International Journal of Computer and Organization Trends
ISSN: 2249 – 2593 / https://doi.org/10.14445/22492593/IJCOT-V14I1P303

Volume 14 Issue 1, 19-26, Jan-Apr 2024

Original Article

Optimize Multiple Route Discovery for Manet Using Energy and Velocity Constraint

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Received: 14 February 2024 Revised: 26 March 2024 Accepted: 12 April 2024 Published: 30 April 2024

Abstract *- Mobile ad hoc networks, or MANETs, are networks of mobile devices that function without the need for fixed infrastructure. They are dynamic and self-configuring. Because MANETs are inherently mobile, power-constrained, and have variable link quality, they present particular difficulties for routing protocols. Therefore, in order to provide the best paths for data transfer, a routing protocol that can control node mobility while preserving node energy efficiency and helps minimize packet loss is required in order to overcome the challenges. In order to increase the lifespan of the network, a routing protocol that provides velocity-constrained, energy-efficient routes with improved link reliability is thus proposed in this paper.*

The optimization of multiple route discovery mechanisms through energy and velocity constraints is the main focus of this research, which examines the most recent developments and difficulties in MANET routing protocols. This research aims to enhance the overall performance of MANET networks in various scenarios by improving the efficiency, reliability, and resilience of communication by incorporating energy and velocity considerations into route discovery processes.

In terms of QoS matrices, the suggested protocol outperforms the current protocol. The novel simulation has been performed using the network simulator NS-2.35 tool. According to simulation results, the suggested routing protocol performs better in terms of QoS metrics. We can infer from the graphs that the suggested EV-AOMDV protocol works better to offer route optimization during route discovery. Using more dependable paths from source to destination also decreases lost packets and delays with an increase in the number of successfully delivered packets.

Keywords *- Ad hoc Networks, Node Velocity, Energy Efficiency, EV-AOMDV, QoS.*

1. Introduction

A Network can be formed using various nodes connected. The network architecture can be wired or wireless. This type of self-organizing wireless communication network without any pre-constructed infrastructure is known as a mobile ad hoc network (MANET). Multiple hops are needed to exchange information across all the nodes in a manner due to the restricted range of communication of the nodes. Every single node in Manet is permitted to adjust its position dynamically, which changes the topology.[1] Furthermore, every single node in such a network serves as both a host and a router, enabling it to share information with other nodes without the need for a central server to be present. The decentralized routing mechanism uses routing schemes to transfer packets and it may cause looping when failure happens. It is caused due to the absence of network topology. [16] QoS-aware apps include real-time multi-media audio, video, and other communications; therefore, protocols used in uni-path routing, namely AODV[2], DSDV, DSR, etc., are not appropriate. Consequently, the need for a routing protocol with various paths arose. By a multiple-path routing technique, the source and destination produce a variety of pathways. Therefore, it is suggested that load balancing be used to offer improved consistency of effective data transport. [3] The two primary characteristics of a MANET that should be taken into consideration while identifying the best path are the limited energy and the erratic mobility of mobile nodes.[18] Energy consumption is one of the main obstacles to building Internet of Things (IoT)-based systems for monitoring along with associated applications since maintaining sensing systems in a continuous and correct operational state for a prolonged amount of time is one of the prerequisites.[17]

During a route-finding process, AOMDV[4] enables the nodes to explore a variety of routes from source to destination. The difficulty in managing these pathways increases, and the nodes become mobile. Routes frequently break down as a result of the nodes' erratic movement, and having to install them again uses up more of the resources and energy on the network. Furthermore, because MANET devices have a finite amount of power from their batteries, energy economy is a crucial problem in the design of the routing protocol.

The initial source node commences the AOMDV route-finding process. Every intermediary node releases the RREQ packets after receiving them. The said route discovering approach causes a significant amount of packet flooding throughout the network. This results in the source's deluge of route requests, and network congestion worsens in the pre-existing routing protocol for discovering various paths. Additionally, there is a high likelihood of route failure for data transmission if we take into account the paths discovered by AOMDV's route discovery. [5] Having an efficient use of energy is a difficult task in order to provide the best QoS. If any node dies or runs out of energy leads to network partitioning and communication letdown in the mobile network.

The nodes in this sort of network are normally energy-constrained as they have inadequate battery power, whereas a large amount of energy is consumed during wireless communication. Mobile devices are no longer useful, without the power and resources.[6] So, to extend the lifetime of a network through energy optimization is an essential task. As shown in Figure.1 this work implements the power management scheme by offering a threshold value to every node all through the route-finding process. As shown in Figure 2, this work proposes a solution to the problems being faced by the pre-existing AOMDV routing protocol by keeping track of the residual energy and node velocity of every node to find its neighbor. The work centers on transforming the pre-existing multipath routing protocol for finding several routes taking energy and velocity as a constraint to achieve the QoS requirements. Constrained-enabled routing protocols, in contrast to AOMDV, prioritize taking into account a variety of network constraints in order to maximize resource usage and route selection. The particular needs and features of the ad hoc network being deployed will determine which option is best. The proposed protocol follows the following routing control mechanism:

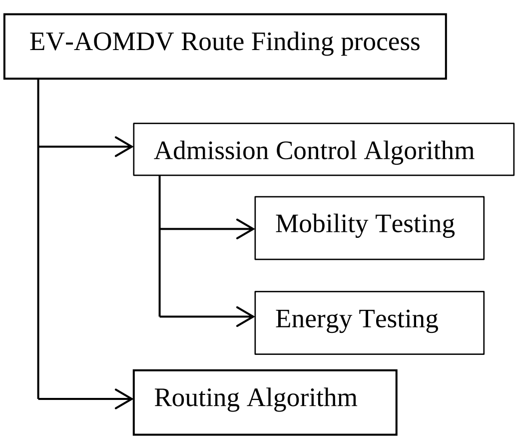

Fig. 1 EV-AOMDV Routing control mechanism

The following architecture can illustrate the proposed EV-AOMD:

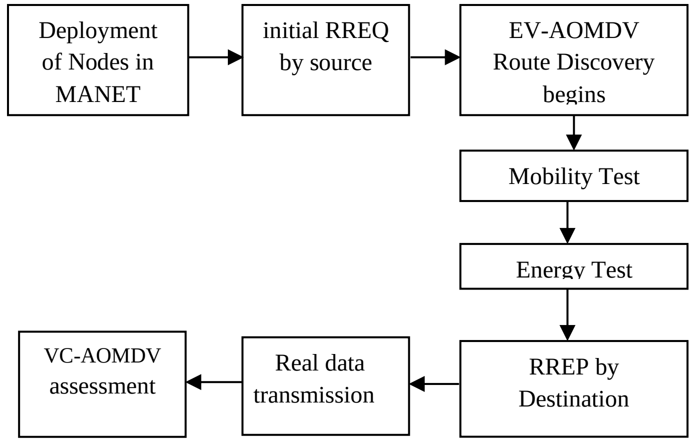

Fig. 2 EV-AOMDV basic architecture

The performance evaluation of EV-AOMDV and AOMDV is performed against the QoS matrices like Packet Delivery Fraction (PDR), End point Delay, Lost packets and throughput etc.[7] NS-2.35 is used to simulate, and the results here show that this presented protocol is superior to the conventional multiple-path routing technique.

2. Literature Review

This section presents the work that has been done in the field of multipath routing in MANET to prove better quality of service. It also outlines the work done by the researchers in the area of energy efficiency, load balancing and shortest path finding. The work presented in [8] focuses on energy optimization in MANET. It shows that the two main important issues of MANET-like power optimization and prolonging network lifetime, can be resolved using a threshold value of energy. Authors present an OEAR, i.e. an optimized energy-aware routing [9], the energy level of nodes and the total amount of buffered Packets in that node are considered during path selection for information transmission.

The work in [10] presents an approach for finding stable routes for multipath routing. The number of route recoveries needed during the data transmission is reduced by applying the simple route stability model and a method for route maintenance. An energy-efficient routing is proposed in [11] for the AODV routing protocol. Since nodes are power-constrained and due to lack of energy, nodes may die prior to the expected time, causing the network partition. The proposed idea suggests an energy-efficient approach for finding the optimal route for a source-destination pair. QOS-oriented, Robust Routing for multiple paths (QRMR) for ad-hoc networks [12], loads are assigned towards separate links based on measures like an endpoint delay, quality of the link, and channel quality. QRMP intends to balance the traffic to improve the network capacity.

Table 1. Comparison between existing and proposed work

Features	**AOMDV**	**Constraint-Enabled Routing Protocol**
Basic Functionality	Its main goal is to increase the robustness and dependability of data transmission by offering several paths between a source and a destination.	It is intended to take into account a variety of network limitations during route discovery and maintenance procedures, including energy levels, available bandwidth, and node mobility, among others.
Route Establishment	In order to provide load balancing and redundancy, AOMDV dynamically creates multiple paths between nodes.	When determining routes, these protocols take certain limitations into account. For example, they might choose paths with enough bandwidth for specific kinds of data traffic or stay away from routes with low-energy nodes.
Routing Metrics	To assess the quality of routes, AOMDV mainly uses metrics like hop count or route length.	These protocols optimize route selection by utilizing additional metrics associated with particular constraints, such as available bandwidth, node residual energy, or link stability.
Adaptability to Network Dynamics	Typically, AOMDV is more concerned with offering redundancy and flexibility in the event of route changes or node failures.	The protocols above ensure effective resource utilization and network performance by adjusting routing decisions in response to evolving network conditions and constraints.
Application	When redundancy and multipath routing are essential, as in emergency response systems or military applications, AOMDV is appropriate.	These are utilized in networks where certain limitations must be taken into account, like sensor networks, where energy efficiency is the main priority.

3. Proposed work

3.1. Overview

An improvement over the current AOMDV algorithm for routing is the suggested EV-AOMDV networking protocol. EV-AOMDV routing protocol allows us to discover multiple paths from the source to the target during the path-finding process of EV-AOMDV. Only the primary route will be taken into consideration for information transfer, and this route discovery procedure ensures the disjointness of any alternate routes discovered. The only routes having velocity as a constraint and being energy aware will get stored in the routing table for information transmission. EV-AOMDV uses node-disjoint paths for information transmission because of the strongest degree of path independence. The primary path is chosen for information transmission, and in case of route failure, the backup paths will be used to carry forward the transmission of data.

During the EV-AOMDV path-identifying process, we have taken into account two different forms of control messages. These are the RREQ and RREP messages. The source node in the EV-AOMDV routing protocol begins the route-finding process and broadcasts the RREQ request packets into the network. The forwarding of packets commences promptly as the source node's neighbors acquire the RREQ. When the intermediate node receives the RREQ, the packet forwarding is done considering node velocity and energy as a constraint. This discovery procedure leads us to the conclusion that there are fewer overall packet drops, which reduces the overall inundation of RREQ packets. The network simulator NS-2.35 tool has been used to simulate the network. The results obtained during the process of simulation show that the proposed work performs better when there are more mobile nodes deployed in the network, and there is less battery power.

3.2. Calculation of Node Velocity

In pre-existing AOMDV routing protocol, the initial node broadcasts request packets into the network. Upon receiving RREQ by the intermediate nodes, an immediate look-up to the routing table is performed. If it is not the target node, then again request packet is broadcast into the network. In AOMDV, broadcasting of the RREQ message is performed every time an intermediate node receives it. This unnecessary broadcasting leads to the excessive flooding of the RREQ packets into the network, and the paths found through the route discovery mechanism are prone to failure because of the excessive node mobility. Thus, to solve this problem the proposed protocol uses node velocity as a constraint in order to find more reliable paths for information transmission. Assume that there are n nodes and m connections, all of which were established utilizing CBR traffic. Manet can be illustrated realistically. G = (V, E), It is assumed that there is a set of nodes and edges, where V depicts the set of nodes and E depicts the set of edges. The edge that is inside the nodes' communications range represents a connection between two nodes. N(vi) represents a node vi's neighbors as a group. Let us assume that the span between the source point and the destination point is n, and the path is depicted by (S= Vi), where each vi is greater than V and smaller than N(vi -1). Let us assume that S1 and S2 denote the speeds of two adjacent nodes, and that represents the angle between them. The relative speed of S1 and S2, according to the Cosine Theorem, is:

$$S=\sqrt{(S1^2 + S2^2 - 2S1S2\cos\theta)} \tag{1}$$

During the route request phase, we calculate the speed of the node and compare it with the threshold velocity. Vmin, Vmax is the range from which this velocity is chosen. The value default value of Vmin is 1 m/s, and the value of Vmax varies between 5 to 25 m/s. The packet forwarding decision is then taken considering the following equation. We check if we can send the packet to the next hop or not. The following equation provides evidence for this judgment.

$$IF \begin{pmatrix} vi \le Vthr & Forward\ RREQ \\ else & Drop\ RREQ \end{pmatrix} \tag{2}$$

Where vi is the node velocity at a specific point in time, let us say t, and Vthr is the maximum speed at which a node in the entire network may travel. When a node's velocity exceeds this threshold, it either dumps the packet or passes it to the next hop. Therefore, by using EV-AOMDV, we may reduce unnecessary packet flooding and network congestion.

3.3. Calculation of Residual Energy

We know that the nodes in MANET are battery constrained, so to have an efficient use of battery power is essential for prolonging network lifespan. Network lifespan here is well-defined as the total interval between the start of the simulation and the very first node getting exhausted. The energy model proposed in this work considers the following modes a node may acquire.

1. Transmission mode, E_t: The amount of energy that is employed to send a packet
2. Receiving mode, E_r: Energy consumed in the reception of a packet
3. Sleep mode, E_s: Energy consumed during sleep state
4. Idle mode, E_i: Energy consumed in an idle state

Amid the route discovery of EV-AOMDV, it is possible to find the nodes which have consumed a large amount of energy, So that the only nodes consuming a limited amount of energy will get included in the desired path to the destination. We can calculate the amount of energy consumed at each node during different time intervals. Furthermore, the equation afterwards has been employed to calculate it:

$$E_t(c) = N_t * E_t + N_r * E_r \tag{3}$$

Where $E_t(c)$ is the amount of energy consumed at a particular time t, N_t is the total transmitted packets, One packet's transmit energy is symbolized by Et, and Er expresses a packet's receiving energy. Let us say we have initialized initial energy as E(i), then the residual energy is:

$$E_R = E(i) - E_t(c) \tag{4}$$

Now, after finding the residual energy of each node, the path having limited or lesser than threshold energy will not get stored in the routing table ($E_R \le$ Ethr). Various values of initial energy and threshold energy have been taken, and the best results as throughput, PDF, an end-to-end delay and packet drop have been found at the value when the threshold value of energy is half of the initial energy. Thus, the only routes that are energy efficient will be chosen for information transmission to enhance the network lifetime. The routing decision will be taken according to the following equation:

$$IF \begin{pmatrix} ER \ge Ethr & Forward\ RREQ \\ else & Drop\ RREQ \end{pmatrix} \tag{5}$$

3.4. Algorithm for Proposed Routing Protocol

Step 1 sadd==index
Then, that node is the source node, and RREQ broadcasting is performed.
i.e. Route Discovery

Step 2 node== intermediate node

If (packet_type == RREQ)
Then check for request node i, node velocity V_i, residual energy E_R, Threshold velocity Vthr and threshold energy Ethr.
Begin:
Find the velocity of each node V_i ;
Compare with the threshold velocity Vthr;
If $V_i \le$ Vthr
Then go to 3.
Otherwise, drop the packet and quit.

Step 3 Calculation of Residual Energy
$E_R = E(i) - E_t(c)$

$E_t(c)$ is the consumed energy at instance t, and E(i) is the initial energy.

If($E_R \geq$ Ethr)
Then forward the packet (RREQ)
Else Drop Packet (RREQ)

Step 4 node = destination
Halt broadcasting RREQ,
Allocate advertised_hop_count =0;
Send (RREP) along with Routes list to source;

4. Performance Matrices

Here, we examine how well different routing protocols perform in relation to the following QoS metrics:

1. Throughput: The whole amount of packets that have been delivered effectively to their destination, while the entire simulation period is referred to as throughput. Unit for throughput measurement is no of bits per unit of second (bits/sec).

$$\frac{(number\ of\ packets\ delivered * size\ of\ packet)}{total\ simulation\ time} \quad (6)$$

2. Endpoint delay: The time it takes a packet to travel from where it originates to its location is referred to as the endpoint delay.

$$\frac{\sum Packet\ arrival\ time\ at\ dest. - Packet\ sent\ time\ at\ source}{Number\ of\ total\ connection\ pairs} \quad (7)$$

3. Packet Delivery Fraction: This is the fraction of successfully delivered packages with total emissions of packages done by source.

$$\frac{Number\ of\ packets\ transmitted\ successfully}{Total\ number\ of\ transmitted\ packets} \quad (8)$$

5. Simulation operations and effects

Network Simulator tool, version ns2.35, is the program that we employed in this simulation. The technique is event-driven and offers excellent support for networks with multiple hops [13, 14].

With the aid of cbr traffic, simulation has been conducted under many different test situations shown in Table 1. [15] A variety of events, including those with various ranges and simulation times, as well as cbr traffic (such as fluctuating node numbers), have been simulated.

A variety of traffic arrangements, various densities, links, ranges, and also time outcomes from the simulation are recorded.

Table 2. Simulation factors of ns-2.35

Factors	Value
Time in sec	100
Map Size	1000*1000
Amount of Connections	8,10
Transmission Rate	0.01 to 0.1
Pause Time	1, 2, 3,……,9
Mobility Model	Random Way Point
Traffic type	CBR
Medium	Wireless Channel
MAC	802.11
Package Size	210, 512 up to 900

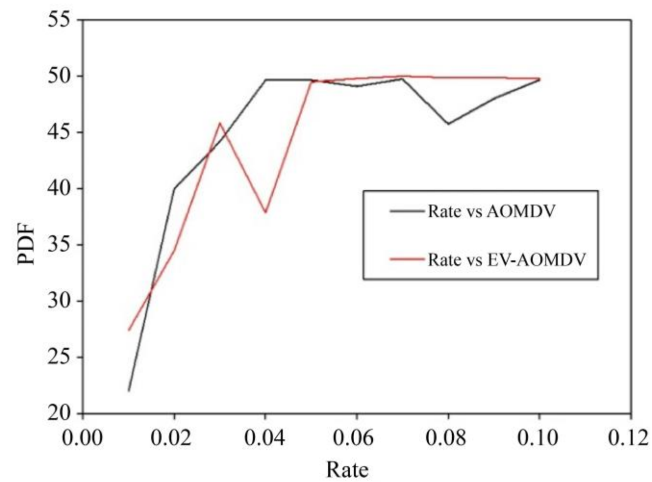

Fig. 3 Packet delivery fraction with respect to varying rate

The above figure demonstrates the packet delivery fraction with fluctuating data rates. As the send rate increases, the proposed routing protocol shows a comparatively better packet delivery fraction than the original AOMDV routing protocol.

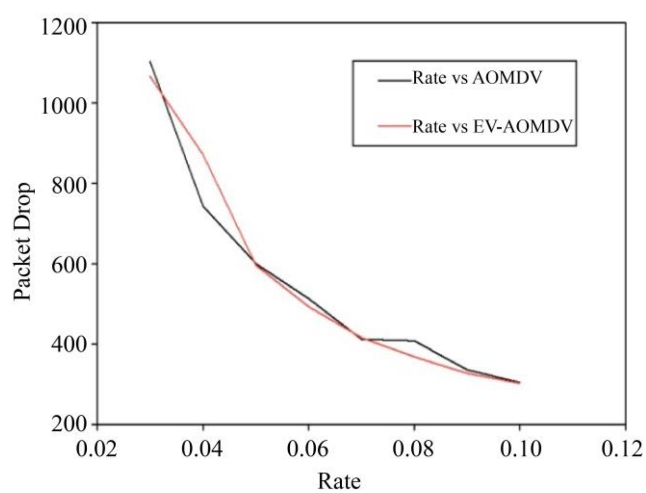

Fig. 4 Packet drop with varying rate

According to Figure 4, when the send rate varies, the dropped packages are comparatively lower in the case of the proposed protocol than the AOMDV routing protocol. However, at some moments, it shows higher packet loss due to degradation of energy level and high mobility.

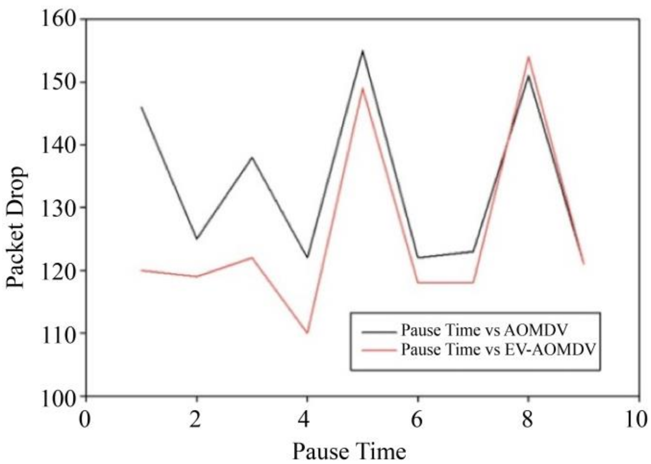

Fig. 5 Packets dropped with different Pause Time

As the above Figure 5 depicts, the total packets dropped for the proposed protocol is lesser than the AOMDV routing protocol when compared against varying pause times.

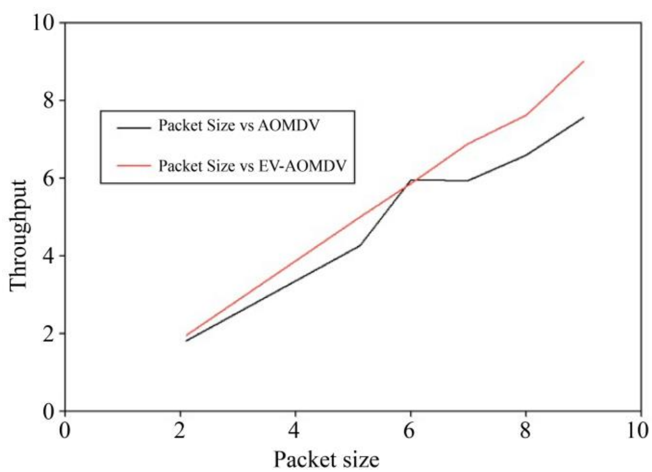

Fig. 6 Throughput with varying packet size

It has been clearly shown in Figure 6 that when the packet size is varied, EV-AOMDV provides better throughput than AOMDV.

As seen in Figure 7, with varying packet sizes, the proposed routing protocol EV-AOMDV gives a higher packet delivery fraction than the AODMV routing protocol. As the routes provided by EV-AOMDV are optimized, thus it results in a better packet delivery fraction.

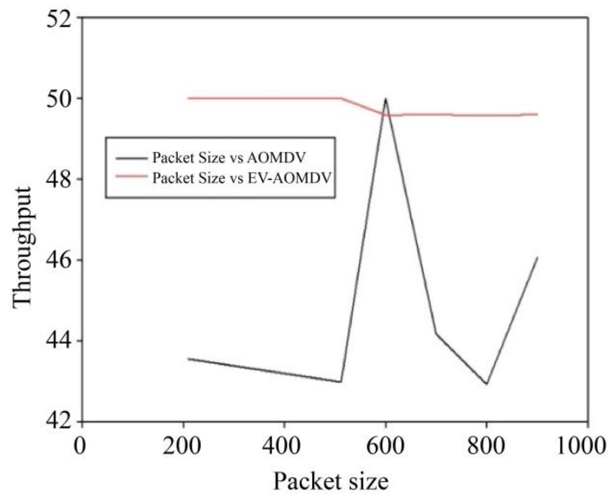

Fig. 7 PDF with varying Packet Size

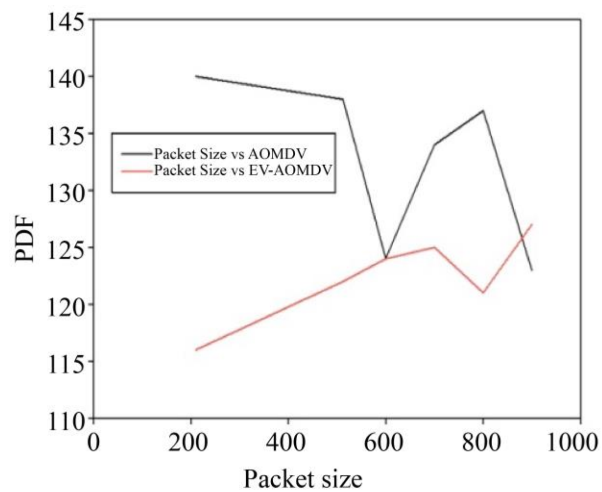

Fig. 8 Packet drop with varying packet size

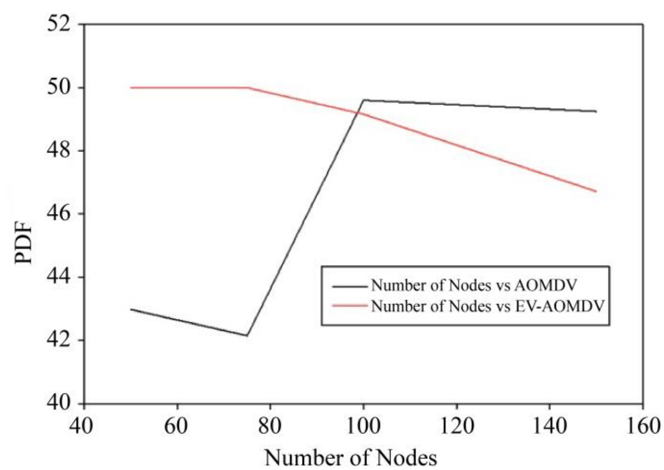

Fig. 9 PDF with varying number of nodes

As shown in Figure 8 above, when the packet size is varied the proposed routing protocol indulges less package drop than the existing AOMDV one.

As shown in Figure 9, when the network density is low, EV-AOMDV provides a better packet delivery fraction than AOMDV. However, as the network density increases due to the high node mobility and network traffic, the PDF starts dropping down.

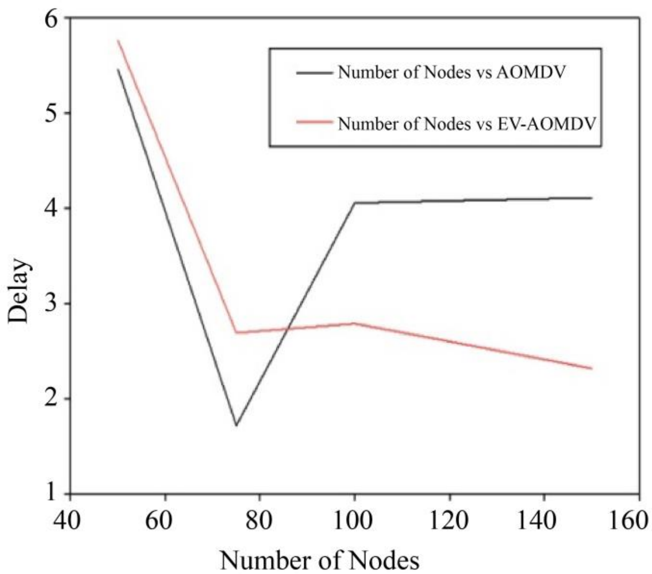

Fig. 10 Delay with fluctuating number of nodes

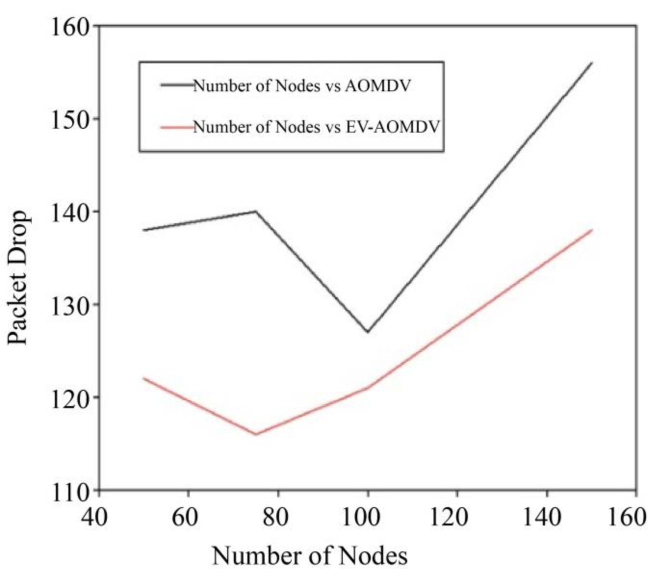

Fig. 11 Packet drop with varying number of nodes

As per Figure 10, initially, when there are fewer nodes deployed throughout the network, EV-AOMDV shows a higher delay than AOMDV because the longer routes were chosen for data transmission. But with the increasing network density, EV-AOMDV gives a lesser end to end delay than AOMDV routing protocol.

It has been clearly shown from Figure 11 that EV-AOMDV prevents flooding of control packets by means of applied velocity and energy constraints. As the network density increases, EV-AOMDV shows less number of packet drops than the AOMDV routing protocol.

6. Conclusion

The presented work is a modified version of the AOMDV protocol for MANET using the velocity and residual energy of nodes as constraints for its functioning. The primary objective of this work is to monitor and improve the network's performance in a variety of scenarios involving multiple routes. For the evaluation of the protocols, both AOMDV and EV-AOMDV were assessed using a constant bit rate. The assessment has been carried out considering performance matrices for, e.g. Endpoint delay, throughput, packet delivery fraction, and packet loss.

The results here show that the proposed protocol performs superior against these metrics as compared with the existing protocol. EV-AOMDV also shows the controlled traffic by restricting the needless overflowing of RREQ request packets. Two major issues, prolonging network lifetime and energy optimization, can be resolved using threshold values for node velocity and residual energy.
The route-finding process of EV-AOMDV uses velocity and residual energy as constraints. It gives reliable paths for the transmission of data with a lesser number of lost packets and results in less congestion.

Conflict of Interest

With regard to this paper, I, Rajshree Soni, hereby declare that there is no conflict of interest. I have no affiliations, financial interests, or connections to any groups or people that might be seen as influencing the information or conclusions this manuscript presents.

Acknowledgement

RS conceived, designed research and conducted experiments. VM and RS contributed to analytical tools and manuscript writing. Both authors thoroughly read and approved the manuscript.

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