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PEO-AODV: Preserving Energy Optimization Based on Modified AODV Routing Protocol for MANET

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Abstract

Mobile Ad hoc Networks (MANETs) is a popular wireless technology that employs mobile devices to communicate directly with one another for data transmission through intermediate nodes without fixed infrastructure support and non-centralized administration. MANET is susceptible to high energy consumption and link breakage because of node mobility and communication. To mitigate the energy problem. Preserving Energy Optimization (PEO-AODV) is proposed by modifying the standard AODV routing protocol to take the best energy efficient into consideration by determines the minimum hop count in the route and uses geographical position field that can be exchanged using the hello packet. These modifications will increase the routing accuracy and network lifetime, minimize route failures and link breakage between mobile nodes, and decrease energy consumption. The modified algorithm (PEO-AODV) has been simulated using the NS-2.35 network simulator. A range of metrics has been considered for performance evaluation of the modified protocol, including energy consumption, route losses, control overhead, end-to-end delay, and packet delivery ratio. The simulation results show that the (PEO-AODV) proposed algorithm outperforms the conventional AODV under all proposed metrics. Moreover, PEO-AODV saves more than 20% of the consumed energy in conventional AODV.

Keywords: *AODV, Ad-Hoc, Network Lifetime, Energy Consumption.*

1 INTRODUCTION

The fast development and growth of wireless network technology reveals the need for ad-hoc networks that emerged in many applications. MANET consists of several mobile nodes (MN) that cooperate to form a wireless network, those nodes communicate within a specific radio range without centralized control [1]. The (MN) in MANET can communicate directly with one another within a limited wireless transmission range. Thus, the mobile nodes willact as a host and router at the same time to send the packet over multiple hops to reach itsappropriate destination [2], [3].

MANET has a dynamic movement, where node can explicitly join or leave the network, causing rapid and unpredictable network topology changes, which lead to link breakage between nodes and route loss. The nodes mobility raises the issue of node battery drain or energy consumption, where all mobile nodes have limited energy resources [4]. The earliest approaches resolve the problem focused on techniques that aim to improving energy conservation and efficiency so as to minimize the energy consumption of the sensors and increase the network lifetime. Another approach uses wireless charger to recharge mobile nodes in the field [5]. Although various algorithms have been proposed to reduce the energy consumption (EC) in MANET, but they still suffering from a unified solution, in that the drain of battery power will limit the communication capabilities of the nodes [6]. Therefore, energy efficient communication is critical of MANET and for design criteria of optimization energy conservation. AODV is essential reactive routing protocol of wireless networks that can construct the route from the origin to the destination and maintain the route during the network's lifetime to achieve specific tasks. AODV has several advantages such as no central administration is required to manage and control traffic messages to keep traffic messages to a minimum, but this results in increased delay in finding a new route [7], [8].

Mobile nodes (MN) in Ad-Hoc network are limited batteries power. Those batteries get depleted with every reception, transmission, and processing of packets. The intermediate nodes consume more energy in transmission when the packet travel through several number of hops, especially if the packet travel over long distance. Thus, to maximize the network lifetime, each node has to regulate its transmission power to reduce the link breakagecases that occurs because of the dead nodes [9], [10]. In addition, when the nodes lose their energy, they will lose their connection with other nodes and decrease the network's lifetime, which will affect the performance and the capability of the network communications [11].

The high traffic with free movement of nodes and multi-hop wireless transmission will increase the power consumption for battery-powered mobile devices [12]. The essential goals of mobile ad-hoc networks are to reduce consumed energy, which plays a vital role in existing research works. MANET runs battery-powered [13]. Thus, the level of survivability is limited by energy consumption.

The objectives of the modified algorithm (PEO-AODV) are resolving energy consumption problem in wireless mobile network and reduce link breakage. PEO-AODV is proposed to take the high node's mobility and energy into consideration when determining the route lifetime. The contribution of our work, namely PEO-AODV, can be summarized as follows:

- Perform analyses of the AODV routing protocol to discover its limitation and constraint.
- Designing an efficient algorithm that will decrease the overall energy consumption and reduce route losses while transmission will effectively extend the network lifetime.
- Proof the effect of multi-hop data transmission on the energy level of a node as an essential metric.
- Performing a comprehensive comparison between the proposed routing protocol and the conventional AODV routing protocol proves the performance of PEO-AODV.
- Finding the shortest possible route to destination with the lowest energyconsumption and highest link connectivity between nodes.

The remaining of this paper are summarized as follows: Section II presents related works. Technical preliminaries are discussed in Section III. Section IV demonstrates the proposed methodology. Section V describes security analysis. Section VI provides simulation setup and parameters. Section VII present our experimental result performance and comparison. Finally, section VIII the conclusions.

2 RELATED WORKS

The following describes existing methods of energy optimization and mobility-aware metrics. The study in [14] proposed an efficient approach which will balance the energy between all available mobile node in the wireless network to prolong the network's lifetime. The proposed protocol stands for (LEA-AODV) reduces energy consumption and maximizes battery lifetime of a mobile node. LEA-AODV is implemented in route discovery operations and is based on the most critical routing protocols (AODV). LEA-AODV will distribute Load balance to avert congested power nodes. In addition, to select the appropriate route that are easily loaded.

The study in [15] proposed a mechanism to find out the optimal route from sender to receiver by employing the minimum battery power per mobile node. In this approach, the route request(RREQ) has been modified by adding the total node's energy field, where each mobile device receives the RREQ packet and then rebroadcasts the RREQ after adding its energyto the total nodes' energy. This can be achieved by ensuring the total nodes' energy field isupdated by all nodes in the route when the RREQ successfully arrive the appropriate destination.

In [16], the authors proposed routing protocol called (EA) Energy Aware for MANET based On Route Energy Comprehensive Index (RECI). A new metric, Route Energy Comprehensive Index (RECI)added to the standard protocol AODV. It selects the optimal route with the maximum valueof RECI and minimum hop count. The main idea of the proposed protocol is to reduce the energy of bottleneck nodes, which lead to increases the lifetime of the network. This protocol defines a Utility Function (UF) which reflects the node's energy consumption when RREQ is sent to Intermediate nodes based on the remaining power of the node and the rate of power depletion. Thus, the RECI value of a node is a ratio of the node's UF to the UF of all nodes.

The authors study in [17] proposed an energy level that relied on the routing protocol. The main objective of this protocol isto increase the network lifetime by enabling the RREQ packets that traverse higher energynodes to reach earlier to the destination node. The idea of the request-delay mechanism isto make intermediate nodes that do not contain an ant a route to the destination holds the RREQ for a period of time. After the waiting period, the intermediate node forwards the RREQ packets to its neighbors. As a result, from this mechanism, the packets that need a long time are forwarded from an intermediate node with a lower energy level. Thus, the RREQ packets forwarded from low-energy nodes have a higher probability of being discarded than those forwarded from a higher-energy level.

The research in [18] proposed Load balancing maximal minimal nodal residual energy ad-hoc on demand multipath distance vector routing protocol (LBMMRE-AOMDV). LBMMRE-AOMDV will constructs a link disjoint path and evaluates the available routes through considering the maximum residual energy of the mobile node, then selecting the path with maximum residual energy. After selecting the path, the node starts calculating the transmitted and received packets over particular path. In addition, the packets count must not increase over the path bandwidth. In other words, the LBMMRE-AOMDV protocol establishes multiple disjoint links and maintains them if link failures occur. Then the load balancing stage starts by switching the data packets among all paths so that the energy of the paths is not consumed.

3 TECHNICAL PRELIMINARIES

In this part, we describe the preliminary steps needed to conduct this research.

A- OVERVIEW OF AODV PROTOCOL

Several routing protocols have been used in wireless networks. Those protocols can be categorized into proactive and reactive routing protocols. In proactive protocols, nodes maintain a routing table to use those routes when needed. While reactive routing protocols find routes on demand. Ad-hoc On-Demand Distance Vector (AODV) is suitable and accepted choices for reactive routing protocols that use discovery processes on demand by the source to its appropriate destination [2]. Figure.1 shows route request RREQ and route reply RREP operations from the source node denoted as *S* through (Node A, Node B, and Node C) to reach the destination node denoted as *D*. In AODV, each active node advertises its information periodically by broadcasting the HELLO packet to its neighbors. Next, the neighbors update their routing table according to it. Thus, when a node does not receive a HELLO packet from one of its neighbors within a period of time, the link between this node and the neighbor node is broken [12], [19].

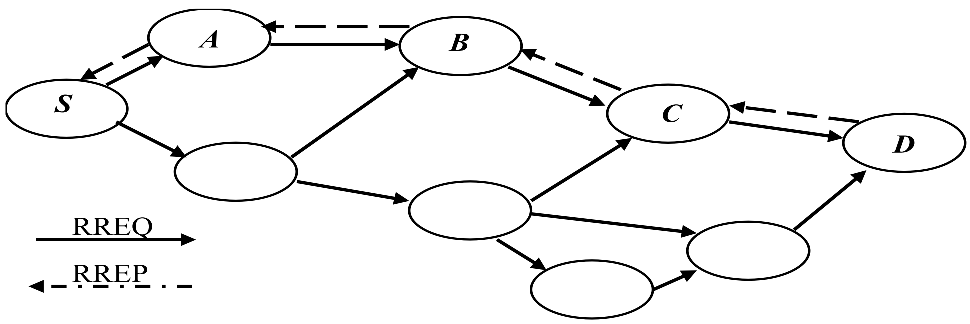

Fig 1: RREQ and RREP Operations

AODV has several advantages that make it one of the most preferred protocols in wireless networks. Those advantages include the control traffic messages being minimized and minimal routing is practiced because routing information is previously contained in the routing table, which shows the active paths in the current network. It responds relatively quickly when the topology changes [7]. On the other hand, AODV has some limitations, such as AODV may bear a flood of RREQ messages into the network. It can also consume a largeamount of bandwidth, especially when the link is frequently broken [20], [29].

B- ENERGY CONSUMPTION MODES IN MANET

Nodes in MANET have restricted energy resources, limiting the mobile nodes' lifetime. Nodes consume their energy in three modes with different amounts. Those modes are transmission and reception modes when the mobile device is active, while the Idle mode consumes less energy when the node is inactive.

- Data Transmission Mode

Transmitting data between mobile nodes to reach its destination requires a high level of energy. The energy needed for this transmission depends on the number of transmitted packets, their sizes, the range among transmitter and receiver, and the hop count [21], [22].

- Data Receiving Mode

MANET employs multi-hop techniques when the destination is not in the source range. Thus, when an intermediate node receives a packet, it will act as a router to retransmit it to the next network node to reach its appropriate destination. Thus, this process consumes the node's energy [21].

- Idle Mode

The idle mode is the default situation for all mobile nodes in MANET; all nodes are inactive for any operation. In another way, a node will not receive nor send a data packet but lose energy [23] [30].

4 PROPOSED PROTOCOLS

The proposed (PEO-AODV) Preserving Energy Optimization protocol is a modified algorithm of conventional AODV protocol. PEO-AODV has been developed based on geographical position by modifying the AODV protocol and calculating the hop count for a particular route and hello packet. The main objectives of PEO-AODV are to reduce the consumed energy in the network, which will lead to maximizing the network lifetime. Moreover, minimize route failures and link breakage between mobile nodes.

4.1 ASSUMPTIONS

This section provides some assumptions concerning the network performances are made in the design of the proposed algorithm.
Assumption 1: All mobile nodes begin at the same level of energy while also have mobility direction and random speed.
Assumption 2: All nodes employ omnidirectional antennas to communicate with one another.
Assumption 3: All mobile nodes are distributed randomly in 2- dimensional square network.
Assumption 4: All nodes can determine their geographical coordinates using GPS.

4.2 PEO-AODV ALGORITHM

- **Hello Packet Modification**

The HELLO packet has been modified by adding the geographical position/location to be sent as a part of the HELLO packet, as shown in Table 1. Each node has knowledge of its location. Thus, they will broadcast their location while in a dynamic movement. The source node will ensure adequate accuracy when locating the nodes based on their location. Therefore, geographic routing is generally considered a good option for large networks. In addition, the energy consumption of each hop can be minimized if the next relay node is correctly selected. The node's position includes the geographical coordinates.

Table 1: Modified HELLO packet

The field needs to be added to the HELLO packet	**Type**
GP	Coordinates X and Y of the Node

Therefore, the geographical position (GP) is used to send information about the geographical position of the mobile nodes in the network and to know their location relative to the source node and if they are close or far from the source. This can save a lot of protocol overhead and energy for the nodesand provide the current physical location of a node forwarding the packet [24].

- **Hello Packet Procedure**

Hello packet is used to maintain the connectivity information between mobile nodes. All nodes advertise their information periodically by broadcasting the HELLO packet to the source node that is denoted as node ***C***. Thus, if no HELLO packets have been received from its neighbors (node ***A*** and node ***B***) within a period of time, the link between node ***C*** and its neighbors are considered broken links as shown in Figure 2. Thus, each node calculates the distance to its neighbors two times. Then it can determine whether the distance between them is increasing, decreasing, or constant.

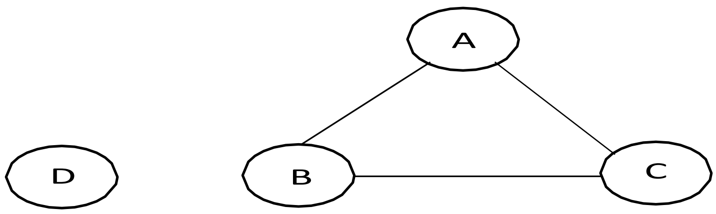

Fig 2: Exchange HELLO Packets

When the second HELLO packet arrives successfully at node C, it calculates the distance between itself and the neighboring nodes to determine the shortest path to the destination based on time as shown in Figure 2. Thus, to find out the total hello interval for all nodes, this can be calculated by equation 1.

$$\text{Hello Interval} = 2^{nd}\ \text{Hello\_Packet} - 1^{st}\ \text{Hello\_Packet} \tag{1}$$

By using equation 1, we can calculate the Total Hello Interval (THI) for all neighboring nodes as in equation 2.

$$\text{Total Hello Interval} = \text{Hello Interval\_}_1 + \text{Hello Interval\_}_2 + \ldots\ldots + \text{Hello Interval\_}_{n.} \tag{2}$$

Equation 2 is employed to find the Threshold value, which will determine the nearest node to the source, as shown in equation 3.

$$Threshold = \frac{Total\ Hello\ Interval\ for\ all\ nodes}{Number\ of\ immediate\ Node} \tag{3}$$

Then, compare the threshold value result with the HELLO interval for a particular node. The node is closest to the source if the threshold is greater than the hello interval.

Otherwise, the node is away and will not be considered to forward the packet due to the extra energy consumption that needed for the packet to be transmitted, as shown in Pseudocode in Figure 3.

Input: Hello Interval, Total Hello Interval and threshold.
Output: Find the Nearest node to the source, where the packet will not consume high energy while transmission.
Begin

1. Node C receives successfully First HELLO packet from node B
2. Node C receives successfully Second HELLO packet from node B
3. ***Start***
4. Calculate the Hello Interval for all successive node to find theTotal Hello Interval.
5. Calculate the Threshold value and compare it with the HelloInterval of each node.
6. **If** (Threshold > Hello Interval) **Then**
7. Set node = Nearest to the source =1.
8. **Else**
9. **if** (Threshold < Hello Interval) **Then**
10. Set node = Away from the source, discard it =0.

End of Pseudocode

Fig 3: Pseudocode of selecting the nearest node to the source in PEO-AODV Protocol

- **Techniques Based on Hop-Count**

When the source node is ready to transmits data to the destination node and does not have direct path, the packets will reach the destination with the help of the mediatory nodes (Node A, Node B, or Node C) after modifying the received RREQ message, such as increasing number of hop count as illustrated in Figure 4

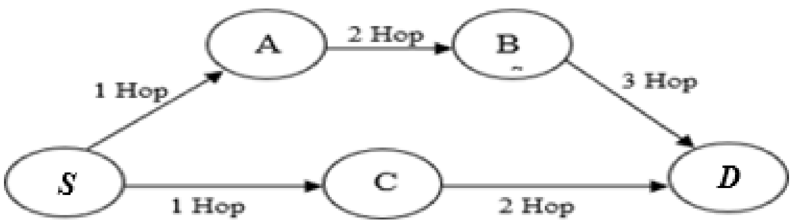

Fig 4: Hop counts.

A source node (S) broadcasts the RREQ to all neighboring nodes, i.e., nodes *A* and *C*. Then, nodes A and C increment the hop count by value of 1 and rebroadcast the RREQ packet to their next neighboring nodes to reach the destination node (D). Node D may receive the same packet through different routes. The optimal route is selected by the destination based on minimum number of hops. The destination node will transmit RREP back to the source node through the selected path and discards other routes (Node *A* and Node *B*). In case of having multiple routes with identical number of hop count, the decision will be taken based on the calculations of the Hello packet using Equation 3.

Therefore, based on the above figure that shows the minimum hop count from source to destination and in establishing an approach to determine a routing strategy which will minimize the consumed energy and increase the route lifetime in MANET [25][27]. Next, the protocol will find the route to the destination node through minimum number of intermediate forwarding nodes. Moreover, suppose the packet has been transmitted over a long distance or a higher numberof hops. In that case, the consumed energy will be higher, whereas if the packet is transmitted for a short distance or the minimum number of hops, the consumed energy is less, which is in line with the study [26], [28] and proved in the equations 5 and 7. Therefore, the consumed energy relies on the transmit packet's hop count between nodes. Figure 4 shows the equation regarding the route from S, A, B, and D, as shown below.

$$Y=X + 2X +3X \tag{4}$$

$$\text{Total of } Y=6X \tag{5}$$

And regarding the routes S, C, and D, we can find the equation below.

$$Y= X+2X \tag{6}$$

$$\text{Total of } Y=3X \tag{7}$$

Where X is the energy consumption for each hop, and Y is the total energy consumption for the complete route. Therefore, when we compare two routes together, equation (5) with equation (7), we can find that routes S, C, and D for just two hops consume less energy compared with other routes. However, the Pseudocode for a destination node after receiving RREQ is illustrated below in Figure 5.

```
Begin
    1. Node D receives a RREQ packet for Path 1Calculate the
       Hop count
    2. Node D receives a RREQ packet for Path 2Calculate the
       Hop count
    3.   Node D will make comparison
    4.   If (Path1 is Min) then
    5.       Send RREP through Path 1
    6.       Discard Packet from other paths
    7.    Else
    8.        If (Path 2 is Min) then
    9.           Send RREP through Path 2
    10.          Discard Packet from other paths
    11.  If (Path 1 and Path 2 is same) then
    12.        Send RREP based on Equation 3

End of Pseudocode
```

Figure 5: The Pseudocode after receives RREQ

4.3 : Summary of the Proposed Protocol

The proposed algorithm highlighted on several facts compared to the base AODV algorithm. Following, we list those facts that help modify the algorithm to overcome the AODV base algorithm.

- Modified the Hello Packet by adding the geographical location of a node (coordinate X and Y) to be sent as a part of the HELLO packet of the node for position accuracy.

- Determine the nearest node that will be used to send RREQ using Hello Packet.
- Determine the optimal route by the destination and resend the RREP message back to the source node.
- The consumed energy that has been improved by PEO-AODV over the conventional AODV is about (20 %).

5 PERFORMANCE EVALUATION AND PARAMETERS

To evaluate the accuracy and performance of modified algorithm. PEO-AODV was simulated using the NS-2.35 simulation environment on Ubuntu operation system, version 16.04 LTS. Then the modified algorithm was examined against certain parameters that allow the system to perform at its best. The details of simulation parameters are illustrated below in table 2.

Table 2: Simulation Parameters

Parameters	Value
Simulator	NS2/ Ubuntu 16.04 LTS
Simulation area	500 m x 500 m
Simulation time	100 seconds
Node locations	Randomly
Propagation Model	Two-ray ground reflection
Initial Energy	200 Joules
Mobility model	Waypoint
Size of Packets	512 bytes
Number of nodes	15 - 115 nodes
Transmission range	300 meters

5.1 Evaluation Results and Comparison

To evaluate the overall performance and accuracy of the modified algorithm PEO-AODV. The results for modified algorithm PEO-AODV have been compared with original AODV results. The performance metrics take into consideration to assess the proposed algorithm and analyzing performance are, end to end delay, packet delivery ratio, consumed energy, Routing overhead and packet losses.

1) Consumed Energy

Energy Consumption is a crucial issue in most mobile nodes for evaluating the performance and efficiency of MANET, which plays an essential role in increasing the network lifetime.

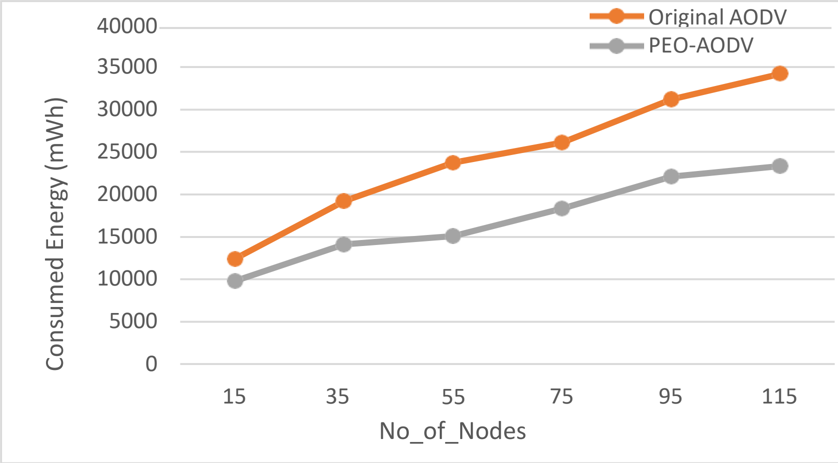

Fig 6: Energy Consumption of various network densities

Figure 6 shows the simulation outcomes and analysis of the proposed algorithm PEO-AODVcompared with base AODV with various effects of network density. As established, PEO-AODV provides lower energy consumption, reflecting positively on increasing the network lifetime compared with standard AODV. The reason behind that is reducing the breakage of the link in the network and selecting the route with the minimum number of hop counts, which improves the consumed energy. Moreover, whenever the network density increases, it increases energy consumption in a network.

2) End-to-End Delay:

End to End Delay has been considered one of the evaluation metrics which plays a vital role in measuring network performance.

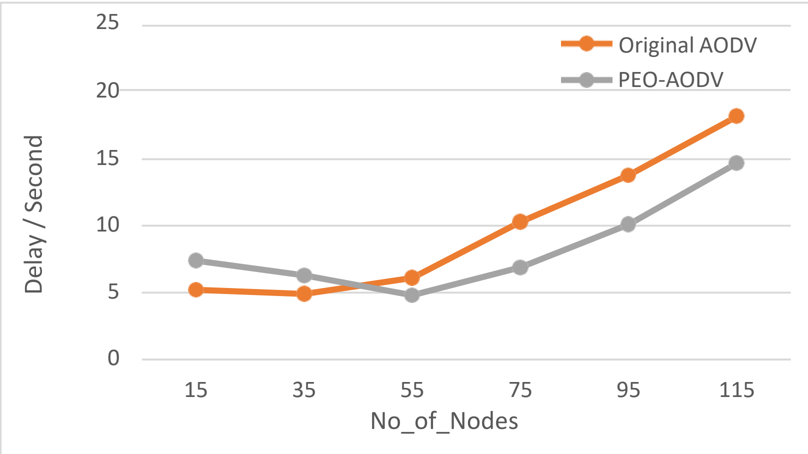

Fig 7: Delay of various network densities

Figure 7 shows the outcomes of the modified algorithm PEO-AODV compared with the standard AODV over various network densities. As established, PEO-AODV provides lower delay compared with AODV. In addition, when the numeral of nodes increases, the numeral of participating nodes for forwarding the packet in the route will definitely increase, increasing the collision and delay. PEO-AODV reduces the delay because of decreasing rebroadcast trails. Therefore, PEO-AODV outperforms the original AODV in reducing the delay.

3) Packet Delivery Ratio

PDR has been considered to evaluate the modified algorithm. It plays an essential role in measuring network performance as a network metric.

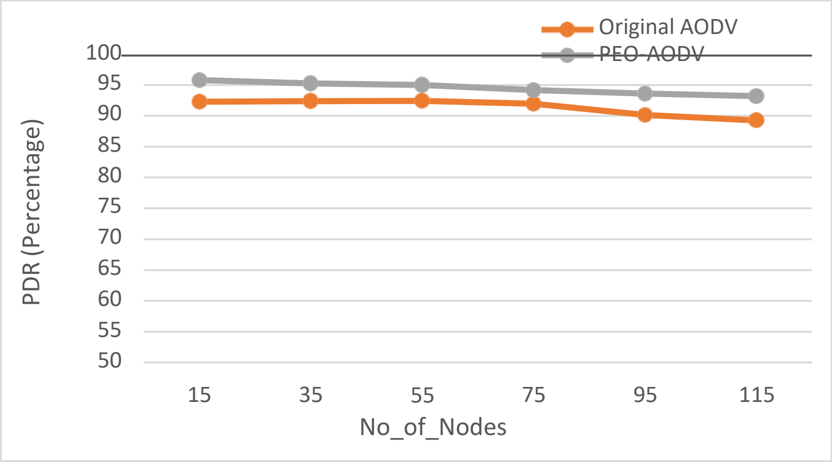

Fig 8: PDR of various network densities

Figure 8 shows the simulation outcomes of the modified algorithm PEO-AODV compared with standard protocol AODV over various network densities. The modified algorithm provides a higher packet delivered to the destination because an increase in the number of nodes will lead to a rise in the connectivity among them, allowing more information to be exchanged and hence more input to the algorithm. Furthermore, PEO-AODV reduces the link breakage that may positively affect the PDR, reduces the route losses, and ensures data is delivered to the destination.

4) Route Losses

It refers to the total number of times that any mediatory nodes transmit a packet to inform the source that the link is broken.

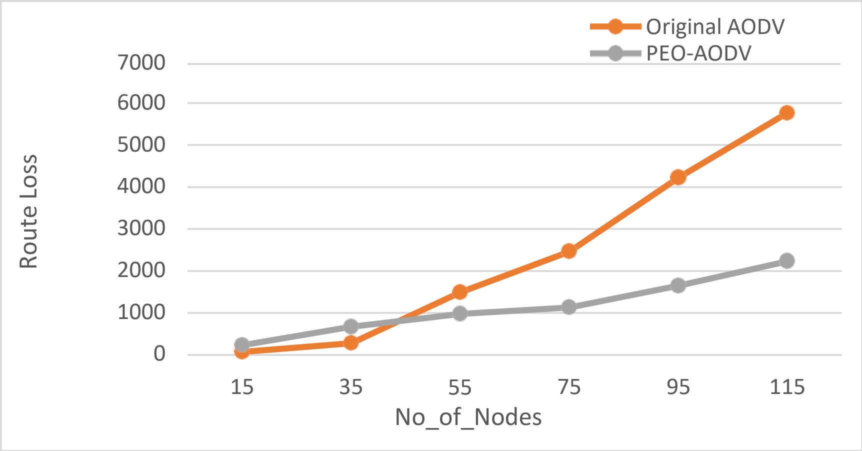

Fig 9: Route Losses of various network densities

Data in Figure 9 shows the PEO-AODV decreased the route losses by figuring out the minimum time to the route lifetime, which reduces the unpredictable link breakage. Therefore, all routes toward the destination are available to transfer data, decreasing route losses. Thus, the unexpected breakage in the link is reduced, and the route losses appreciably decrease.

5) Control Overhead

Control overhead is a critical issue in most mobile nodes. It is the number of control information transmitted to the actual data received.

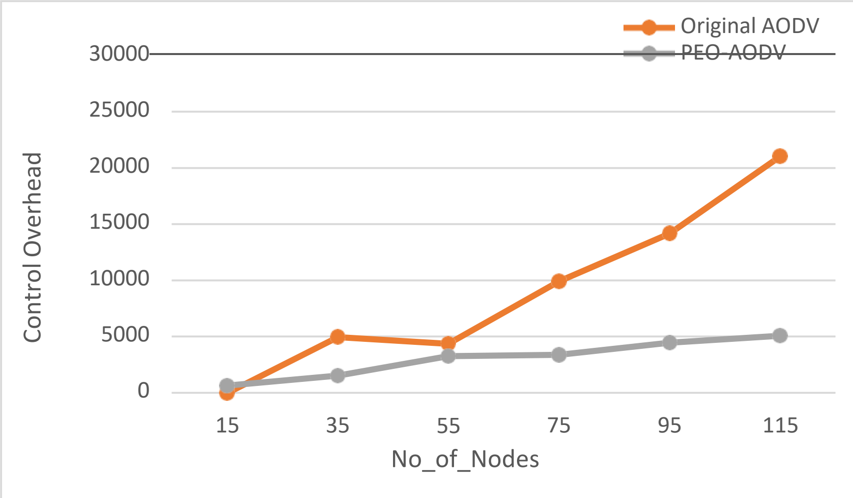

Fig10: Control Overhead of various network densities

Figure 10 shows the simulation outcomes of the modified algorithm PEO-AODV compared with standard protocol AODV over various network densities. The results show that the control overhead increases while the number of nodes grows due to the increased control packets transmitted to discover new routes. Moreover, PEO-AODV reduces the RERR packets by figuring out a route lifetime for all routes in the network. Therefore, all nodes check the route expiry time before transmitting data among the routes, which also decreases the control overhead.

6 SUMMARY

In this section, we summarized the performance and achievements of the PEO-AODV that was analyzed using the NS 2.35 Simulator. The modified algorithm was compared with the standard AODV routing protocol in terms of Packet delivery ratio, End-to-End Delay, Energy Consumption, Route Losses, and Control Overhead. The modified algorithm increases link stability and decreases route losses, which significantly affect the network. In addition, packet delivery increase guarantees the delivery of actual data to the destination.

7 CONCLUSION

MANET has several challenges in a routing protocol, such as mobility, bandwidth constraints, limited battery capacity, and resource constraint. These challenges limit the performance and routing protocol capability. This research proposes a preserving energy algorithm called PEO-AODV, which represents a modified version of the standard AODV routing protocol to reduce energy consumption and route losses while transmission to have stable links in the network. In addition, PEO-AODV will decrease unpredictable link breakage and prevent network disruption. The modified algorithm shows higher performance and effectiveness than the AODV protocol. It significantly overcomes the limitation of standard protocol AODV in various metrics in terms of route losses, packet delivery ratio, control overhead, delay, and mainly reduced energy consumption metrics.

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