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Selective Hopping and Stable Path Integration to Boost AODV's Message Delivery Assurance

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Abstract: In addition to carrying communications, Vehicular Ad-hoc Networks can be utilized to transfer vital information across nodes in the network, potentially averting disastrous losses. By following the established standards, this vital information is transmitted by moving cars on the road in conjunction with parked cars. In this case, the communication is forwarded via a mediator known as a "roadside unit." The Ad-hoc On-Demand Distance Vector (AODV) routing protocol is one of the finest for such a wireless environment because it can tolerate variations in vehicle density and speed. Though it performs better than other comparable protocols, the AODV routing protocol does not show much promise when it comes to unreachable nodes, unstable forwarding paths, broadcasting storms, and short connection lifetimes. In order to improve efficiency, this research paper suggests adding multiple Road Side Units, modifying the conventional AODV routing protocol by adding selective hopping and the Delay Minimization Problem. To confirm the usefulness of the suggested model in terms of propagation delay, transmission loss, network lifetime, etc., it is also simulated. The findings gained support the superiority of the suggested strategy, laying the groundwork for its wider implementation.

Keywords: AODV protocol, Jamming, Quality of Service, Routing, VANET, Selective Hopping, Stable Route

1. Introduction

Vehicle ad hoc network (VANET) is the name given to the wireless network that consists of both fixed and mobile cars engaging with one another. VANET faces the greatest barrier in terms of moving nodes and quickly changing network topologies because it involves moving vehicles. Furthermore, every car in VANET functions as a node, allowing data to be transferred from one vehicle to other vehicles or units on the road and enabling vehicle-to-vehicle (V2V) data transfer. VANET is a crucial part of the Intelligent Transport System (ITS) because it is primarily utilized to maintain driver and passenger safety while also enhancing the effectiveness of traffic safety [1, 2]. VANET creates a pool of mobile networks among the vehicles as part of the Mobile Ad-Hoc Network (MANET) to enable information sharing. Based on their characteristics, uses, and other details, the protocols in VANET can be broadly divided into three groups [3] as Proactive routing protocols, Reactive routing protocols, and Hybrid routing protocols.

The core of transmission in a VANET is On-Board Units (OBUs), and the communication between vehicles functions as a node that contains OBUs. Various vehicle characteristics, including speed, location, distance, and inter-vehicular distance, must also be taken into account in this situation. Furthermore, there is a tremendous volume of data transfer among multiple VANET nodes due to the cars' explosive rise in the last few decades. The volume of data transport is increasing exponentially, which congests communication channels and lowers application QoS (quality of service) [4, 5]. To address these challenges, optimized RSU deployment strategies have been introduced to improve connectivity and reduce communication delays in VANET networks [4]. Technological developments in the IoT and cloud computing domains effectively tackle the difficulty of managing limited processing power, ensuring efficient communication between vehicles and infrastructure [4, 5]. Nevertheless, a cloud server might not be able to meet the modern application's latency needs after a certain point. To address this, fog computing has been introduced as an alternative to reduce network delays and improve real-time responsiveness [6]. As a result, Cisco launched fog computing, a system that is more effective due to additional advancements in technology and computational capacity Vehicular Fog Computing (VFC), the application of fog computing in VANET, seeks to maximize bandwidth utilization, improve productivity, and lower latency [7, 8].

By helping the vehicles in the area create the necessary pool of network architecture, VFC helps VANET so that the vehicles can connect and communicate with one another [9]. It has Road Side Units (RSUs), a high-power radio frequency, and a long-range antenna that functions as a wireless medium in addition to cars, also known as nodes [10]. Its job is to send data packets to other RSUs and On-Board units (OBUs) within its range so that OBUs can aggregate safety information and operate as a gateway to enable Internet connectivity to OBUs [11]. By utilizing VFC and OBUs, every vehicle can now send and receive messages, functioning as a node within the ad hoc network. Data traffic can be navigated throughout the network thanks to RSUs. Additional cars in the network serve as access points, also known as nodes, which facilitate Internet connectivity for the system as a whole. In addition to moving vehicles, stationary vehicles also have a significant impact in the sequential method of communication [12]. The terms node and vehicle have been used interchangeably in the paper. VFCs and OBUs have the capability to process data locally, significantly reducing transmission latency by avoiding the need to upload and download data from the cloud. This is particularly beneficial in autonomous, self-driving vehicle scenarios [13]. Vehicles can communicate with each other to ensure smooth driving and obstacle avoidance. In emergency situations, such as accidents or other incidents, one vehicle can inform and guide other vehicles regarding route changes or instruct them to clear the way for high-priority vehicles like ambulances or military convoys. For this purpose, the AODV protocol can be used, as it offers greater robustness in message delivery [14].

Due to mobility support, VFC benefits from data processing cooperation with neighboring cars. As a result, VFC uses neighboring cars to collaborate with one another rather than sending information to a central server, thereby reducing processing, deployment, and cost times [15]. Due to its close closeness to end users, extensive geographic coverage, and mobility support, VFC distinguishes itself from rival tactics. The traditional AODV protocol is efficient in on-demand route discovery and adapts quickly to topology changes. However, in scenarios with high vehicle density, it encounters broadcast storm attacks and struggles to identify the best route or gateway for packet forwarding. Another challenge arises when the shortest route is chosen as the optimal path; though initially effective, frequent vehicle movement in ad hoc networks causes these paths to break down more quickly than longer routes with more hops. This results in repeated route recalculations, leading to communication delays or failures [16]. To resolve these issues, the authors propose an enhanced AODV protocol by deploying multiple RSUs and modifying it to prioritize alternative routes over the shortest one.

Here, in this paper, authors aim to provide a methodology for collision avoidance through selective hopping technique. The suggested protocol ensures guaranteed communication even in case of broadcast storm (jamming) [17], which results in significant redundancy, conflict, and collision. This reliable and guaranteed communication advocates its deployment in emergency services. The simulation of the suggested method yields improvement in AODV performance metrics and hence establishes its significance.

There are multiple sections in the current paper. The introduction to this research study is laid out in Section I. The AODV protocol is explained in great length in Section II. Part III goes into further detail on similar work on the same subject. The recommended approach and the experimental design and findings are presented in Sections IV and V, respectively. Section VI concludes with recommendations for further work.

2. Ad hoc On Demand Distance Vector Routing (AODV) Protocol

Link information is used by the topology-based on-demand routing protocol known as AODV to route packets from a source to a destination. Based on the experimental research conducted by the authors in [2], it is found that AODV outperforms standard routing protocols with respect to performance measures including throughput, average end-to-end delay, and packet delivery ratio (PDR). This outperformance is also achieved for varying network behavior like varying vehicle density, varying parking duration, and various parking speeds and thus AODV has been established to be amongst most efficient protocols in VANET.

2.1 Working of AODV protocol

Using a hopping pattern, the protocol primarily operates in two phases: route discovery and route maintenance [2]. When a sender node wishes to send a message to a certain destination node, it uses its neighbor to broadcast a Route Request (RREQ) message [7]. Route discovery is the term for this procedure. The source and destination addresses are two important pieces of information in this RREQ packet. Intermediary nodes also copy the address of the source node and append their own data to the message during the route discovery phase [8]. Until the destination node is reached, the previously described process of appending intermediate node information is repeated. Once at the destination node, it sends the addresses of all intermediary nodes to the source node as part of a Route Reply (RREP) message. Additionally, route maintenance makes certain that every node uses a routing table to monitor the route of the next destination hop. This information can be used to generate a route error message Route Errors (RERRs) if any intermediate node fails indicating that the path to the destination nodes is no longer reachable so as to determine a new route. Thus, there are 3 distinct routing messages in AODV protocols namely RREQ, RREP, and RERRs. The source node will broadcast the route request method before forwarding RREQ packets to the destination node through intermediary nodes. Each intermediate node stores only the nodes it received the RREQ packet from and the nodes it transmitted the RREQ packet. RREP data packets are sent upstream and unicast from the destination node to the source node after the RREQ packet has reached the destination node. Any nodes in the path that are connected to two nodes—the node from which it received the RREP packet and the node to which it broadcasts the RREP packet—update their data when a node uses RREP. When the source node receives the RREP packet, the route path is established, the shortest path between the source and destination nodes is selected, and a connection is established. An RERR message is transmitted upstream and downstream from the point of error to the source and destination nodes in situations such a path that is no longer functioning due to a node's inactivity, an unreachable destination node, and a link disruption. Depending on the kind of error, an effective fix is put into place.

Because it enables mobile nodes to establish routing pathways, AODV has noticed its extensive implementation in MANETs and VANETs. Moreover, path information does not need to be maintained by nodes that are not in use. As a result, a considerable quantity of work has been produced as a number of researchers have been interested in studying in this field. In the section that follows, authors attempt to describe the major discoveries made by eminent scholars.

2.2 Features of AODV protocol

AODV (Ad hoc On-Demand Distance Vector) is an efficient routing protocol for mobile ad hoc networks (MANETs). Its on-demand route discovery establishes routes only when needed, reducing control overhead and conserving bandwidth [7]. AODV ensures loop-free routes through the use of sequence numbers, preventing routing loops and ensuring stability [8]. The protocol's route maintenance feature monitors active routes and triggers rediscovery when links break, making it highly adaptable to dynamic topologies. By leveraging sequence numbers, AODV guarantees fresh routing information, avoiding stale routes. Additionally, its minimal control overhead uses a limited set of control messages, enhancing efficiency in dynamic networks.

3. Related Study

As discussed previously, AODV works in 2 phases viz. Route Discovery and Route Maintenance. It is made to be a resilient protocol that can endure various network problems such packet losses, link failures, and node movement. Owing to this robustness, AODV has the potential to be a prime player in VANETs. However, it has a shortfall in terms of broadcast storm and route stability limiting its application. Broadcast storm can be considered as bombardment of broadcast and multicast traffic that leads to consumption of a huge portion of network resources barring the communication. To solve this problem, a variety of strategies have been put forth, namely: location-based, cluster-based, distance-based, probabilistic, and counter-based methods. A simple counter-based scheme [9] eliminates several rebroadcasts when the host distribution is dense. Although the reachability of the farther distance-based strategy is higher, the amount of rebroadcasts saved is not adequate. It has been found that location-based schemes outperform because they may reduce reachability without compromising the majority of rebroadcasts under all host distribution scenarios.

H. Yu *et al.* [10] propose an RSU deployment strategy based on traffic demand in VANETs to address the problem of uncertainty in the transportation system, which results in changes in time that cause the relative positions between vehicles to fluctuate continuously and, in turn, cause changes in the communication topology relationship. Road networks are constructed using the Simulation of Urban Mobility (SUMO) software, and traffic data is then used to numerically simulate VANETs. Two optimization goals and a novel RSU deployment technique were implemented in this model. It first reduced the VANET latency and then increased the number of cars served by RSUs. More importantly, this approach is more realistic because it is based on traffic demand. To assess the impact of various traffic needs and road network topologies on the placement and deployment stage of RSUs, however, there was no combination of the real data available. The idea put up by O.K. Tonguz *et al*. [11] is to improve VANET connection on highways using RSUs. One of the main problems with many safety applications' design and implementation is that it is not possible to determine how long it will take for a message to heal between two nearby clusters. The purpose of this article is to deploy a few RSUs with a message advertising scheme in an effort to increase VANET connectivity. In this enhanced VANET environment, it additionally examines the broadcast-based safety applications' routing efficiency. First, the analytical performance of a unique safety message routing flow technique between the automobiles and the RSUs is proposed. The authors suggest a neighbor identification method that gauges the neighborhood's topology by keeping track of the regular hello updates that one-hop neighbours send. Nonetheless, it is essential to adapt this model to metropolitan environments because incidents are not dispersed equally across the road due to junction traffic, which is more complicated and accident-prone. For energy harvesting RSUs in VANETs, W.S. Atoui *et al.* [12] suggest offline and online scheduling algorithms where they investigate and utilize captured energy, which some researchers believe is insufficient to fulfill communication needs. Authors propose two near optimal algorithms using greedy heuristic and particle swarm optimization (PSO) respectively to solve the offline problem in polynomial time. Sindhwani *et al* [13] propose an improvisation of optimization technique and AODV routing protocol in VANET using Ant Colony Optimization (ACO). The strategy focused on finding the best path to the intended location to increase network resilience, which in turn improved throughput, delivery ratio, and delay reduction. This improved interoperability and stability. Nonetheless, there is still room for development by increasing the number of vehicle nodes in the network for locations with high traffic density and then adjusting different network characteristics.

In addition to VANET, the MANET's AODV protocol floods the network with routing control packets in an attempt to find a path to the target. Nevertheless, this can cause the battery's energy to run out quickly. This could be prevented by employing a fuzzy logic system. [14]. One effective method for creating reliable routes is fuzzy logic, which helps to overcome the drawbacks of more conventional routing protocols like the AODV. The four stages of fuzzy logic's operation are: fuzzification of the input crisp parameter values (node speed, node residual energy, and hop counts); assessment of the IF-THEN rules; aggregation of the outputs; and lastly, the defuzzification process. A significant improvement in the performance metrics is observed by employing fuzzy logic in routing protocol during the experimental setup.

Fog computing, a decentralized computer infrastructure where data, storage, and applications are stored somewhere between the data source and the cloud, is another suggestion made by authors in [15] to increase route stability. It is frequently employed for security, efficiency, and compliance purposes. The authors of [15] suggested that cars be thought of as fog nodes and that a unique method known as vehicular fog computing (VFC) be used. According to the suggested design, neighboring nodes constitute an infrastructure that helps end users communicate and do computing tasks. In addition to moving vehicles, stationary vehicles act at Road Side Units (RSUs) and contribute to the analysis at the edge of network facilitating data traffic routing along with existing RSUs.

In an effort to advance the study, scientists in [16] suggested optimizing AODV by applying the African buffalo optimization (ABO) method. The suggested protocol, known as B-AODV, performs better than conventional AODV because it uses a new criterion to create a robust path between the source and the destination. In addition, authors in [17] suggested a three-phase AODV routing system to handle AODV load balancing by classifying network traffic into three groups: high priority, low priority, and regular network traffic. As per the proposed protocol, the priority class route is reserved for a defined time period while an alternate route is determined for ordinary communication of neighboring sensors.

Although all of the top optimization protocols strive to provide effective communication, authentication continues to receive insufficient attention despite its undeniable importance. VANET's availability, integrity, and authentication could all be jeopardized because of how easily it can be attacked. As a result, methods for stopping and identifying these dangerous attacks are needed to create a safe and efficient ad hoc vehicular system. As per work suggested by authors in [20], it is necessary to detect black hole attack as it may lead to network collapsing. Authors in [20] propose an algorithm that successfully detects the malicious node removes it from the network. Experimental results demonstrate that proposed algorithms achieve an improvement in packet loss ratio over traditional AODV routing protocol. Authors in [21] have also proposed a novel Vehicular Authentication Security Scheme (VASS) that ensures secure communication among RSUs to OBUs (On-Board Units) using ID-based authentication. However, despite the significance requirement of security, the work done in this direction in terms of routing protocols is still lacking. An AODV-based Mutual Authentication Scheme for Constraint-Oriented Networks is proposed by M. Adil et al. [22]. The proposed technique resolves the black-hole attack issue.

AODV enhances link stability assessment by incorporating two additional headers: speed and distance between vehicles. This allows nodes to evaluate the stability of individual links [23-24], which can be aggregated to determine the overall stability of the entire route. As a node moves, it calculates its link lifetime with neighboring nodes and updates its routing table accordingly. This dynamic update process ensures that routing decisions reflect current conditions, improving the reliability and efficiency of the network.

Innovative routing protocols for VANETs and MANETs focus on enhancing efficiency and reducing latency. One method enhances the AODV protocol by predicting route lifetimes to reduce disruptions from vehicle mobility [20]. Another approach optimizes the placement of RSUs to minimize transmission delays and improve communication reliability [25]. Additionally, a comparative analysis shows that ant colony optimization algorithms outperform traditional routing protocols in finding shorter paths, collectively addressing the routing challenges in dynamic environments [21].

Recent enhancements to the AODV protocol [26] address routing challenges in MANETs due to frequent topology changes. Enhanced-Ant-AODV uses ant colony optimization for better path selection, while TOPSIS and Fuzzy algorithms improve route decision-making. Fungi network-based routing adapts biological methods, and Dynamic Power AODV (DP-AODV) focuses on energy efficiency. The Dragonfly algorithm offers a bio-inspired optimization approach. These algorithms are evaluated based on throughput, Packet Delivery Ratio (PDR), end-to-end delay, and routing overhead, highlighting performance improvements and identifying areas for further refinement.

The paper [27] provides a comprehensive review of the AODV routing protocol, highlighting its evolution and various extensions, such as QoS-AODV, MAODV, AOMDV, and SAODV, aimed at improving quality of service, multicast routing, multipath routes, and security. It categorizes AODV variants based on their objectives, such as energy efficiency and routing strategies, noting that despite extensive research, there is still room for improvement in unpredictable, resource-constrained MANETs.

Several studies have explored improvements to the AODV protocol [28] to address its limitations in route selection for MANETs. Traditional AODV uses hop count as the sole metric, often leading to unbalanced network load and path instability. Research has introduced various metrics such as energy, link stability, and velocity to enhance routing decisions. For instance, protocols like Energy-Aware AODV and Load-Balanced AODV incorporate node energy and network traffic to prevent congestion and extend network lifetime. These enhancements demonstrate improved performance in terms of path stability, network efficiency, and packet delivery ratio, offering better alternatives to the basic AODV protocol.

The paper [29] introduces OAM-AODV (Optimized Adaptive Multipath AODV Protocol) to enhance AODV by selecting optimal paths, reducing route discoveries, and minimizing packet drop through proactive link monitoring and switching to alternate paths before breakages. It improves throughput, reduces delay, and lowers control overhead by considering energy level, signal strength, and hop count for route selection.

Traditional AODV suffers from issues such as unstable paths, unreachable nodes, broadcasting storms, and short connection lifetimes, especially in environments with rapidly changing topologies, such as VANETs. To address this gap, the proposed solution incorporates reinforcement learning to dynamically update the state information of intermediate nodes, allowing for adaptive routing that ensures QoS guarantees in 5G-MANETs [30].

The elliptic curve Diffi-Hellman problem (ECDDHP) and elliptic curve integrated encryption standard (ECIES) are hybrid data encryption techniques that are used to further enhance the authenticity, confidentiality, and integrity of the data. Even if the method achieves the best average packet delivery ratio, the lowest end-to-end latency and communication cost, and the highest throughput, it is not appropriate for the multi-hop communication infrastructure.

Here, authors in this paper aim to bridge this research gap by proposing an algorithm that uses selective hopping technique for performance enhancement. Also it enhances AODV by addressing issues like route instability, packet loss, and broadcasting storms. By predicting link failures and optimizing route selection dynamically, it significantly improves the performance of AODV in ad-hoc networks like MANETs and VANETs, leading to more reliable communication in these environments.

The proposed enhanced algorithm is elaborated in the subsequent section.

4. Proposed Methodology

A large overhead result from traditional AODV sending many RREP packets in response to a single RREQ packet. Furthermore, AODV's periodic beaconing uses up a lot of bandwidth. As a result, when traffic volume exceeds a certain point, many vehicles using the shared channel at once to broadcast the same safety message choke the system. On the contrary, vehicles in sparse networks may experience network disconnections as vehicles in the desired direction may be beyond the transmission range [21]. Also, traditional AODV suffers a shortfall that intermediary nodes might cause inconsistencies in routes. Resultantly, it also has limitations in terms of overhead and packet loss.

The suggested algorithm reduces overhead and improves packet loss by using a selective hopping technique to address these problems. Additionally, by using many RSUs to provide route stability, the suggested solution greatly lessens the difficulties brought on by broadcast storms. It is important to note that, in contrast to conventional approaches that use parked cars as RSUs, the suggested strategy makes use of dedicated RSUs. This dedicated RSUs strengthens the performance of proposed method by ensuring the communication. Another improvement of proposed method is elongation of network lifetime even in case of broadcast storm. The proposed enhanced AODV differs from traditional AODV as follows:

I. Selection of stable route over shortest route

II. Deployment of multiple RSUs

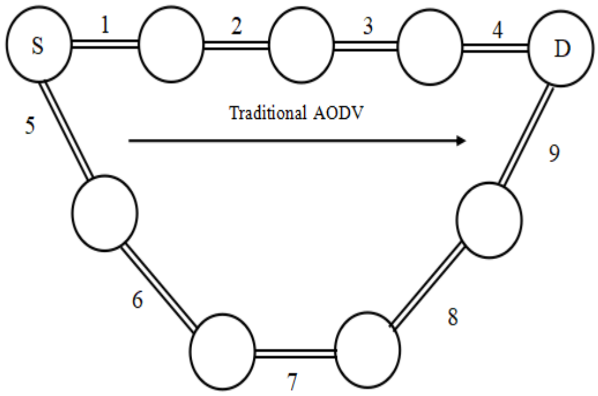

Figure 1. Route Selection in Traditional AODV vs. Improved AODV

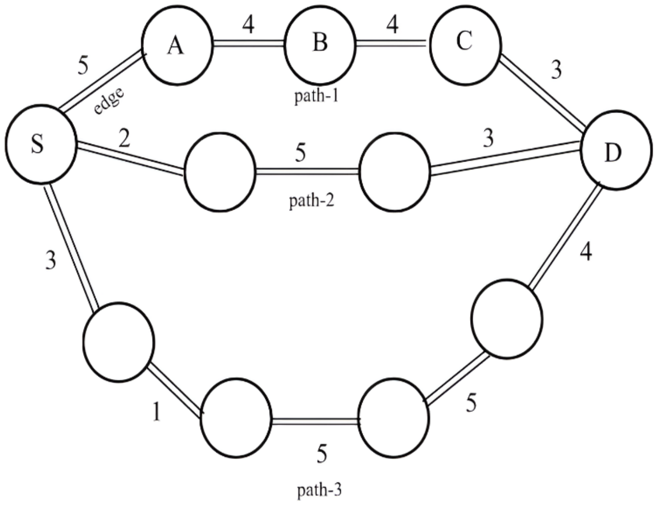

Figure 2. A scenario where multiple paths with edges are present between S and D

4.1 Selection of stable route over shortest route

As seen in figure 1, the suggested strategy selects a stable link over the shortest path (in classical AODV). The amount of time that incident nodes remain within each other's transmission range during the active link's duration determines how stable the link is. While nodes are constantly shifting and may result in cars traveling outside of transmission range, choosing a stable link increases the likelihood of effective communication via the shortest path. It can be understood that stable route stays alive for a longer duration. In order to determine the link stability, proposed AODV uses 2 additional headers namely speed and distance among vehicles.

The stability of the links can be aggregated to evaluate the stability of entire route [21-22]. Now whenever a node moves, it calculates its link lifetime with its neighbors and updates the routing table accordingly which is used to calculate the route lifetime.

As illustrated in figure 1, proposed enhanced AODV selects the stable route path S-5-6-7-8-9-D over shortest route S-1-2-3-4-D. Here, length of route is calculated by number of hops or intermediate nodes. This selection of stable route over shortest route is suggested owing to mobility in nodes leading to disruption in network routes. Here, route stability of a path among nodes s and d represented by l_i *(s,d)* along route *i* and can be formulated as:

$$l_i(s,d) = \left(\frac{\alpha}{d(a,b)} + \beta * rel(a,b)\right) \mid \forall (a,b) \in p_i(s,d) \quad (1)$$

Here, *d(a,b)* is the distance among nodes *a* and *b* where *(a,b)* is an edge along p_i *(s,d)*. *rel(a,b)* of the edge *(a,b)* indicates the reliability of edge and depends upon various factors namely bandwidth, traffic along the link etc. α and β are tuning parameters such that α+β=1. Let us consider the same using an example as shown in figure 2 for enhanced understanding. In figure 2, there are 3 paths namely p_1, p_2, and p_3 from source node *S* to *D*. The reliability of each link in the graph is written along the link. Now as evident from the figure 2, p_1 includes edges $S\,5 \rightarrow A\,4 \rightarrow B\,4 \rightarrow C\,3 \rightarrow D$. Here, numbers along the edge indicates reliability of the edge. Now, as per the equation (1), the route stability l_1 *(S,D)* is minimum of edge reliability of all edges in path p_1 from *S* to *D*. Now as there are 3 possible paths from *S* to *D* in figure 2, we have l_1 *(S,D)*=3, l_2 *(S,D)*=2 and l_3 *(S,D)*=1. Among all possible paths, the path p_i *(S,D)* with maximum l_i *(S,D)* is selected as per the proposed method.

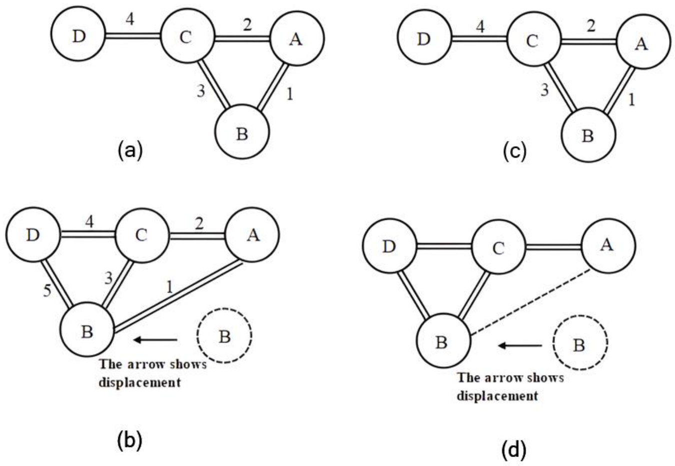

Figure 3. Traditional ((a), (b)) vs Proposed Link-lifetime management technique ((c), (d))

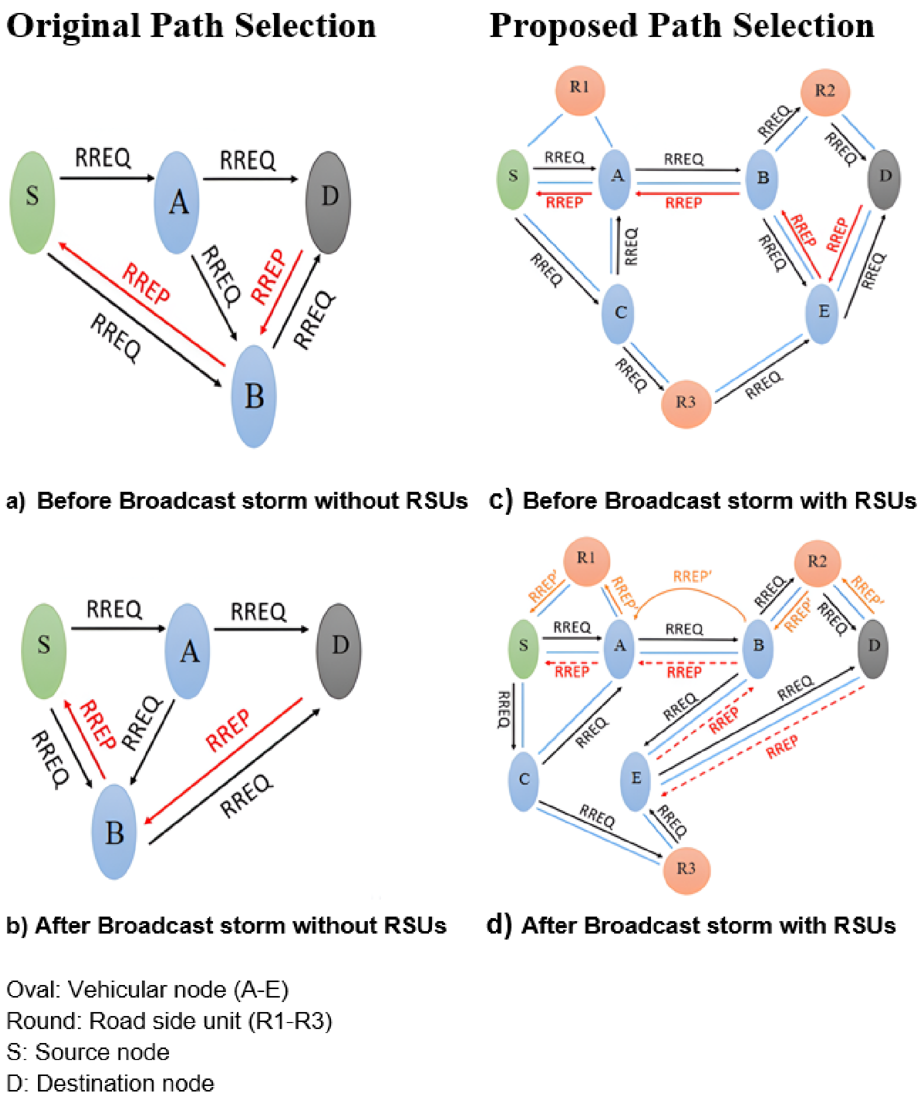

Figure 4. Path Selection in traditional ((a), (b)) and proposed enhanced AODV ((c), (d))

Further, figure 3 illustrates that usage of link lifetime ameliorates the connection of vehicles in proposed method. Here, figure 3(a) and 3(b) represent the traditional AODV and the figures 3(c) and 3(d) demonstrates the improved AODV. As vehicle B overtakes vehicle C, link 1 between vehicle A and vehicle B breaks off (shown by dashed line) in proposed method unlike traditional AODV. Now, as there are lesser links now, count of RREQ packets sent during route discovery decreases significantly. This helps to alleviate the rebroadcasting storm problem. The problem of broadcasting storm arises when there are dense nodes in a region leading to interference of radio signals. This causes failure of transmission of messages which may cause serious consequences in case of emergency situations. Hence, it is imperative to ensure that emergency messages are delivered without fail which is addressed by the proposed method.

4.2 Deployment of multiple RSUs

Vehicles broadcast packets for route finding to all nodes, including RSUs, in a conventional AODV. All of the packets with data on the vehicles' respective speeds and distances are received by these packets. When RSUs get these packets, they assess the relative speeds of the cars and choose the one that is closest to them in terms of relative speed to establish a direct link.

This is because vehicle is expected to interact with more vehicles in its due course of the journey and the probability of that vehicle receiving or generating emergency messages is high. This vehicle shares the messages with RSU so that RSU knows if there is any mishap in the vicinity. The RSUs can also be used to reduce the network latency leading to solving Delay Minimization Problem (DMP). This also aids towards dealing with variations in vehicle density and vehicle speed [5]. Each RSU has an assigned segments indicating its range and hence it communicates with the vehicle while it is in its designated segment beyond which it sends the message to next RSU. RSU's main purpose is to relay emergency messages to vehicles that aren't able to connect directly. Vehicles traveling in the same direction and on the same side of the road create VANETs according to the suggested strategy. The program also takes into account the fact that cars don't suddenly shift their direction of motion.

Figure 4 shows the suggested procedure. Unless a new RREQ is broadcast, nodes in classical AODV keep a single route to the target node. It is possible for a new path to be generated and saved after the RREQ has been generated. The older route may take longer to send messages since it is weaker and more unstable. As was previously said, conventional AODV always chooses the shortest option without taking connection and path stability into account. However, in proposed enhanced AODV, the older path (red line) is dropped (shown by dashed line) as it is prone to network delays and slower message transmission and new path is considered for future communication owing to its stability. The scenario before and after broadcast storm for traditional and proposed method is clearly illustrated in figure 4 for enhanced understanding of the reader.

The pseudocode for proposed Enhanced AODV routing method is as shown in Algorithm 1:

Algorithm 1. Proposed Enhanced AODV Routing Protocol

```
AODV_RREQ(RREQ, node Y) //Y: Destination node
begin
If(checkBroadcastStorm())
While(RREQ_TTL > 0) Do
BROADCAST RREQ to neighbouring node N
if(N_energy < Threshold) then
Drop RREQ
break while
Endif
if(N == Road_Side_Unit) then
RSU_count = RSU_count +1
AODV_RREQ(RREQ, node N, node Y)
Endif
Update Route_Table,Route_Path
Update Route_cache of every node
if(N == Y) then
Start RREP process
return
Endif
RREQ_TTL = RREQ_TTL - 1
endwhile
Endif
sendRREQBroadcast(node X ) //X is destination node
set destination_sequence_number to 1
set RREQ_hop_count = 0
BROADCAST RREQ to neighbouring Nodes
End
// Routing Request Handling Method
begin
receiveRREQ(RREQ, node X)
If(X == Destination_Node) then
Update Route_Table, Select_Stable_Route_Path(source, destination)
START sendRREPUnicast(node X, RREQ)
else if (RREQ_TTL > 0)
RREQ_TTL = RREQ_TTL - 1
RREQ_hop_count = RREQ_hop_count + 1
Update node X
Forward RREQ
else
Drop RREQ
Update Route_Table, Route_Path
Endif
End
// Routing Reply Unicast Method
Begin
sendRREPUnicastOverSelectedStableLink(node X) //chosen and calculated by destination
set destination_sequence_number to previous_node_sequence_number
set RREQ_hop_count to pathLength
Unicast RREP to previous Node (upstream flow)
End
//Route Reply Handling Method
begin
receiveRREP(RREP, Node X)
if(X == Source Code) then
Update Route_Table
If(Route_Path_length < prev_Path_length) then
```

```
Update Route_Path
Start communication
else
If(RREP_TTL > 0 and Route_Path_Energy < Threshold) then
RREP_TTL = RREP_TTL - 1
RREP_hop_count = RREP_hop_count + 1
Update node X
Forward RREP
else
Drop RREP
Send RERR // Error message for path
Endif
Endif
End
Select_Stable_Route_Path(node S, node D)
Begin
For every possible path i connecting S and D
Path[i] = LS (path i)
Endfor
J = max (Path[i])
Return path j
End
Calculate P[i] for every path
Begin
//Pi = ith path
//n = total number of routes available between Link(S,D)
//k = total number of edges present between Link(S,D)
//Li = ith edge
For i = 1 to n
min=L1;
For j = 2 to k
if(Lj < min) then
min = Lj;
Endfor
P[i]=min;
Endfor
End
```

In the proposed enhanced AODV routing protocol, authors have incorporated an important function *checkBroadcastStorm()* to check presence of broadcast storm. This broadcast storm may result due to presence of high number of vehicles in the smaller region. As per the proposed method, if broadcast storm is present, it drops the current path and a new RREQ broadcast is initiated by taking RSUs into consideration. However, the route will be selected based on stability of the path as discussed previously through *select_Stable_Route_Path(s,d).* RSUs can be used to establish this path selection between the source and destination nodes because they have information about all the nodes within their range. *select_Stable_Route_Path(s,d)* method selects the path which has more link lifetime over shortest path.

5. Implementation and Results

Table 1. Simulation Parameters for Implementation

Parameter	Values
Channel Type	WirelessChannel
Packet size	500 bytes
Network interface type	WirelessPhy
Interface queue type	PriQueue
X dimension of topography	3100
Y dimension of topography	2000
Maximum packet in queue length	100
Routing protocol	AODV
Acknowledgment-Based Broadcast Protocol	ABSM
MAC type	802.11
Simulation end time	40.0
Antenna model	OmniAntenna
Transport Layer protocol	TCP
Radio-propagation model	TwoRayGround
Application Layer protocol	FTP
Link layer type	LL

The proposed enhanced AODV is implemented on NS-2 on i5 processor with windows 11 Pro 64-bit operating system. The simulation setup parameters are given in Table 1.

Figure 5 shows the environment for the conventional AODV. In this case, a vehicle, also called a node, has a coverage area, which is its defined transmission range. Each vehicle is also equipped with OBU which is capable of exchanging data and control packets. Exchange of packets is shown by double sided arrows in figure 5 (a) while broadcast storm is demonstrated in figure 5(b).

As previously mentioned, as shown by the antennas in figure 6, the proposed AODV has stationary and dedicated RSUs positioned on both sides of the road. Deployment of stationary and dedicated RSUs ensure that no vehicles will be out of transmission range unlike in traditional AODV where vehicles could enter into no coverage zone and become isolated from the network.

Additionally, figure 6 shows how cars communicate with each other and with RSUs. The communication from RSU-30 to vehicle-5 is sent through vehicle-7, which is closest to the RSU-30, and subsequently travels through vehicle-6, as shown in figure 6(a). Further, figure 6(b) illustrates the communication among RSU-30 and vehicle-5. Now as vehicle-7 has gone beyond the transmission range of RSU-30, it uses vehicle-9 (being the nearest vehicle to RSU-30) to forwards the message. This scenario is quite common as each vehicle is moving at different speed and hence the links keep on changing quite often. The suggested AODV behaves like the old AODV, and RSU-30 is also functioning as a traditional node in figure 6.

However, as figure 7 illustrates, RSU-30's behavior varies if the context is altered.

As seen in figure 7, there is currently an accident or mishap close to RSU-22, and vehicle-8 has been notified of it. Vehicle-8 will now broadcast this message across the area so that appropriate action can be taken. Likewise, vehicle-8 chooses the trustworthy node. The Vehicle-7 as opposed to conventional AODV, which consistently chooses the closest node. Vehicle-7 again selects the reliable node among vehicle-6 and RSU-23. Here, RSU-23 is more reliable as it is stationary and hence the message is forwarded to RSU-23 which further forwards the message to RSU-22. Now RSU-22 will broadcast this message in its transmission range.

Now, in order to establish the efficacy of the proposed method, authors have used various performance parameters [21] which are Packet Delivery Fraction, Overhead, and Packet Loss Ratio.

The performance of the proposed enhanced AODV is compared with the traditional AODV, and the results are visually displayed in figure 8. Here, the x-axis represents time, and all performance metrics have been plotted in relation to it.

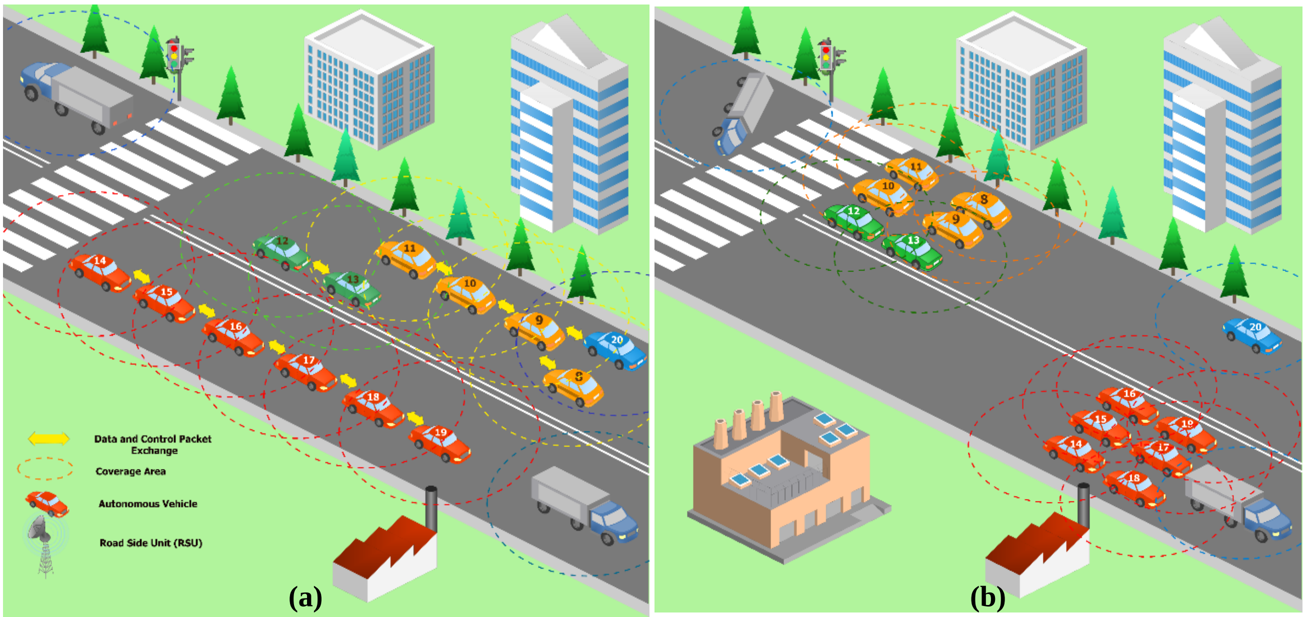

Figure 5. (a) Illustration of environment setup (b) Illustration of broadcast storm

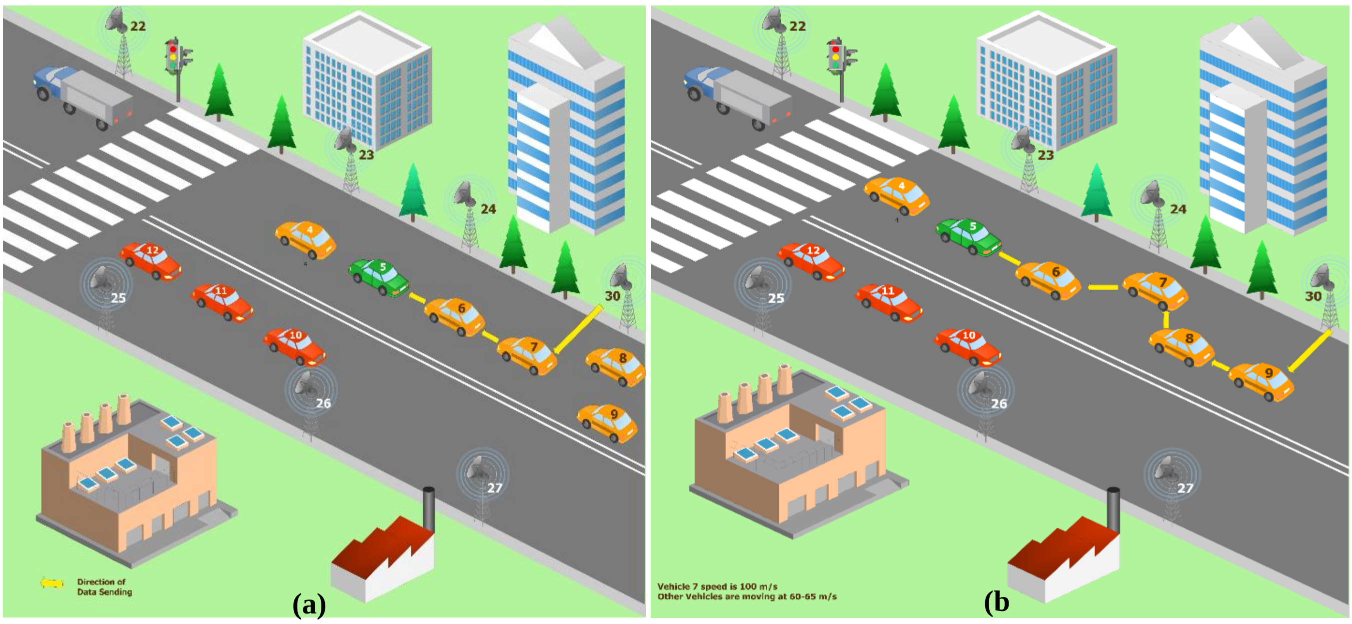

Figure 6. Environment setup (a) RSU- 30 sending data to Vehicle-7 (b) RSU-30 sending data to Vehicle-9

Figure 7. Illustration of proposed enhanced AODV in emergency

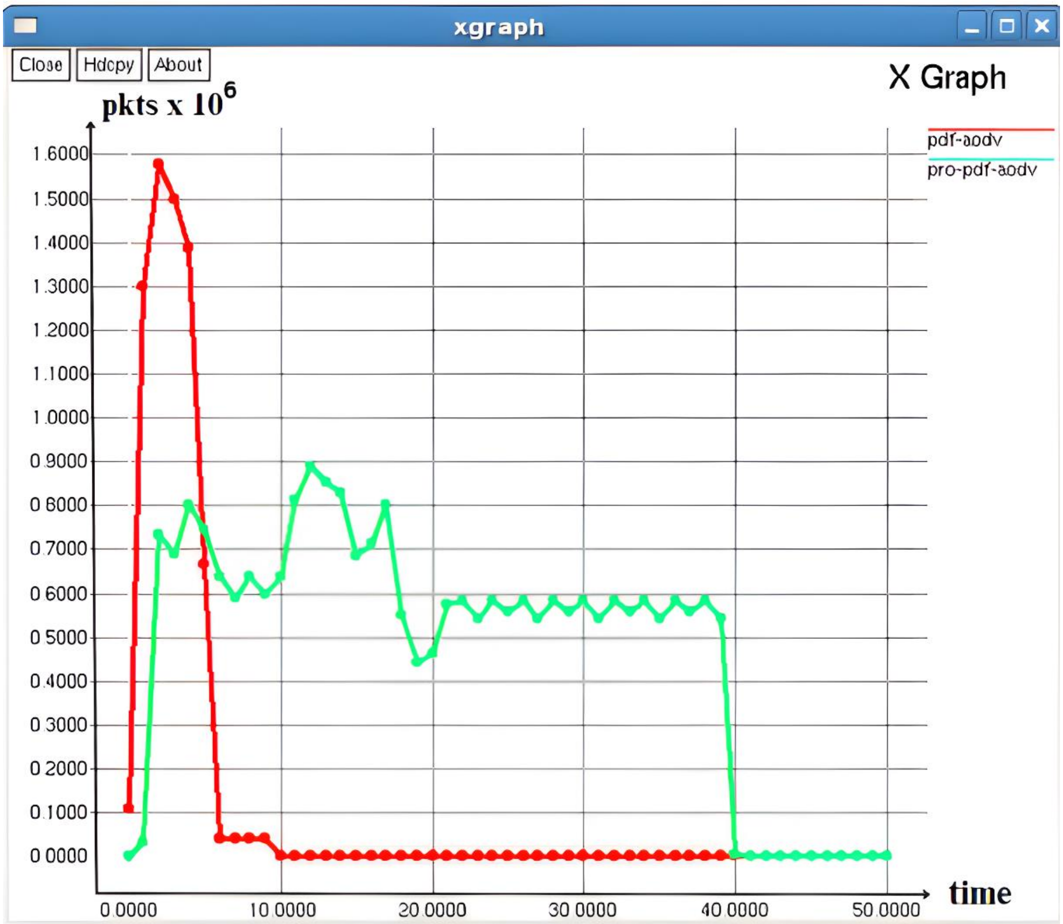

Figure 8. Comparative analysis of AODV and enhanced AODV: Packet Delivery Fraction vs. Time

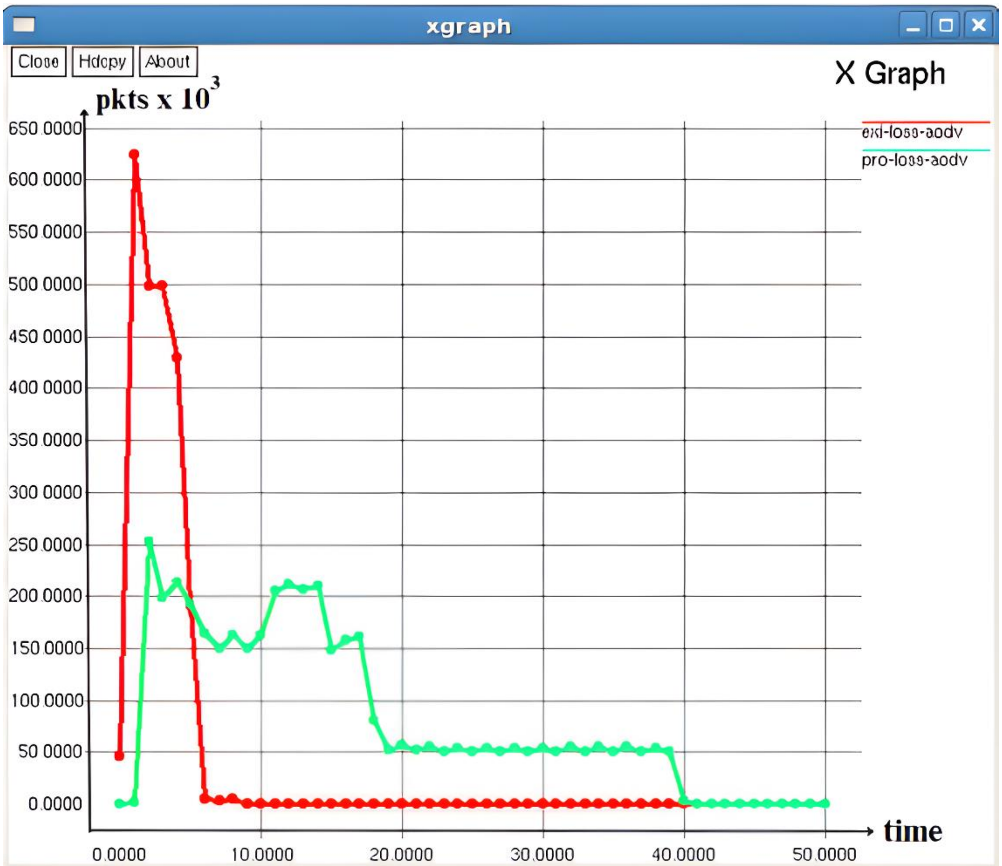

Figure 9. Comparative analysis of AODV and enhanced AODV: Packet Loss Ratio vs. Time

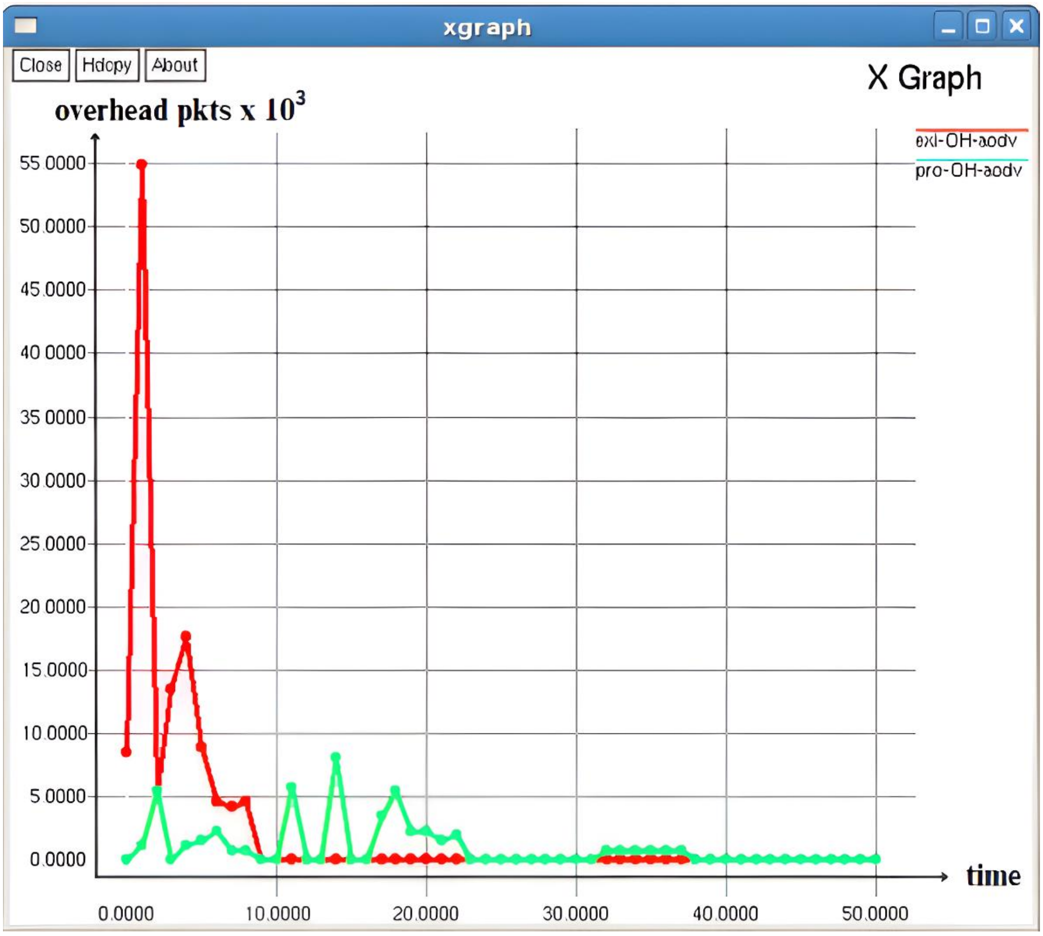

Figure 10. Comparative analysis of AODV and enhanced AODV: Overhead vs. Time

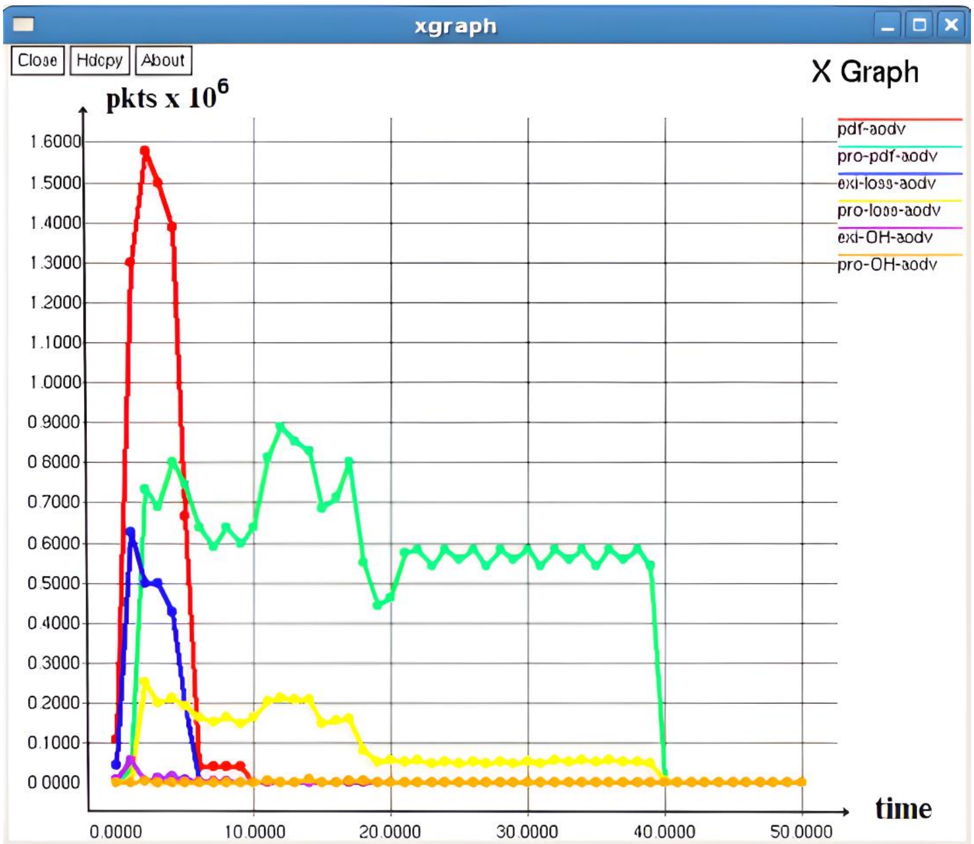

Figure 11. Comparative analysis of AODV and enhanced AODV: All performances vs. Time

The performance metric for the existing AODV is represented using a red line in figure 8, while the proposed enhanced AODV is plotted using a green line. Figure 8 illustrates the packet delivery fraction which clearly illustrates that packet delivery fraction for traditional AODV is very high in the beginning but rapidly converges to 0 owing to broadcast storm. On the other hand, packet delivery fraction for proposed AODV is moderately high and remains high for a long duration. This clearly advocates that proposed enhanced AODV alleviates the broadcast storm issue. Similar kind of behavior can be observed for packet loss ratio illustrated in figure 9.

The communication overhead is depicted in figure 10, which makes it abundantly evident that typical AODV has a significant upfront overhead. The network as a whole might be disrupted by this enormous overhead. Additionally, the suggested AODV's overhead always falls within a predetermined range, extending the network's lifetime. This is achieved because frequency of route discovery process and size of the routing table in proposed enhanced AODV significantly decreases. Also, the availability of bandwidth plays an integral role in decreasing the number of overheads in the new simulation. All said performance metrics have been combined in figure 11 for enhanced understanding of the reader.

It is clearly evident from the graphical representation that proposed enhanced AODV outperforms traditional AODV in terms of well-established performance metrics advocating its widespread employment. To validate the proposed approach, an NS2 simulation was conducted using varying numbers of nodes: 50, 100, 150, and 200. In each simulation, random scenarios were generated with different node placements, while keeping the RSU positions fixed. The performance metrics consistently demonstrated that the proposed enhanced AODV outperformed the existing AODV protocol.

6. Conclusion

The purpose of the current research is to provide an enhanced approach to AODV that can be used for emergency services and guarantees message delivery. The suggested approach uses stationary, dedicated RSUs to assure delivery. Additionally, because nodes are movable, the suggested technique prefers stable routes over shortest ones because the former constantly changes. The suggested approach is put into practice in NS2, and its effectiveness is contrasted with that of conventional AODV. This performance comparison is carried out with respect to established performance metrics namely Packet Delivery Fraction, Overhead and Packet Loss Ratio. The efficacy of proposed AODV is established as it achieves improvement in all performance metrics and hence can be widely deployed. Apart from significant improvement in performance metrics, the proposed approach also alleviates the issue of broadcast storm. Additional advantage of employment of stationary RSUs is that processing can also be carried out on these RSUs so that it acts as a fog node in fog computing. The requirement of having processing capability at RSUs further enhances in view of unprecedented rise in the network size.

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Authors Contribution Statement

Pratik Kanani: Investigation, conceptualization, validation, and writing—original draft. Neel Kothari: Investigation, data analysis, and writing—original draft. Lakshmi Kurup: Methodology and formal analysis. Deepali Patil: Data collection, visualization, and validation. Darshana Sankhe: Data curation and supervision. Gayatri Pandya: Review and editing. All authors have read and agreed to the published version of the manuscript.

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Competing Interests

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Has this article screened for similarity?

Yes

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