBR-connections Simulation

Fig.7 shows different number of CBR connections: 20, 25, 30, 35 and 40 are applied on 30 mobile nodes. Fig. 7 (a) illustrates that MDA-AODV scheme enhances the packet delivery to 29% compared with AODV. Because AODV broadcasts large number of routing messages and loses more data packets due to the high mobility nodes that participate in the routing process. Fig. 7 (b and c) shows that MDA-AODV reduces the amount of route losses to 37.4% and the control overhead to 4.63% compared with AODV.

The delay is adversely affected by the route repair procedure, because the data packets are buffered until an alternative route is found. Fig. 7 (d) shows that MDA-AODV outperforms AODV on end-to-end delay with large number of connections on opposite of when the number of connections is few.

Because of increasing the connections, all nodes will suffer from transmitting, receiving and buffering control and data packets. Therefore, this will increase the consumed energy for both protocols. Fig. 7 (e) shows that MDA-AODV outperforms AODV on the consumed energy to 0.36%.

## 5. Conclusions and Future Work

We propose a new Mobility and Direction Aware routing protocol (MDA-AODV) scheme to a decrease the effects of the link breakages by selecting more stable and reliable path between the source/destination pairs. It allows only nodes that their speeds are less than a specific threshold to participate in the route discovery process. In the route reply process, MDA-AODV will select the most stable path from different paths, through which requests were



received. This path excludes high mobility nodes or which are moving away. The new scheme achieves better performance over AODV in terms of reliability and delivery ratio. It also minimizes the control overhead, the consumed energy and end-to-end delay for different network simulations (packet rate and CBR connections simulations).

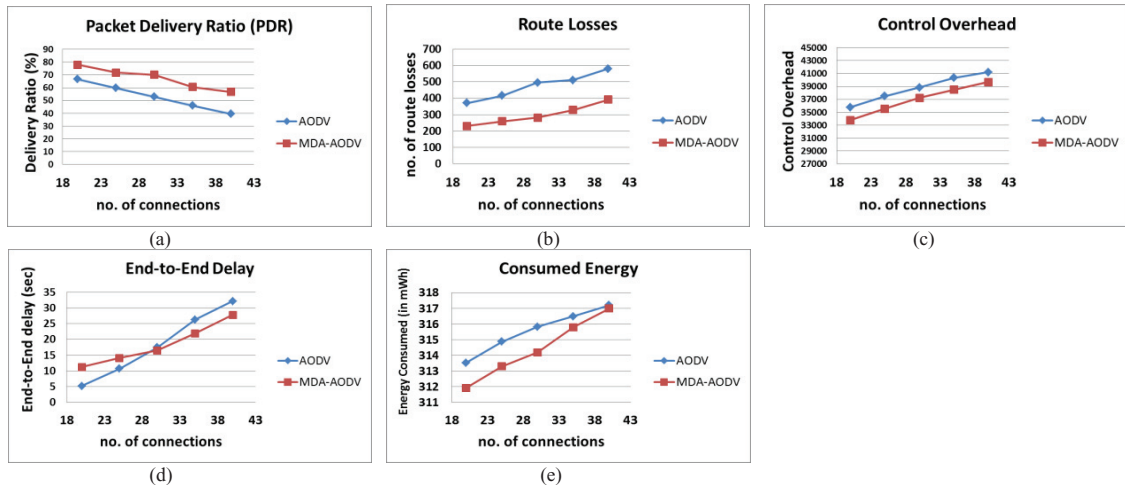


Fig. 7. CBR-connections Simulation Results at 90 mps Maximum Speed and 4 Packets/second.

In the future, we propose including other factors in the decision process such as wireless link quality, remaining power capacity and the routing load. It is recommended to reduce unnecessary HELLO messages by investigating the relationship between the sending HELLO interval time and the node mobility. MDA-AODV depends on low mobility nodes to send data while other high-speed nodes stay on idle mode. So, a maintenance system is recommended for monitoring the routing load and checking if the low mobility nodes are in the congestion state or not.

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