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Original Article

Performance Evaluation of Parameters in Enhanced Adhoc on Demand Multipath Distance Vector (EAOMDV) Routing

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Abstract - *Efficient energy utilization is a critical challenge in MANETs due to limited battery resources and dynamic topology. Multipath routing technologies have emerged as effective solutions for addressing energy consumption challenges, enhancing network performance, and improving fault tolerance. In MANETs, nodes communicate wirelessly without dedicated paths, relying on routing methods to discover the most efficient routes for packet transmission. This paper introduces an energy-efficient multipath routing protocol supported by a MANET optimization algorithm, focusing on three key routing protocols: Adhoc On-Demand Distance Vector (AODV), Ad hoc On-Demand Multipath Distance Vector (AOMDV), and Enhanced AOMDV (EAOMDV). AODV serves as a baseline for single-path routing, while AOMDV provides multipath capabilities to reduce latency and improve reliability. EAOMDV further optimizes AOMDV by integrating energy-aware mechanisms to reduce power consumption. This paper evaluates the protocols across metrics such as energy consumption, end-to-end delay, packet delivery ratio, and packet delay time through simulation-based experimentation. Results demonstrate that multipath routing, particularly EAOMDV, significantly reduces energy consumption, increasing network lifetime compared to AODV and AOMDV.*

Keywords - *MANET, AODV, AOMDV, EAOMDV routing protocols, Energy Consumption and Throughput.*

1. Introduction

In a wireless ad hoc network, a collection of mobile hosts forms a transient arrangement of nodes rather than following a predetermined plan or reporting to an authoritative body. Even though there are a lot of nodes in the network, they may be organized into clusters, and all the resources can be used efficiently [1]. The transmission power determines the coverage region, which mobile members of a cluster are often positioned inside.

The widespread availability of low-cost wireless networking gear and the lightning-fast development of mobile device technologies like laptops and portable computers have sparked a surge in interest in wireless connectivity among mobile users [2]. Mobile Ad Hoc Networks (MANETs) are one way to offer wireless connection [3]. The ability to handle wireless multi-hop routing has been the primary focus of ad hoc routing technologies. Main research challenges arise from the fact that wireless links often have less capacity than cable links and that the routing systems of MANET have different load balancing capabilities [4]. Overloading the network leads to congestion, which in turn causes packet loss and dropping. Ad hoc wireless networks shine with their adaptability and special advantages for certain settings and uses. Fixed infrastructure and existing base stations are not required [5].

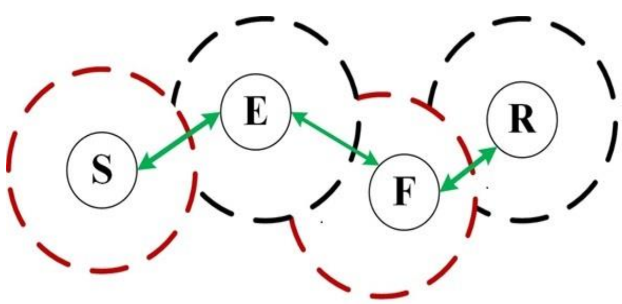

Fig. 1 Example of MANET

This creates a shared environment where energy is wasted. Ad-hoc networks rely on multi-hop communication. The majority of researchers alluded to Enhanced Ad-Hoc on Demand Multipath Distance Vector (EAOMDV) as a future solution for improving the AOMDV protocol [6]. So, EAOMDV was chosen as the protocol to compare its performance with AOMDV. This provides a comparison of two experimental settings, one with varied simulation time and the other with varying node counts for 512 packet sizes [7].

2. Ad-Hoc On-Demand Multipath Distance Vector (AOMDV)

One protocol that has been modified from the original AODV is the AOMDV, which stands for Ad-Hoc On-Demand Multipath Distance Vector. Another reactive routing technique that borrows features from proactive ones is AOMDV. As they are required, routes are created dynamically [8]. On the other hand, once a route is set up, it is kept up for as long as it remains necessary or until it fails. In reactive routing protocols, a path is only found between the source and the destination when the path is needed, meaning data needs to be sent between the two locations. Unless a link is required, the AOMDV network remains silent [9].

The node in the network that is in need of a connection will then broadcast a request for one. Another AOMDV node, which is also a recorder, relays the message to the node that needs it after hearing it from the explosion of temporary links. Upon receiving such a message, a node that is already connected to the intended node might reverse the process by sending a message backwards via a temporary route to the node that originally requested it. Next, the node in need starts taking the path with the fewest intermediate stops [10]. The AOMDV protocol's quality and property is that, in the event of a link failure, the transmitting node receives a routing error message and, in response, the source node selects the alternate route stored in the nodes' memory [11].

Nodes that need network connections publish requests. Other AOMDV nodes transmit this message and record the sender, producing a flood of temporary routes to the needed node. A node that already has a route to the requested node sends a message backwards through a temporary route to the asking node. The needy node uses the route with the fewest hops through other nodes. When a link fails, a transmitting node receives a routing error, and the source node chooses the alternative saved path in its memory to forward packets.

We compare AODV and AOMDV protocols. Simulations are done in NS3[12]. Practically, protocols have been tested on ad-hoc networks. Various scenarios are made. Different nodes create contexts to analyze protocols. Node movement should also be addressed when analyzing the protocol [13-15].

To its immediate neighbors A, B, and E, node S broadcasts an RREQ. And then A, B, and E communicate with their neighbors G, C, and E by sending RREQ. But this time it will send an RREQ to F and D. We call the first sequence S-E-D. Packets will be sent down this path since it is the shortest. The second path, S-B-C-D, will be used if any of these fail. If it does not work either, it continues down the list of alternatives S-A-G-F-D. Figure 3 describes the circumstances described above.

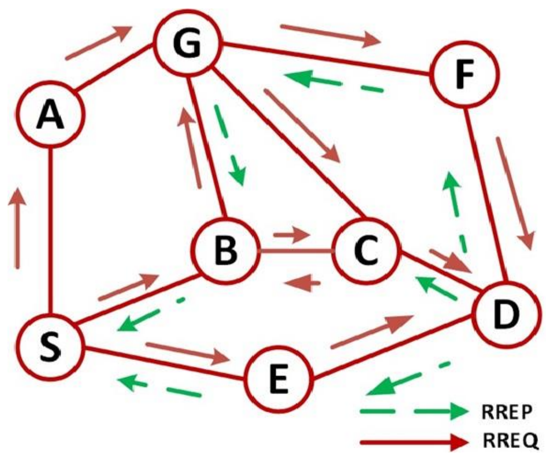

Fig. 2 AOMDV routing protocol

3. Enhanced AOMDV (EAOMDV)

Many routes can still pass through the same node while using AOMDV because it uses the link-disjoint routing discovery and management technique. Transmission delays increase as a node's limited resources are rapidly depleted when multiple paths pass through it. This could lead to the failure of some of the node's associated links, which could negatively affect the network's performance. Consequently, to improve the functionality of Ad hoc networks, we need to lessen the frequency of heavy-load-related link failures.

In the original AOMDV, we induce a precautionary method of route overlap to prevent link failures caused by the heavy burden of nodes. The following is a detailed demonstration of the precaution algorithm. We find the total number of packets that node $_i$ received between time 0 and time t, and call it Nt. The number of packets received by node $_i$ at regular intervals (Δt) is also measured and denoted as Nt. So, from 0 to t, the average amount of packets received by node $_i$ is:

$$\bar{E} = Nt/t \tag{1}$$

At intervals of Δt, the node$_i$ typically receives an average of:

$$\bar{E}\Delta t = N\Delta t / \Delta t \tag{2}$$

If the average value of E is less than $2E_{\Delta t}$, then the level of precaution is considered low; otherwise, it is high. We presume that node$_i$'s burden is fairly small when the precaution level is low. Under these conditions, node$_i$ does not disrupt the current conversation. So that it does not get much busier with more routes going through it, $node_i$ refuses the new RREQ. In this manner, the present data flow could continue uninterrupted, and the load on $node_i$ could be managed. If the precaution level is set to high, it indicates that $node_i$ is under a tremendous amount of load and that transmission delays may be substantial due to the node. This means other nodes can reasonably take on some transmitting workload. In order to lighten its load, $node_i$ rejects RREQ packets and then indicates a route switch to its upstream peers with RERR packets.

Once the upstream nodes receive the RERR from $node_i$, they compare D $E_{\Delta t}$ - E to 0. If D is more than 0, the upstream node will look up a different route in its routing database, switch to it, and then deduct D by 1. On the other hand, if D is equal to 0, the upstream nodes will just discard the RERR packet since other nodes have reduced the number of routes that pass through $node_i$. The precaution mechanism can alleviate both the transmitting latency and routing control overhead by reducing the overlap of the routing method.

Furthermore, the Enhanced AOMDV (EAOMDV) protocol enhances the QoS performance of the Ad hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol by supplementing its routing capabilities. The following steps demonstrate the proposed routing scheme to find the optimal route at the intermediate and destination nodes in the EAOMDV routing protocol, while Figure 3 demonstrates the flowchart of the proposed EAOMDV routing protocol.

3.1. Receiving RREQ Packet at the Intermediate Nodes

Step : 1 Once the network is initialized, node S forwards the data packets to a particular node D It verifies whether it has a route to node D in its routing table. If a path is identified, it sends the data through the route.

Step : 2 Node S promotes an RREQ packet and forwards it to all its neighbor nodes if node S does not have a valid route to node D in the routing table.

Step : 3 All the neighbouring nodes receive an RREQ packet from node S.

Step : 4 An RREQ packet is received by the node S, corresponding to its first time, then it produces a reverse path towards the node S in its routing table. Then, the creation of a reverse path is needed for transmitting the RREQ packets from node D to node S.

Step : 5 The nodes' Remaining Lifetime of Link (RLTl) is calculated, and regularised the RLTl value is regularised.

Step : 6 The coming RREQ packet is dropped if the RREQ packet is likely not the first, or the Route Duration Time (RDT) value is not shorter than the existing route duration time received earlier in the routing table.

3.2. Route Selection at the Destination Node

In the traditional AODV routing protocol, when the node D receives the initial RREQ packet, it generates the Route Reply (RREP) packet and forwards it back to node S and tears other RREQ packets that are received later due to its shortest path construction behavior.

In the proposed routing selection process, when the initial RREQ packet is collected by node D, it does not return the RREP packet. The procedure below is implemented at node D:

Step : 1 By noticing the node S ID and RREQ ID in the routing table, node D will examine whether or not the RREQ packet will appear for the first time.

Step : 2 If it is the first time, it calculates the Route Stability Factor (RSF) and the value is saved in the routing table. Then, node D has to wait for a small amount of time $\Delta\tau$ to collect additional RREQ packets, if any.

Step : 3 node D examines its waiting time $\Delta\tau$, if it is not the first time.

Step : 4 The algorithm calculates RSF for the appeared RREQ packet, if the waiting time for the collected RREQ packet is not decreased and makes a contrast with the RSF value that has been saved earlier in the routing table.

If the RSF value of the newly arrived RREQ packet at node D is higher than the RSF value available in the routing table, then node D updates the routing table entry with the arrived copy of the RREQ packet. Otherwise, the arrived RREQ packet is ignored.

Step : 5 Step 4 is repeated if the node D receives further RREQ packets before the waiting time $\Delta\tau$ expires.

Step :6 If the waiting time expires, node D produces and forwards a RREP packet back to node S. As a result, depending on the highest RSF value, node D selects the optimal route.

Step : 7 When the RREP packet is received by node S, it starts sending data packets through that route to node D.

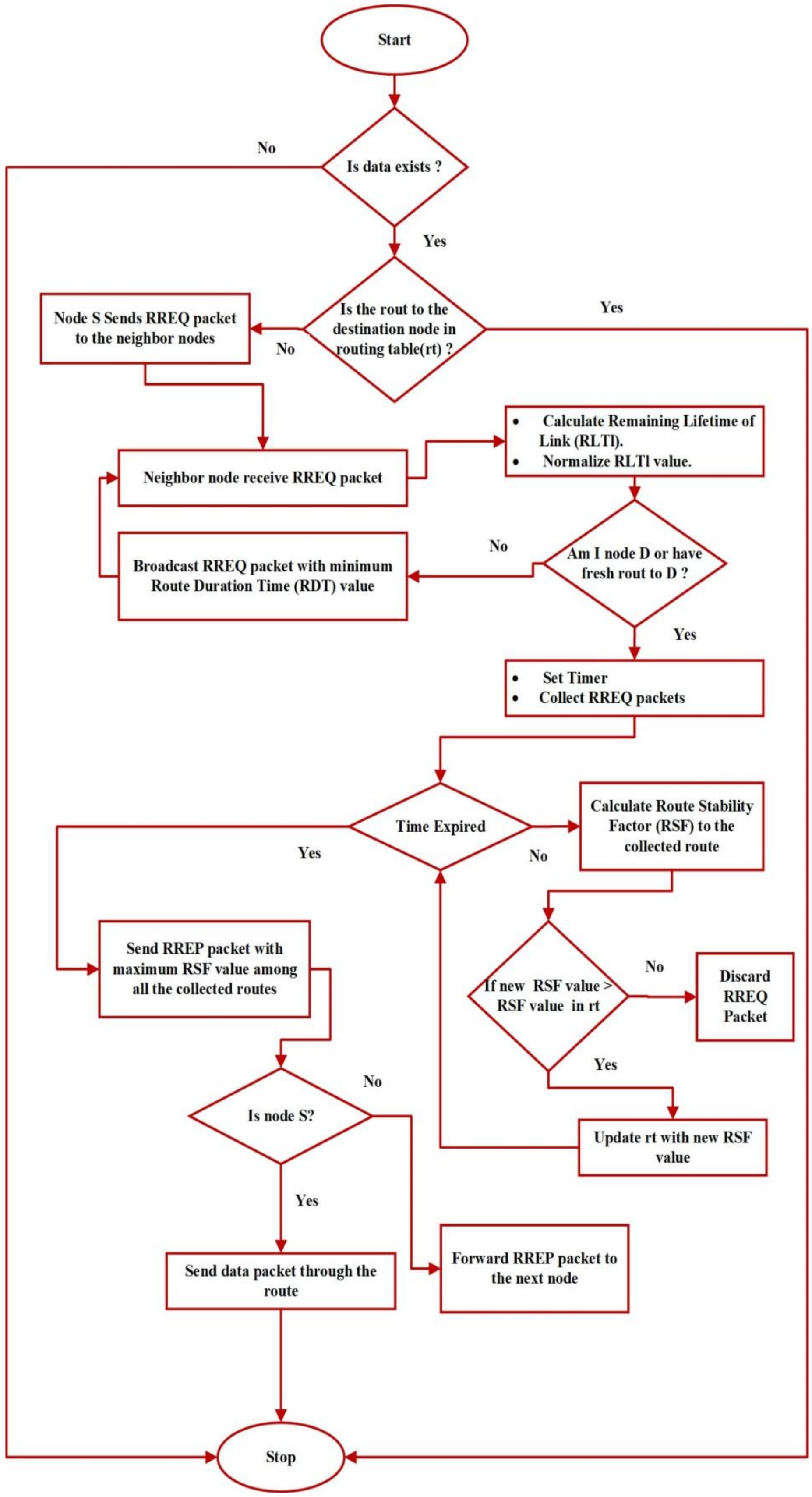

Fig. 3 Flowchart of EAOMDV

4. Energy Consumed

4.1. Total Energy Consumed by all Nodes (TE)

Energy consumption is calculated as follows:

The time needed for transmitting a data packet is

$$Time = 8\,x\,(p_{size}/BW) \quad (3)$$

Therefore, we have:

$$E_{ti} = P_{ti} \times Time \quad (4)$$

$$E_{ri} = P_{ri} \times Time \quad (5)$$

$$E_{ldi} = P_{ldi} \times Time \quad (6)$$

Using a transition time (tt), the following is the transition power mode:

$$Etpi = Ptpi \times Time(tt) \quad (7)$$

In this context, E_{ti} denotes the energy consumption of $node_i$ in the transmission power mode, Eri denotes the consumption of $node_i$ in the reception power mode, E_{Idi} denotes the consumption of $node_i$ in the idle mode, Esi denotes the consumption of $node_i$ in the sleeping mode, and E_{tpi} denotes the consumption of $node_i$ in the transition power mode with Transition Time (tt), which is utilized for passing from sleep to idle [16, 17]. A node's total energy consumption is determined by:

$$\text{Total } E_i = E_{ti} + E_{ri} + E_{ldi} + E_{st} + E_t \quad (8)$$

The Total Energy utilized (TE) by all nodes (N) is:

$$\text{TE}= \sum_{i=0}^{N} TotalEi \quad (9)$$

4.1.1. Average Utilized Energy (AUE)

This term describes a node's total energy consumption (TE) divided by the total number of nodes (N).

$$AUE = TE/N \quad (10)$$

4.1.2. Average Residual Energy (ARE)

The formula for it is the number of nodes (N) divided by the difference between their Total Energy consumption (TE) and their total energy input (IE) [18].

$$\text{ARE} = \frac{\sum_{i=0}^{N} \text{IE} - \sum_{i=0}^{N} \text{TE}}{\text{N}} \quad (11)$$

Some simulation metrics that can be used to evaluate the performance of AODV, AOMDV and EAOMDV include end-to-end delay, packet delivery ratio, Throughput, and missed packets. Below, you can find a summary of the results together with the relevant graphs.

4.2. Packet Delivery Ratio (PDR)

The packet-to-source ratio measures the amount of data sent and received at a certain point in time. The network's maximum Throughput is constrained by the packet loss rate [19]. The protocol's capability to transmit data packets is measured by the packet delivery ratio. The ratio of packet delivery is calculated using.

$$\text{PDR} = P_r / P_s$$

In this case, P_r represents the received packet count while P_s stands for the sent packet count.

4.3. Packet Delay Time

Average End-to-End Delay measures how long data packets delivered from a source take to reach their destination [20]. The total amount of time spent on buffering, interface queuing, retransmission, MAC execution, and propagation is known as the Average End-to-End latency. The efficiency improves as the delay time decreases.

4.4. Throughput Rate [kbps] (TR)

This metric indicates the total size of received packets that were successfully reached per unit of time.

Table 1. Parameters for performing the simulation

Parameters	Value
Simulator	NS-3 (version 3.29)
Simulation time	100 (s)
Number of nodes	10,20,30,40,50
Routing protocol	AODV, AOMDV, EAOMDV
Traffic rate	Constant bit rate
Packet size	512 bytes
Initial node energy	50J
Minimum speed	0 m/s
Maximum speed	50 m/s
Transmission range	250m
Pause time	10 s

The performance of the enhanced AOMDV is tested by simulation in the following section of the paper.

5. Results and Discussions

In wireless ad-hoc systems, the performance of routing protocols is crucial, particularly as the network size expands. Due to their dynamic routing capabilities, the AODV, AOMDV, and Enhanced AOMDV protocols are prominently utilized in Mobile Ad hoc Networks (MANETs). However, their performance exhibits significant variation in the node density. This study aims to analyse and compare these protocols under varying node densities, evaluating their efficiency in terms of Packet Delivery Ratio (PDR), end-to-end delay, Throughput, Energy consumption, and Packet

Delay Time. Through the simulation, this research seeks to determine the adaptability of these protocols to increasing node counts and their overall suitability for dense and large-scale network environments. The overall amount of energy used by every node in each case is displayed in the Figure 4. The results showed that EAOMDV used less power than AODV; this could be because, as a single-path protocol, AODV only needed power to reach its destination once. The average percentage of energy spent by each node is represented by the term average energy consumption. With an increase in the number of nodes, the EAOMDV utilized more energy, as seen in the Figure 4.

Table 2. Comparison table for energy consumed with AODV, AOMDV, EAOMDV

No. of Nodes	AODV	AOMDV	EAOMDV
10	50.34	48.89	45.52
20	58.98	57.45	52.23
30	62.31	62.02	61.23
40	68.83	68.25	64.22
50	74.92	74.54	67.34

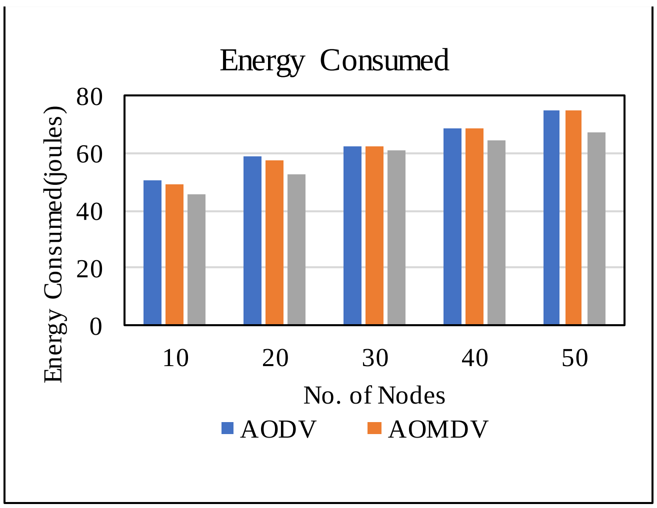

Fig. 4 Total energy consumed by the nodes

In Figure 4 It can observe the comparison that is shown around energy use. At 40 nodes, the processes AODV and AOMDV use 68.83 and 68.25 Joules of energy, respectively. According to the findings, the EAOMDV technique offers the best and most efficient way for ad hoc networks to transmit data.

Table 3. Comparison table for packet delivery ratio

No. of Nodes	AODV	AOMDV	EAOMDV
10	79.23	79.88	82.26
20	79.56	81.25	83.28
30	79.65	83.26	84.69
40	79.78	84.52	85.36
50	79.91	84.72	86.45

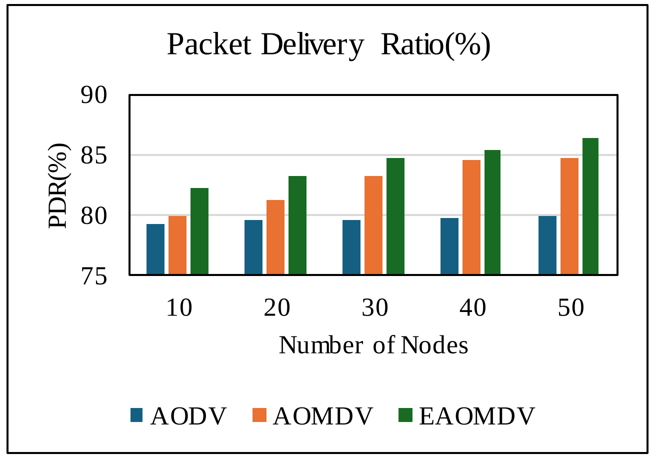

Fig. 5 Comparison of packet delivery ratio

Figure 5 demonstrates the packet delivery ratio of three routing protocols, in which the proposed EAOMDV gradually increases when compared to the other routing protocols. The EAOMDV protocol improves the PDR ratio by 2% as the number of nodes increases. The EAOMDV routing protocol chooses an optimal route to forward its packet to the destination with the help of the Route stability factor.

Table 4. Comparison table for packet delay time

No. of Nodes	AODV	AOMDV	EAOMDV
10	0.1425	0.1356	0.1251
20	0.1432	0.1368	0.1225
30	0.1442	0.1373	0.1223
40	0.1456	0.1382	0.1258
50	0.1467	0.1395	0.1287

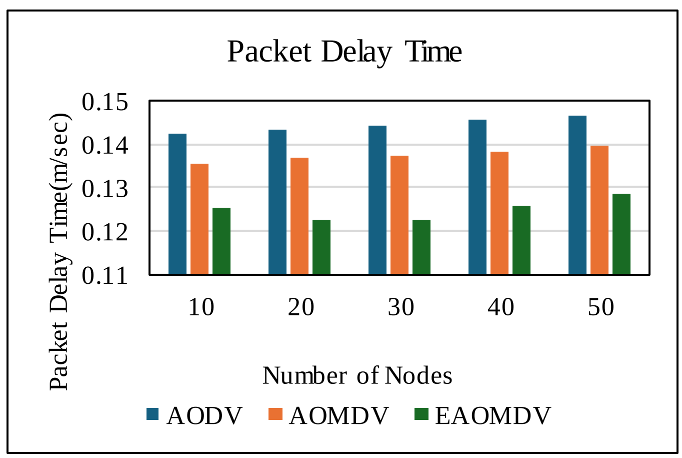

Fig. 6 Comparison of packet delay time

Figure 6 displays the relationship between the number of nodes and the network Packet Delay time of AODV, AOMDV, and EAOMDV. The results showed that EAOMDV had a lower Packet Delay time.

Table 5. Comparison table for throughput

No. of Nodes	AODV	AOMDV	EAOMDV
10	356.23	369.25	402.55
20	365.24	389.25	402.36
30	385.26	398.20	400.55
40	388.56	399.02	400.58
50	392.67	400.35	400.82

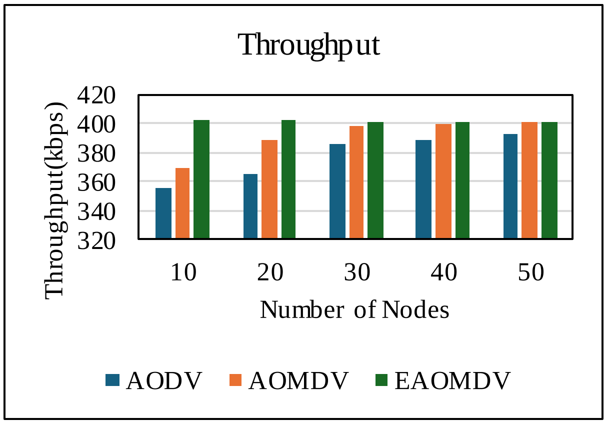

Fig. 7 Comparison of throughput for the nodes

Figure 7 displays the relationship between the number of nodes and the network throughput rate of AODV, AOMDV, and EAOMDV. The results showed that EAOMDV had a high throughput rate. The EAOMDV throughput was positively correlated with the number of nodes and negatively correlated with the decrease.

The average end-to-end delay of AODV, a single-path routing protocol, is greater than that of multipath protocols. Figure 8 demonstrates that AOMDV has a higher delay with increasing nodes and connections, while EAOMDV has a lower delay. Because of its design, the EAOMDV protocol can find backup pathways in the event that the primary one becomes unavailable without retracing its steps, saving valuable processing time.

Table 6. Comparison table for end-to-end delay

No. of Nodes	AODV	AOMDV	EAOMDV
10	0.12	0.11	0.105
20	0.14	0.12	0.10
30	0.1	0.15	0.12
40	0.3	0.2	0.18
50	0.8	0.6	0.52

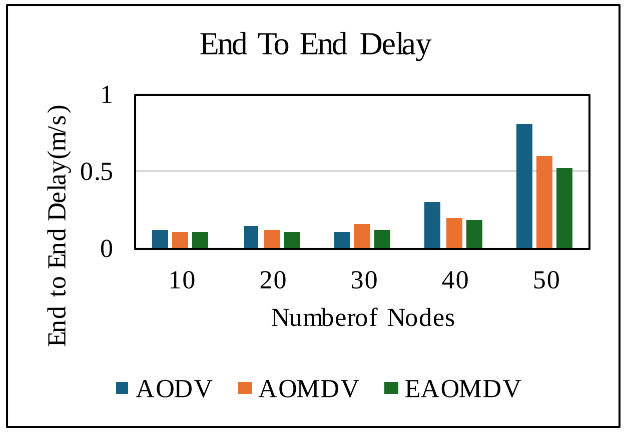

Fig. 8 Comparison of end-to-end delay

Table 7. Performance comparison of the EAOMDV with AOMDV

Metrics	% of Increase or Decrease
Energy Consumed	Decreased by 7%
Packet Delivery Ratio	Increased by 2%
Packet Delay Time	Decreased by 10%
Throughput	Increased by 3%
End-to-End Delay	Decreased by 12%

6. Conclusion

This paper examined the success of three routing protocols, AODV, AOMDV, and EAOMDV, in MANETs. Mobile ad-hoc network methods do not get enough attention when it comes to how much energy they use. Also, it is important to look into how much energy known protocols are used in MANETs for future research projects. Most of the studies focused on performance parameters that were based on standard performance measurements. The results of this study show that the energy consumption of the EAOMDV is decreased by 7% compared to standard AOMDV.

Similarly, the PDR was increased by 2% compared to AOMDV, and the packet delay time was reduced by 10% when compared to AOMDV. The NS3 simulator has been used for a lot of simulations. After doing some studies, it was found that EAOMDV works better than AOMDV when it comes to packet delivery ratio, packet delay time, end-to-end delay, and energy consumption. As a further enhancement, combining machine learning models for dynamic path evaluation and selection has been proposed to reorganise the changing network topologies.

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