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RESEARCH ARTICLE

EDA-AODV: Energy and Distance Aware “AODV” Routing Protocol

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Abstract – ”Mobile Ad Hoc Network” (MANET) is composed of a set of wireless mobile nodes, it is a self-organized environment which does not need any infrastructure. The topology of this type of network is formed dynamically and the mobility feature of the nodes causes rapid, unpredictable and frequent network topology changes. All nodes in this network are mobile in nature and driven by batteries, that could cause link breakage if a battery of a node goes empty. Rapid topology change and the limited resources in these networks made designing an efficient routing protocol a challenging problem. In this paper, we propose a new route discovery scheme of AODV that reduces routing overhead, prolong route life time, and relatively minimum hop counts. The suggested scheme is called EDA-AODV, where the route is selected using two main metrics: node energy factor and node distance from its transmitting predecessor node. The proposed scheme has been implemented using network simulator (NS2. Ver.2.31). The emulation results indicate that, the performance of EDA-AODV outperforms the original AODV from point of view: throughput, number of alive nodes, normalized routing load and overall hop count.

Index Terms – AODV, Energy aware, EDA-AODV, RREQ and RREP.

1. INTRODUCTION

Wireless networks consist of group of nodes, where radio waves are used as medium to exchange data among nodes [1]. In the last few years, a great attention has been paid to wireless network technologies, these technologies enable users to simply connect a wide range of devices without need to buy, connect and carry cables. The wireless networks provide useful features such as mobility, reduce the installation time and cost. In general the wireless networks can be categorized into two types:

- Infrastructure Networks.
- Infrastructure-less Networks

In infrastructure networks, communication among various devices is administrated using central point called base station, which assigns certain channel for each two communicating devices. This means that, routing mechanism among nodes is carried out by centralized manner. Also, this type of networks is named "centralized networks" [1, 2].

On contrast, in infrastructure-less networks, there is no any type of centralized management, that is mean routing mechanism among devices is implemented by distributed manner [3]. MANET is a type of infrastructure-less networks, where nodes move freely and organize themselves arbitrary. Because of this freely movement of the nodes, network topology changes unpredictably, so the routing is a very challenging problem in this type of networks [4-8].

In general, MANETs have two main categories of routing schemes: proactive and reactive protocols [4]. In proactive protocols (e.g. DSDV) routes to the destinations are predefined and updated frequently. In reactive protocols (e.g. AODV and DSR) route to destination node is established when source node has desire for sending data packets to it (i.e. on demand) [4].

AODV is the most recent and famous reactive protocol. It is multi-hop routing protocol, where the route selection is based on the minimum hop counts. When source node wishes to communicate with unknown destination node, it sets up route discovery scheme by broadcasting “Route Request” packet (RREQ) to all of its neighbors [9]. On receiving the RREQ, if a neighboring node has valid route to destination node, it sends "Route Reply" packet (RREP) to source node. Otherwise, node sets reverse path to source node and rebroadcasts RREQ to all its neighbors. This process is repeated till RREQ reaches the destination node.

Whereas, destination node may receive same RREQ through different paths, RREP is sent by destination node via reverse path of the first received RREQ to source node and drops others. Many references criticize the mechanism of broadcasting process because it increases the probability of collision, routing overhead that reduces link utilization, and the power consumption of the participating nodes [10]. Moreover, route selection based on minimum hop counts as a metric is not sufficient to get energy efficient and stable route. Therefore, the proposed protocol has been presented with the aim to overcome the abovementioned criticizes in such a way that for minimizing the rebroadcasting process as possible and obtain energy efficient and stable route.

The article organization is as follow: Section 2 discusses the related works in routing techniques. The original AODV routing protocol is demonstrated in Section 3. The proposed protocol has been presented in Section 4. Simulation environment and parameters are indicated in Section 5. In Section 6, Simulation results and discussion have been presented. Finally Section 7 concludes the paper.

2. RELATED WORK

In [1], author proposed Distance-Efficient Power Aware routing protocol which modified the route discovery process where only a specific number of nodes on the border are selected to deliver the route request packet [RREQ] to the next neighboring nodes in the direction of destination till the RREQ arrives its destination. The author in the paper solve the problem of stability because when the nodes on the border move they could be outside the transmission range that causes link failure also the author does not show how to know the direction to the destination node.

The author in [11], proposed an effective power conscious routing approach to enhance the overall life time of the network, the results of the new proposed protocol outperforms the DSR results.

In [12], a new vigorous power mindful routing protocol has been designed for path selection depending on the Max- Mini Mechanism where the protocol selects the path of the minimum energy which in turn is the highest energy compared to the minimum energy of other paths.

In [13], the author proposed an energy-efficient secured routing protocol, the route is arisen accordingly after the nodes’ power status is checked in their routing table.

In [14], an approach has been proposed, where the nodes broadcast RREQ based on two metrics, the signal to noise ratio and delay factor. When the destination node receives RREQ, it chooses the path with smallest delay ratio to send the RREP and that increases the efficiency of the network. But the proposed method did not face problem of the power consumption during broadcasting process.

In [15], the author proposes technique based on nodes’ remaining energy. Where, every node adds its staying energy in RREQ packet during broadcasting. And hence, destination node chooses path which has maximum residual energy. The author does not pay any attention for network stability.

In [16], a power conscious routing protocol has been proposed, where the node sends its energy with the RREQ and destination node chooses route with maximum- minimum energy. The drawback of this approach is that all nodes still participate in the broadcasting process which increases the power consumption of nodes. And also the author neither take care the stability of network nor the short path selection to destination node.

3. AODV

AODV is an on demand routing scheme. Where, the route creation process only carried out when a node wishes to connect with another one and there is no route to it. Every node has its own routes table, that includes valid paths to destination nodes (i.e. routes which have life time not expired yet). When route life time to a certain destination node gets expired, the node removes this route from its routing table. Also, destination sequence number is used in AODV to overcome loop problem and assures freshness of the route, where the requesting node chooses the route which has greatest destination sequence number (i.e. the most recent valid route).

When source node needs to exchange data with target node and does not has valid path, source node starts route discovery procedure by broadcasting RREQ to neighboring nodes. When any neighboring node receives the RREQ for first time, it examines the destination address in RREQ, if it matches own address, (i.e. the neighboring node is the destination itself), it replies by RREP to source node. Otherwise, (i.e. the neighboring node is intermediate node), it investigates the routing table, if a right path has been found, it sends RREP to source node. Otherwise, it sets reverse path and rebroadcasts RREQ. If node received same RREQ for second time, the latter one will be neglected. The rebroadcast process will be repeated until RREQ reaches destination node.

Whereas, the same RREQ may arrive to destination node through various paths, destination node will send RREP packet through reverse path of the first received RREQ and ignores the others [17], where it considers the shortest route is path of the first received RREQ.

4. EDA-AODV

Whereas, the route discovery mechanism between any two nodes in standard AODV depends on shortest path (i.e. minimum hop counts). It is easy this short path to be broken, because of limited wireless transmission range, high relative speed among nodes, or the intermediate nodes, along the path, are located on boarder of the transmission range. Moreover, route discovery mechanism of original AODV does not take into account energy level of intermediate nodes along the selected short route.

The suggested EDA-AODV is introduced to enhance performance of standard AODV through modification of route discovery scheme, where route selection depends on two main metrics: node energy factor and node distance from its transmitting predecessor node. Node energy factor has been used as a metric to prolong life time of selected route, while the distance is being used as a metric to obtain stable route with relatively minimum hop counts in addition to minimizing routing control packets. In our EDA-AODV, it is assumed that all nodes have same transmission range (R), initial energy, and are equipped with GPS device to obtain their own (x, y) coordinates. Node energy factor (NEF) is computed from following equations:

$$\mathrm{NEF} = \frac{\mathrm{E_r}}{\mathrm{E_i}} \quad (1)$$

$$\mathrm{E_r} = \mathrm{E_c} - (\mathrm{E_{tx}} + \mathrm{E_{rx}}) \quad (2)$$

Where

E_i : Node initial energy

E_r : Node residual energy

E_c : Node current energy

E_{tx}, E_{rx}: Consumed energy for each transmitted and received data/control packet respectively.

Distance between any two transmitting and receiving node is calculated using the following equation:

$$\mathrm{d} = \sqrt{(\mathrm{X_2} - \mathrm{X_1})^2 + (\mathrm{Y_2} - \mathrm{Y_1})^2} \quad (3)$$

Where (X_1, Y_1) and (X_2, Y_2) are the coordinates of transmitting and receiving node respectively.

To befall our requirements, slight modification will be made for both RREQ and RREP packet format. Two new fields are added to the RREQ packet, these fields are used for broadcasting current position (x, y) of node and recorded energy factor of RREQ packet (RQEF). While, one field is added to RREP packet to indicate the route energy factor (REF).

4.1. Route discovery mechanism of EDA- AODV

The proposed route discovery scheme predisposes to avoid the routes which comprise nodes with low remaining energy for data transmission. Therefore, method of maximum - minimum energy has been used for route choice.

When source node needs to exchange data with destination node and it does not has valid route to this destination, it broadcasts RREQ packet, comprising its coordinates (x, y) and RREQ energy factor (Rq_{EF}) = 2, to neighboring nodes. Upon reception RREQ packet, if the intermediate node has a right route to destination node, it sends RREP packet to source node S. Otherwise, the intermediate node calculates its energy factor (NEF) and its distance from source node using equation 1, 2 respectively, and obeys the following rules:

- In situation of intermediate node does not satisfy condition: $NEF \geq EThr_F$ && $0.5R \leq d \leq 0.7R$, it drops RREQ packet. Where $EThr_F$ is energy threshold factor and R is radio transmission range. Otherwise,
- If $NEF < Rq_{EF}$, the intermediate node updates both Rq_{EF} field with NEF and (x, y) field with its current coordinates, sets reverse path, and rebroadcasts RREQ packet. Else, it updates only (x, y) field with its current coordinates, and rebroadcasts the RREQ packet.

The above rebroadcasting process is repeated till RREQ packet reaches destination node D. In this context, we can saying that, the received RREQ packet at destination node D contains lowest node energy factor through the reverse path between S and D.

Whereas, the same RREQ may arrive to destination node through different paths, destination node waits a time interval T to receive more RREQ packets and then choses the path of maximum Rq_{EF} for sending RREP packet with the route energy factor (REF) to source node. When source node receives RREP packet, it starts sending packets of data through this route to destination node D. the mechanism of route discovery of the proposed EDA- AODV is shown in Figure 1.

5. SIMULATION ENVIRONMENT AND PARAMETERS

The performance evaluation and comparison between the proposed protocol (EDA-AODV) and the original AODV have been implemented using the network simulator NS2 (ver. 2.31) [18]. This simulation system used to mimic a wide range of networks like wire/wireless networks, MANTs and many others. It is an open-source simulator with numerous modules that enables researchers to modify an existing module or add a new one. NS2 uses TCL language for designing the networks [19]. All results of simulation generated in the trace file have been used by AWK command to perform computable data analysis. The used simulation parameters have been presented in Table 1.

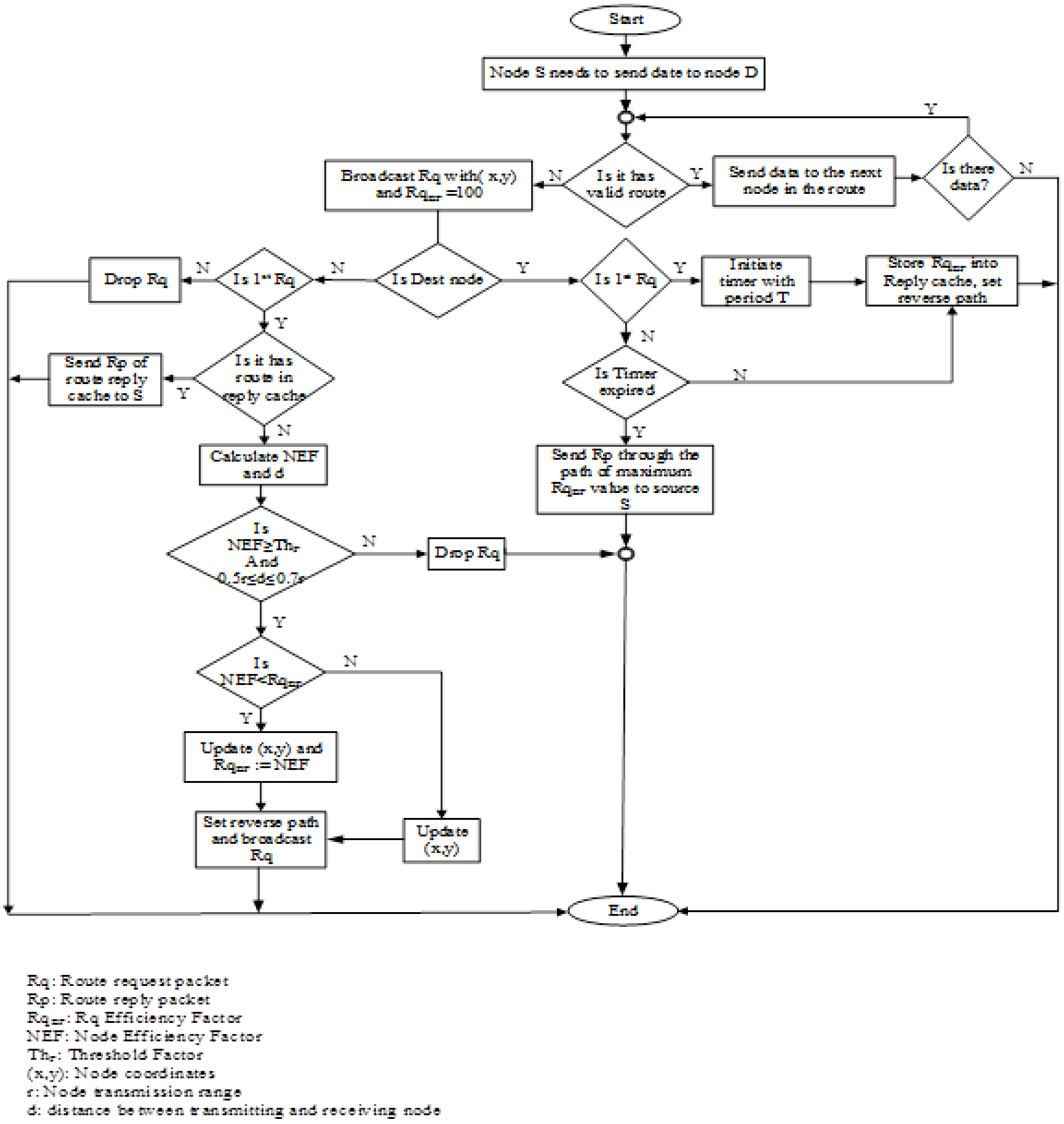

Figure 1. Flowchart of Route Discovery Mechanism of EDA-AODV

Simulation Parameters	Values	Simulation Parameters	Values
Network simulator	NS2 (ver. 2.31)	Channel Type	Wireless
Number of nodes	50	MAC Layer	802.11
Simulation time	500 second	Traffic Type	CBR
Simulation area	400*800 m	Antenna type	Antenna/Omni Antenna
pause time	50-500 s	Radio transmission range (R)	250 m
maximum connections	25, 30, 35, 40, 45, 50	Radio propagation model	Two ray ground
Mobility model	Random waypoint model	Interface queue length	50
Routing protocols	AODV, EDA-AODV	Initial energy of nodes	20 joule

Packets Rate	4 packet/second	Energy threshold factor	10 % of initial energy
Mobility Speed	5 m/s -55 m/s	Transmission energy (E_{tx})	0.6 joule
Packet Size	512 b	Reception energy (E_{rx})	0.3 joule

Table 1: Simulation Parameters

6. SIMULATION RESULTS AND DISCUSSION

This section is concerned with performance evaluation and comparison of the proposed EDA-AODV and the standard AODV, under different scenarios, using metrics of: throughput, number of life nodes, normalized routing load and hop counts.

6.1. Scenario 1

This scenario represents effect of pause time of nodes (i.e. nodes mobility) on performance of the proposed EDA-AODV and AODV in terms of above mentioned criteria, using the parameters of Table 2 and other parameters are same as shown in Table 1.

Simulation Parameter	Value
Number of nodes	50
Simulation time	500sec
Simulation area	800m x 400m
Pause time	0 - 500 sec
Max. mobility speed	5 m/sec
Number of sources	25

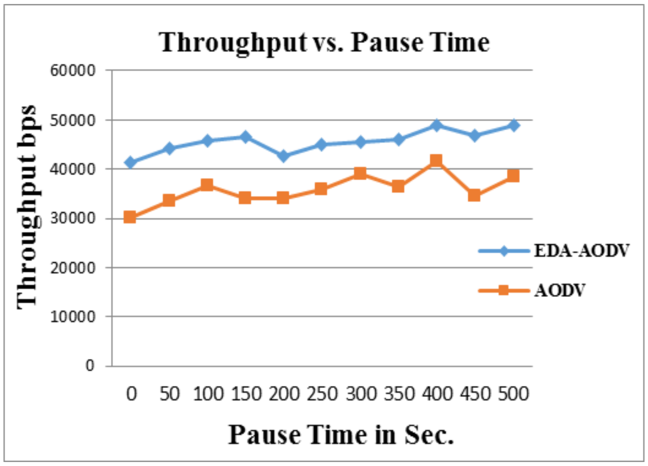

Figure 2 Throughput versus Pause Time

Figure 2 shows throughput against pause time for both the EDA-AODV and AODV. It is obvious that, as the pause time increases, throughput for both protocols increases. This is because, increasing the pause time (i.e. low mobility of nodes) leads to more stability of routes. The throughput of EDA-AODV (45.652 Kbps) is higher than counterpart of AODV (35.851 Kbps), with percentage of enhancement 27%. This is due to, route discovery scheme of EDA- AODV prevents intermediate nodes having low- residual energy and located on the border of the transmission range from participation during the route selection, resulting in route selection consisting of stable and more energy efficient nodes.

The normalized overhead versus pause time for both EDA-AODV and AODV has been illustrated in Figure 3. We note that, with increasing pause time, the normalized overhead for both protocols is decreased. This is because, increasing the pause time (i.e. low mobility of nodes) leads to more stability of routes. Hence, probability to start route discovery process is minimized, resulting in reduction of flooding of RREQ packets. The average normalized overhead of EDA-AODV (0.27) is lower than that one of AODV (1.97), with improved percentage 86%. This is because, probability of initiating route discovery process of EDA-AODV is much lower that of AODV, resulting in reduction of rebroadcasting RREQ packets.

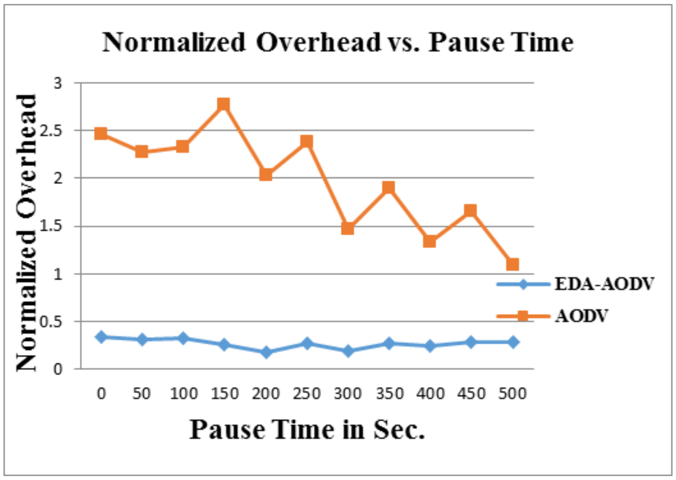

Figure 3 Normalized Overhead versus Pause Time

Number of alive nodes against pause time is presented in Figure 4. It is clear that, as pause time increases, number of alive nodes increases for both protocols. This is because, increasing pause time leads to more stability of network. Hence, decreasing broadcasting of routing packets, which saves nodes' energy. Results indicate that, average number of alive nodes in EDA-AODV (25 node) is higher than its counterpart in AODV (17 node) with enhancement percentage 47%. This is due to, nature of EDA-AODV protocol, which decreases the rate of initiating route discovery process and hence decreasing number of broadcasting RREQ packets, that saves energy of nodes. In addition, destination node choces the route in such a way of avoiding nodes of low energy from participation in route formation.

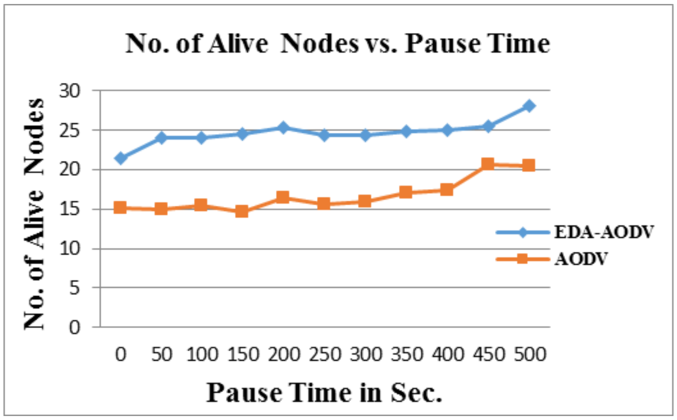

Figure 4 No. of Alive Nodes versus Pause Time

The overall hop count versus pause time has been illustrated in the figure 5. It is clear that, hop count decreases in both protocols with the increase of pause time. The reason is, the network gains more stability with increasing the pause time, that resulting in reducing number of hop count. Results show that, the overall hop count in proposed EDA-AODV (360918 hop) is lower than counterpart in AODV (447457 hop), with improvement ratio 19%. This is because, during route discovery process, only nodes that located in the range 0.5R<d<0.7R will participate in process of route formation to destination node, which means that nodes located close to transmitting predecessor node do not contribute in the route discovery process, resulting in reduction of hop counts to destination node.

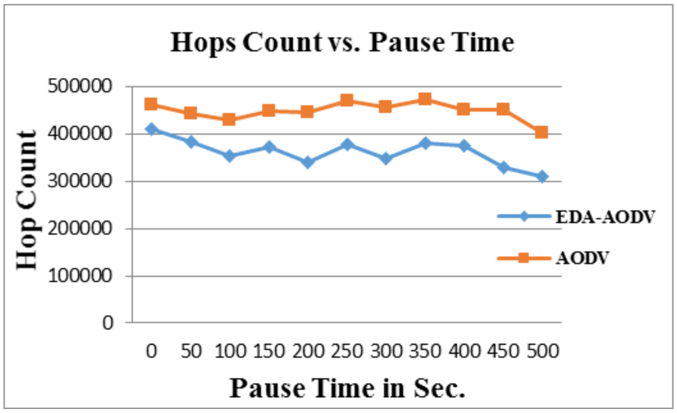

Figure 5 Overall Hops Count versus Pause Time

6.2. Scenario 2

This scenario indicates effect of mobility speed of nodes on performance of the proposed EDA-AODV and AODV from above mentioned criteria point of view, using the parameters of Table 3 and other parameters are same as shown in Table 1.

Simulation Parameter	Value
Number of nodes	50
Simulation time	500sec
Simulation area	800m x 400m
Pause time	15 sec
Max. mobility speed	5 - 55 m/sec
Number of sources	35

Table 3 Network Parameters of 2nd Scenario

Figure 6 presents throughput against nodes' mobility speed for both EDA-AODV and AODV. It is obvious that, as nodes' mobility speed increases, throughput for both protocols decreases. This is due to, increasing nodes' speed leads to increasing probability of route breaking and hence throughput reduction. The results indicate that, average throughput of EDA-AODV (55 Kbps) is higher than counterpart of original AODV (37 Kbps), with enhancement ratio 48%. This is because, the EDA-AODV takes into consideration distance metric, which guarantees link staying, between any two communicating nodes along the route, for relatively long period, even though nodes move with relatively high speed.

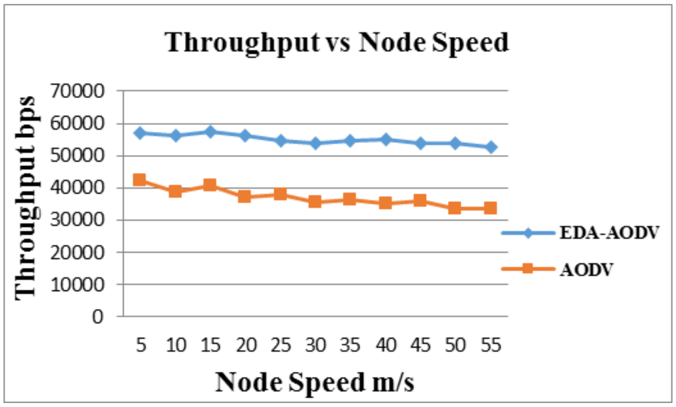

Figure 6 Throughput versus Node Speed

Figure 7 shows normalized overhead against nodes' speed for both EDA-AODV and AODV. It is clear that, as nodes' speed increases, the normalized overhead for both protocols increases. This is because, increasing nodes speed leads to more instability of routes. Hence probability to initiate routes discovery process is increased, resulting in augmentation of flooding of RREQ packets. Average normalized overhead of EDA-AODV (0.59) is lower than counterpart of AODV (3.0), with improvement ratio 80%. This is because, probability of initiating route discovery process of EDA-AODV is much lower than counterpart of AODV, resulting in reduction of rebroadcasting of RREQ packets.

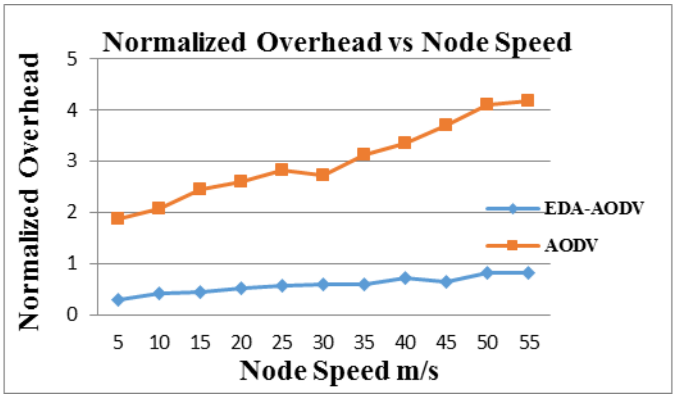

Figure 7 Normalized Overhead versus Node Speed

The number of alive nodes against nodes speed of both AODV and EDA-AODV is presented in figure 8. It is obvious that, number of alive nodes in both protocols decreases with increasing nodes' speed. This because of, increasing nodes' mobility speed leads to high probability of links breakage among the nodes, resulting in more repetitions of route discovery process which in turn increases the energy consumption of nodes due to transmission of control packets. The number of alive nodes in EDA-AODV (18 node) is higher than its counterpart in AODV (10 node), with improvement ratio 80%. This is due to, nature of EDA-AODV protocol, which decreases rate of initiating route discovery operation, hence reducing number of broadcasted RREQ packets, resulting in more saving of nodes' energy and increasing number of alive nodes.

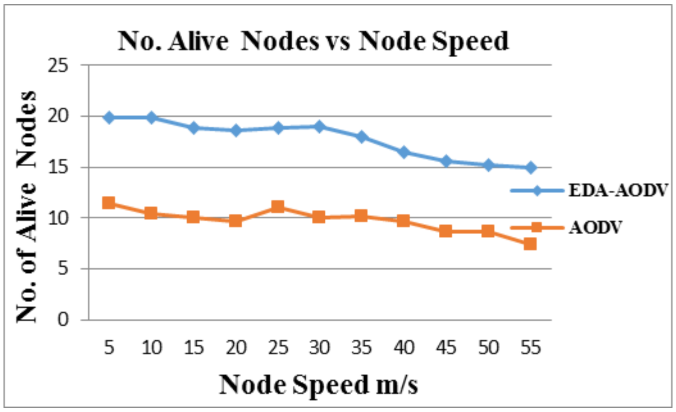

Figure 8 No. of Alive Nodes versus Node Speed

The overall hop count versus nodes' speed is presented in figure 9. It is obvious that, hop count increases in both protocols with increasing nodes' speed. This because of, the instability of network resulting from nodes' high speed. The overall hop count of EDA-AODV (293461hop) is lower than counterpart of AODV (399635 hop), with enhancement ratio 26%. This is due to, during route discovery process, only the nodes located in range 0.5R<d<0.7R will participate in process of route formation to destination node, which means the nodes that located close to transmitting predecessor node do not contribute in the route discovery process, resulting in reduction of hop counts to destination node.

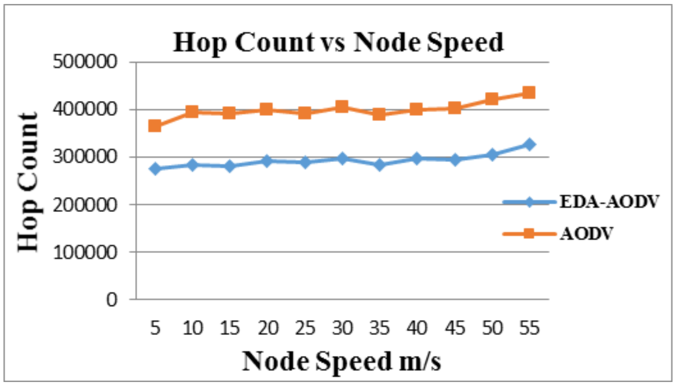

Figure 9 Overall Hop Count versus Node Speed

6.3. Scenario 3:

This scenario illustrates effect of sources connection count on performance of the proposed EDA-AODV and AODV from above mentioned criteria point of view, using the parameters of Table 4 and other parameters are same as shown in Table 1.

Simulation Parameter	Value
Number of nodes	50
Simulation time	500sec
Simulation area	800m x 400m
Pause time	15 sec
Max. mobility speed	15 m/sec
Number of sources	25- 50

Table 4 Network Parameters of 3rd Scenario

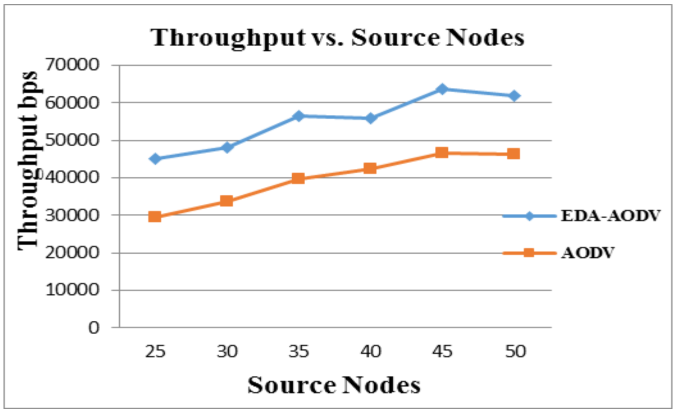

Figure 10 Throughput versus Source Nodes

The throughput versus number of connection has been illustrated in figure 10. We note that, as number of source nodes increases, throughput for both protocols increases. This is because, increasing number of source nodes leads to increase data packets transmission and hence increased throughput. The results show that throughput of the proposed EDA-AODV (55.18 Kbps) is higher than counterpart in AODV (39.69 Kbps), with enhancement ratio 39%. This because of, proposed protocol takes into account metrics of energy and distance that make the network more stable.

Figure 11 presents the normalized overhead against number of source nodes. It is obvious that, as number of source nodes increases, the overhead for both protocols increases. This because of, increase the number of source nodes leads to increase number of broadcasted RREQs in route discovery operation which in turn increases the overhead. The results show that, normalized overhead in EDA-AODV (0.5) is lower than its counterpart in AODV (2.5), with enhancement ratio 66%. This is due to, EDA-AODV takes into account metrics of energy and distance that minimize flooding of RREQ packets.

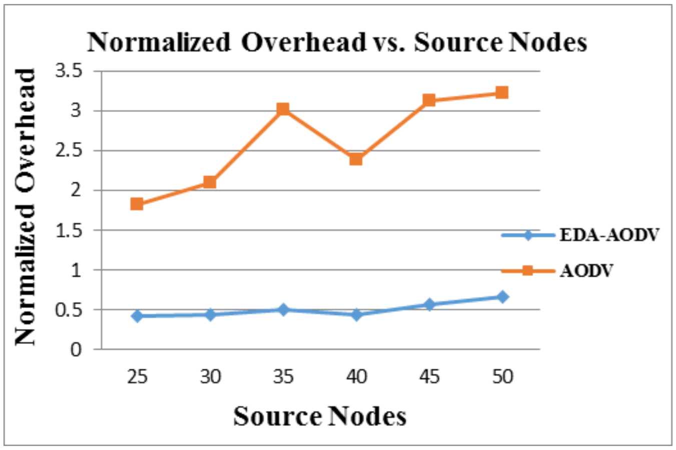

Figure 11 Normalized Overhead versus Source Nodes

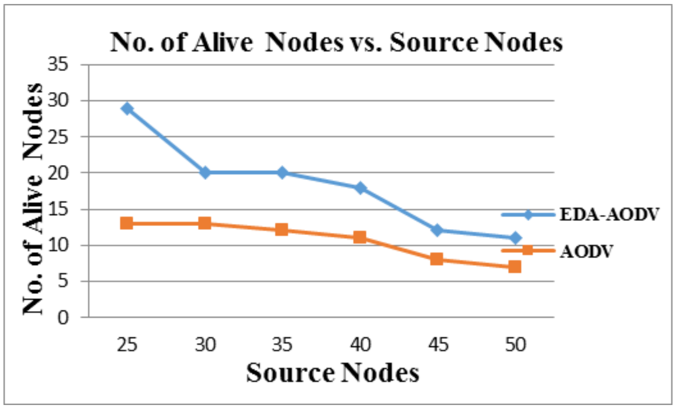

Figure 12 Number of Alive Nodes vs. Source Nodes

Number of alive nodes against number of source nodes has been illustrated in the Figure 12. It is clear that, as number of source nodes increases, number of alive nodes decreases. This is because of, increase of source nodes leads to increase of the transmission and reception of control packets and data packets. This is definitely increases energy consumption of nodes. Hence nodes will be die faster resulting in life time reduction of network. Number of alive nodes of the proposed EDA-AODV (19 node) is higher than its counterpart of AODV (11 node), with enhancement ratio 72%.

In Figure 13, overall hop count versus number of source nodes has been presented. We note that, overall hop count increases with increased number of source nodes, where increasing number of source nodes means many of packets will be transmitted, so the overall hop count will increase. It is lucid that, the overall hop count of EDA-AODV (293461hop) is lower than the overall hop count of AODV (399635 hop), with enhancement ratio 26%. This is because, during route discovery process, only nodes located in the range 0.5R<d<0.7R will participate in process of route formation to destination node, which means the nodes that located close to the transmitting predecessor node do not contribute in route discovery process, resulting in reduction of hop counts to destination node.

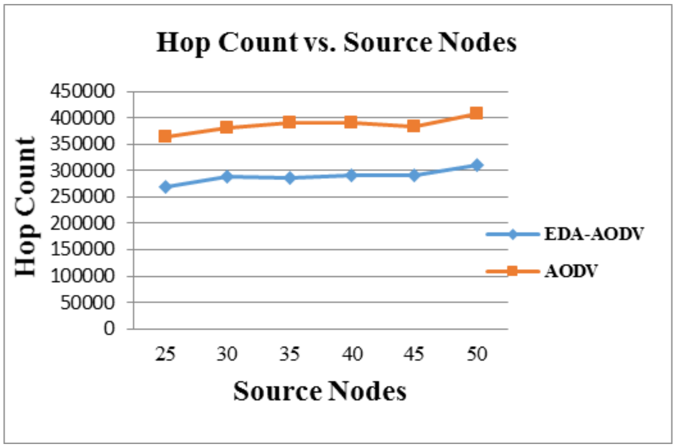

Figure 13 Overall Hop Count versus Source Nodes

7. CONCLUSION

This article presents a new version of standard AODV, named EDA-AODV. Where, the proposed article concerned with modification of route discovery mechanism of the standard AODV, with the aim to obtain a stable route with high energy of nodes, relatively minimum hop count and minimizing flooding of RREQ packets. To realize our aim, the route has been selected based on two combined metrics: energy of nodes and the distance between any two successive nodes. The simulation results proved that the performance of EDA-AODV outperforms the original AODV in respect to:

throughput, normalized overhead, number of alive nodes, and overall hop count.

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