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Original Article

Generation of Optimal Multicast Routing in VANET using Particle Swarm Optimization

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Abstract - *VANET, or Vehicular Ad Hoc Network, is a type of ad hoc network that enables communication between vehicles on the road and between vehicles and other roadside infrastructure. Multicast routing in VANET for intelligent traffic management involves efficiently transmitting data packets from a single source to multiple destinations. Vehicles in VANET are constantly moving, which makes it difficult to maintain connectivity and establish communication between vehicles. Furthermore, high-speed and rapid movements of vehicles, which can lead to frequent disconnections and packet losses, can create sudden gaps in the network, which can lead to data loss and communication breakdowns. In order to overcome such a situation, the current research work implemented an evolutionary algorithm known as Particle Swarm Optimization (PSO), which makes a robust and efficient routing protocol to ensure reliable communication.*

Keywords - *Multicast routing, Vehicular Ad-Hoc Network, Particle Swarm Optimization, Greedy forwarding, Packets delivery rate.*

1. Introduction

VANET technology is designed to improve road safety and traffic efficiency by allowing vehicles to share information about road conditions, traffic, and potential hazards with each other in real-time.

The technology is based on the principle of ad-hoc networking, which means that it is self-organizing and does not rely on a fixed infrastructure to operate. Instead, each vehicle in a VANET acts as a node in the network, communicating with other nearby nodes to form a dynamic, decentralized communication network. VANET-enabled vehicles could receive information about the optimal route based on current traffic conditions, helping to avoid congestion and reduce travel time.

1.1. VANET Applications

VANET has several applications, as listed below:

1.1.1. Collision Warning System

The system uses VANET to exchange safety-related information between vehicles to prevent accidents. The system detects potential collisions and sends warnings to the drivers to avoid collisions.

1.1.2. Smart Parking System

The Smart Parking System is an innovative VANET technology application that helps driver finds available parking spots in real time. The system uses wireless communication between vehicles and infrastructure to identify available parking spaces and share that information with nearby vehicles.

1.1.3. Emergency Vehicle Notification System

The system uses VANET to notify the surrounding vehicles about the presence of emergency vehicles, such as ambulances and fire trucks. The system sends alerts to the vehicles to clear the path for emergency vehicles to pass through.

1.1.4. Traffic Management

VANET can be used to manage traffic flow by collecting and analyzing data about traffic patterns, congestion, and accidents to enhance traffic efficiency. This information can be used to optimize traffic flow and reduce congestion on busy roads.

1.1.5. Navigation

Delivery vehicles equipped with VANET technology could be monitored and managed in real-time, allowing companies to optimize their delivery routes and schedules for maximum efficiency.

2. Literature Survey

Authors in [1] discuss the challenges and potential applications of Vehicle Ad-Hoc Networks (VANETs), which have emerged as an exciting research area due to the increasing use of embedded sensors, processing, and wireless communication capabilities in vehicles. The paper highlights the unique characteristics of VANETs, including their dynamic topology and intermittent connectivity. It discusses the challenges associated with ensuring application quality of service and managing privacy and safety concerns.

Single-layer and cross-layer routing techniques in vehicular ad-hoc networks (VANETs) which play a crucial role in improving transportation security and efficiency [2]. This work highlighted the challenges associated with traditional single-layer routing protocols. It emphasised the importance of cross-layer routing protocols that utilise information from the lower layers of the OSI model.

Boussoufa-Lahlah et al. [3] provide a survey of geographic routing protocols (GR) or position-based routing protocols (PBR) for vehicular ad hoc networks (VANETs) that use the vehicles' positions instead of IP addresses to select the best path for forwarding data. Liang et al. [4] presented an overview of Vehicular Ad Hoc Networks (VANETs) and their unique characteristics, such as high dynamic topology and predictable mobility, which make them an attractive research area for both academia and industry. A comprehensive survey on VANETs highlights their potential to improve road safety and provide comfort to travellers [5]. It presents various aspects related to VANETs, including their architecture, challenges, characteristics, and applications. Ghebleh [6] presented a comprehensive survey on information dissemination in vehicular ad hoc networks (VANETs).

The focus is on critical issues such as security, privacy, adaptability, and scalability. Sharef et al. [7] presented a taxonomy of current routing protocols for VANETs, discussed their advantages and weaknesses, and highlighted unaddressed problems in the field. A comprehensive overview of geographic routing in wireless ad hoc networks, where the position information of nodes is available, covers basic principles, classical techniques, the latest advances, and practical aspects of geographic routing [9]. The authors in [8] proposed five distinct communication patterns that form the basis of almost all VANET applications, which can help to simplify the development of VANET communication systems. The importance of efficient and reliable routing in VANETs due to the fast mobility and intermittent link connectivity between vehicles is discussed in [10].

It focuses on the recent developments in traffic-aware routing (TAR) protocols that aim to make routing protocols robust to frequent communication disruptions and aware of unstable traffic and network conditions, helping in the improvement of the reception of broadcast messages in VANETs, particularly for safety-critical applications. They studied the probability of reception based on distance and signal strength and found that using priority access mechanisms can improve reception rates [11].

Jerbi et al. [12] proposed an improved inter-vehicle ad-hoc routing protocol called GyTAR, specifically designed for city environments with constrained but high mobility patterns, node distribution, and signal transmissions blocked by obstacles. The protocol consists of two modules: dynamic selection of junctions and an improved greedy strategy for packet forwarding. A geographic stateless routing protocol for VANETs called GeoSVR [13] combines node location and digital maps to enhance forwarding paths and overcome connectivity and network partition issues.

The proposed restricted forwarding algorithm also addresses unreliable wireless channel issues. A new routing protocol is proposed in [14], RPS (Reactive Pseudo-suboptimal-path Selection routing protocol), for Vehicular Ad Hoc Networks (VANETs) that addresses intermittent connectivity problems due to vehicle mobility. The protocol allows recently passed intersections to unilaterally determine a suboptimal path, improving the probability of transmission through wireless channels. A traffic-aware position-based routing protocol for VANETs suitable for city environments, called Efficient GSR, is proposed in [15].

It uses an ant-based algorithm to find a route with optimum network connectivity. The simulation results show that the proposed protocol outperforms existing VANET routing protocols in terms of packet delivery ratio, routing control overhead, and end-to-end delay. An attempt is made to improve the accuracy of knowing where nearby vehicles are in Vehicular Ad Hoc Networks (VANETs) [16]. Current methods involve sending messages with location information very frequently, which can use up too many network resources.

Hybrid Broadcasting Protocol (DHBP) [17] helps to broadcast messages effectively while minimizing the delay and the number of broadcasts. DHBP outperforms previous work in terms of reachability, number of broadcasts, and delay, even in congested areas. The prediction of the location of vehicles in vehicular ad-hoc networks (VANETs) using a Kalman filter optimizes resource allocation and performance improvement in VANETs [18].

The previous studies dealt with a few optimization parameter criteria in VANETs for delivering packets from the source node to the destination node. Further, no clear mathematical modeling for VANETs has been described for the implementation. The current study focused on the development of an intelligent strategy that considers various parameters such as packet delay, number of hops, energy consumption, and packet delivery rate. In this paper, an evolutionary algorithm named particle swarm optimization is induced to solve the VANET multicast problem.

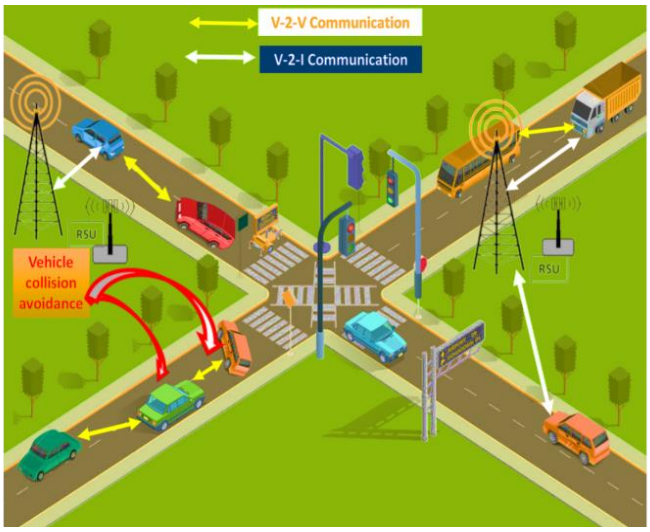


Fig. 1 VANET structure

3. VANET Structure

As discussed earlier, VANET or Vehicular Ad Hoc Network is a type of ad hoc network that enables communication between vehicles on the road and between vehicles and other roadside infrastructure. There are mainly two types of VANETs based on their Network Topology, i.e. (i) Infrastructure-based VANETs and (ii) Infrastructure-less VANETs. In *infrastructure-based VANETs*, communication between vehicles is facilitated by roadside infrastructure such as base stations, access points, and roadside units.

This infrastructure provides a backbone for communication between vehicles and can be used to transmit information about road conditions, traffic congestion, and accidents. In *infrastructure-less VANETs*, communication between vehicles is facilitated by ad-hoc networking protocols. Vehicles act as nodes in the network and communicate with each other directly. Infrastructure-less VANETs do not rely on roadside infrastructure and can operate in areas where there is no infrastructure.

The current research work focused on *infrastructure-based VANETs,* and it has the following advantages:

1) Infrastructure-based VANETs have a higher coverage area than infrastructure-less VANETs.
2) The use of infrastructure allows for more reliable and efficient communication between vehicles.
3) Infrastructure-based VANETs can be used to provide additional services, such as location-based services and real-time traffic updates.

A typical VANET architecture is represented in Figure 1. The communication among the vehicles and the infrastructure is done as follows:

3.1. Communication and Protocols

3.1.1. Vehicle-to-Vehicle (V2V) Communication

In this type of architecture, communication is established between vehicles within the communication range. V2V communication enables vehicles to exchange information related to road conditions, traffic congestion, and other relevant information. The key advantage of V2V communication is that it provides real-time information to the driver, which can help in avoiding accidents and improving traffic flow.

3.1.2. Vehicle-to-Infrastructure (V2I) Communication

In this type of architecture, communication is established between vehicles and roadside infrastructure, such as traffic lights, cameras, and other sensors.

V2I communication enables vehicles to receive information related to road conditions, traffic flow, and other relevant information. The key advantage of V2I communication is that it can provide advance warning to the driver about any potential danger ahead. V2I communication can provide more accurate and up-to-date information about the road and traffic conditions. V2I communication can also be used for applications such as toll collection and parking management. The system consists of a centralized architecture, which has a central entity that is responsible for managing the network.

The key advantage of a centralized architecture is that it can provide better network management and control. In centralized VANETs, there is a central authority that controls and manages the communication between vehicles. There can be following two communication protocols:

- *DSRC*: DSRC is a wireless communication standard designed specifically for VANETs. DSRC uses the 5.9 GHz frequency band and can provide high data rates and low latency. DSRC can support both V2V and V2I communication and can provide reliable and secure communication. However, the disadvantage of DSRC is that it requires a separate infrastructure and may cause interference with other wireless systems.
- *C-V2X*: C-V2X is a cellular communication standard that can support both 4G and 5G networks. C-V2X can use both direct communication (V2V) and cellular communication (V2I) and can provide high data rates and low latency. C-V2X can also provide a seamless integration with other cellular services.

3.2. Challenges in the Implementation of VANET

There are several challenges during the implementation of VANET. Very few of them are detailed here:

- *Security & Privacy:* Security is one of the significant challenges in VANETs. As VANETs are vulnerable to various security threats, including malicious attacks, privacy breaches, and denial of service attacks, ensuring the security of VANETs is crucial.
- *Mobility and Connectivity:* Vehicles in a VANET are constantly moving, which makes it difficult to maintain connectivity and establish communication between vehicles. Furthermore, high-speed and rapid movements of vehicles, which can lead to frequent disconnections and packet losses, can create sudden gaps in the network, which can lead to data loss and communication breakdowns.
- *Quality of Service (QoS):* Ensuring QoS is another significant challenge in VANETs. The QoS requirements of VANETs are different from traditional wireless networks as they need to support real-time applications with low latency and high bandwidth requirements.
- *Cost and Scalability*: Scalability is another significant challenge in VANETs. As the number of vehicles and devices in the network increases, the network becomes more complex, and the communication overhead increases. Ensuring efficient communication between a large number of vehicles and devices is essential to maintain the performance of VANETs.
- *Reliability*: VANETs must provide reliable communication between vehicles and infrastructure, even in harsh environments, such as bad weather and high traffic density. Reliability is critical to ensure the safety and efficiency of VANETs.
- *Energy Efficiency:* Energy efficiency is another significant challenge in VANETs. As VANETs operate in a resource-constrained environment, optimizing energy consumption is essential to prolong the network's lifetime.

The current study is based on the following details of VANET architecture as illustrated:

Table 1. Study details of VANET architecture

Architecture	• infrastructure-based VANETs
Communication	• Vehicle-to-Vehicle (V2V) • Vehicle-to-Infrastructure (V2I)
Protocol	• Dedicated Short Range Communication (DSRC)
Addressed Challenges	• Mobility and Connectivity • Quality of Service • Cost and Scalability • Reliability • Energy Efficiency

4. Mathematical Modeling

Designing an efficient multicast routing protocol for intelligence traffic systems in Vehicular Ad hoc Networks (VANETs) provides reliable and timely delivery of traffic and safety-related information to multiple recipients while minimizing communication overhead, maximizing network throughput, and reducing transmission delay and packet loss. Multicast routing in VANET for intelligent traffic management involves efficiently transmitting data packets from a single source to multiple destinations. To achieve this, this paper addresses the methodology with the following six phases-

- *PHASE-I: Source and Destination Identification*

In the first phase, identification of the source and destination nodes that are involved in multicast communication is done.

- *PHASE-II: Build Network Topology*

In the second phase, the building of the network topology is considered so that the shortest path protocol can easily do data communication among the nodes.

- *PHASE-III: Multicast Tree Formation*

Once the network topology is established, the nodes can be grouped based on their location and communication requirements. This helps to reduce the number of data packets that need to be transmitted.

- *PHASE-IV: Routing Protocol Algorithm*

In this phase, a multicast routing algorithm is used to identify the optimal path for transmitting data packets from the source node to the destination nodes. Due to high mobility, the nodes can join and leave the network frequently. Therefore, the multicast tree must be adaptive and able to handle changes in the network topology.

- *PHASE-V: Quality of Service Mechanism*

In this phase, implementation of Quality of Service (QoS) mechanism is implemented to ensure that the data packets are delivered within a certain delay, and with low packet loss. Several QoS mechanisms, like packet scheduling, priority-based routing, and congestion control, have been considered.

- *PHAS-VI: Performance Evaluation and Optimization*

In the final phase, the performance of the multicast routing protocol is evaluated. This can be done by evaluating the various metrics like packet delivery ratio, end-to-end delay, and packet loss.

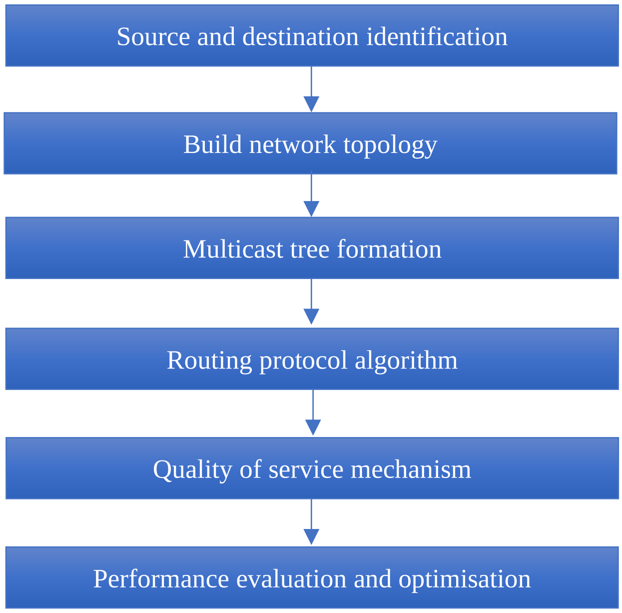


Fig. 2 Flow process of current methodology

Optimum forwarder selection is the process of choosing the best node in a wireless ad hoc network to forward data packets to their destination. The selection of the forwarding node is critical as it affects the performance of the network, including packet delivery rate, energy consumption, and congestion. Overall, selecting the best forwarder depends on the specific requirements of the network and a balance between different objectives, such as minimizing delay, reducing energy consumption, and avoiding congestion. Optimum forwarder selection is a key aspect of LBR, as it determines the path that packets will take to reach their destination. The forwarding node is selected based on a number of criteria, such as its distance to the destination, its connectivity to other nodes, and its available energy.

In this study, several parameters are considered for optimum forwarder selection, including:

- *Energy-Aware Forwarding*

In this approach, the forwarding node is selected based on its available energy. Nodes with higher energy levels are preferred as forwarding nodes, as they are more likely to remain active for longer periods of time.

- *Packet Delivery Rate*

The packets are to be delivered at the earliest so that beacon messages from the vehicle will not be lost. This feature is highly essential as the VANET has a high mobility feature.

- *Greedy Forwarding*

In this approach, the node that is closest to the destination is selected as the forwarding node. This approach is simple and efficient but can result in congestion in the network, as nodes closer to the destination may become overwhelmed with traffic.

- *Minimizing Delay*

This involves the packets to be received from the destination node at the earliest possible.

- *Reducing the Number of Hops*

The forwarding node is chosen based on its proximity to the destination node. The node that is closest to the destination is selected as the forwarding node, which can help minimize the delay and reduce the number of hops. Overall, the choice of optimum forwarder selection approach depends on the specific requirements and constraints of the network. By carefully considering the available options and selecting an appropriate approach, the performance of routing in wireless ad hoc networks can be optimized for a variety of applications and scenarios.

4.1. Fitness Function for Energy-Aware Forwarding and Packet Delivery Rate

Let us consider that there are eight vehicles based on specific criteria, and the network is represented as shown in Fig.3. Assume that the message to be received to the first node from the destination node is the 8th vehicle.In the five parameters discussed above, the first three can be optimized by selecting the nearest node to the source node.

Therefore, the Fitness function

$$F = D_{s,j} \quad (1)$$

Where, $D_{s,j}$ represents the Euclidian distance between the source and the j^{th} connected node.

$$D_{s,j} = \sqrt{(S_x - j_x)^2 + (S_y - j_y)^2} \quad (2)$$

(S_x, S_y)= Position representation of source node in the network
(j_x, j_y)= Position representation of a j^{th} node in the network

Therefore, the optimal node, which has the minimum fitness value among the connected nodes, will be selected.In the considered example, the source is 1-node and is connected with the 2nd,5th, and 6th nodes. Among these connected nodes, the node that is maintaining a minimum distance will be treated in order to forward the packets to the source node.

$$Optimal\ Fitness = Min(D_{s,j}) \quad for\ j = all\ connected\ nodes \quad (3)$$

In the above example, the 6th node is nearest to the source node and is selected for forwarding packets to the source node.

4.2. Fitness Function for Minimizing Delay and Number of Hops

In the above example, it is assumed that the message to be received to the first node from the destination node is the 8th vehicle. In the five parameters discussed above, let us consider the optimal criteria for minimizing delay and the number of hops to forward the messages from the destination node to the source node.
Therefore, the Fitness function

$$F = D_{dest,k} \quad (4)$$

Where, $D_{dest,kj}$represents the Euclidian distance between the destination and k^{th}source-connected node.

$$D_{dest,k} = \sqrt{(dest_x - k_x)^2 + (dest_y - k_y)^2} \quad (5)$$

$(dest_x, dest_y)$= Position representation of source node in the network
(k_x, k_y)= Position representation of a k^{th} node in the network

Therefore, the optimal node, which has the minimum fitness value among the connected nodes, will be selected.

In the considered example, the source is 1-node and is connected with the 2nd,5th, and 6th nodes. Among these connected nodes, the node that maintains a minimum distance toward the destination node will be treated as an optimal node to forward the packets to the source node.
Optimal Fitness = Min($D_{dest,k}$)

$$for\ \ k = all\ source\ connected\ nodes \quad (6)$$

In the above example, the 5th node is nearest to the source node and is selected for forwarding packets to the source node, as shown in Fig.5.

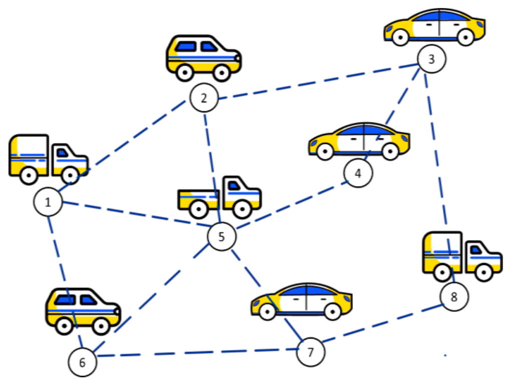


Fig. 3 VANET Formation

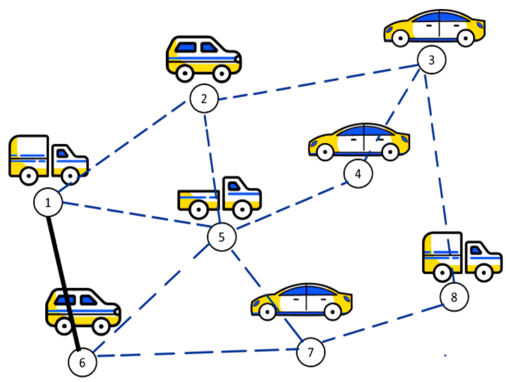


Fig. 4 Optimal node selection in VANET

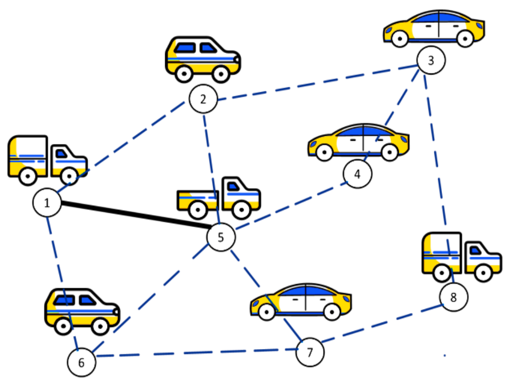


Fig. 5 Optimal node selection in VANET minimizing delay and number of hops

5. Particle Swarm Optimization and Implementation

An evolutionary algorithm named Particle Swarm Optimization (PSO) is implemented to solve multicasting in the VANET structure.

5.1. PSO Architecture

PSO is an evolutionary algorithm that mimics the behavior of fish schooling and bird flocking to gather food from its source place. PSO is a population-based strategy that works according to the decision made by the swarm. Let us assume there are 'n' numbers of particles in the swarm, and each particle is said to be an individual in the swarm.

$$Swarm = \{p_1, p_2, \ldots, p_n\} \tag{7}$$

Where, p_i = i[th]Particle

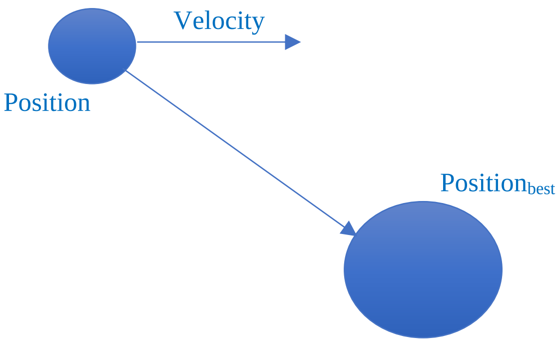


Fig. 6 Position$_{best}$ representation in PSO

Each individual has position and velocity and is represented below.

$$position = \begin{cases} x_1, x_2, \ldots, x_n \\ y_1, y_2, \ldots, y_n \end{cases} \tag{8}$$

$$velocity = \{v_1, v_2, \ldots, v_n\} \tag{9}$$

Here, the position of the particle is represented in two-dimensional scale correspondence to the x and y dimensions. Now, each individual wants to move to their own best position, i.e. $position_{best}$ as represented in Fig.6.

However, the swarm will decide one global best position where each of the particles should move, as shown in Fig.7. Once the swarm's best position value is represented, each individual tries to approach the $Swarm_{best}$ Position by updating its position and velocity, as represented in Fig.7.

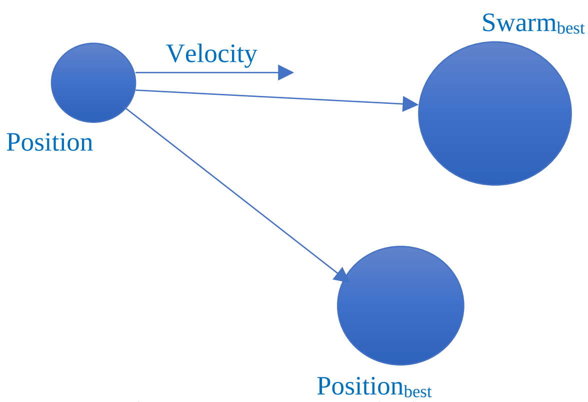


Fig. 7 Swarm$_{best}$ representation in PSO

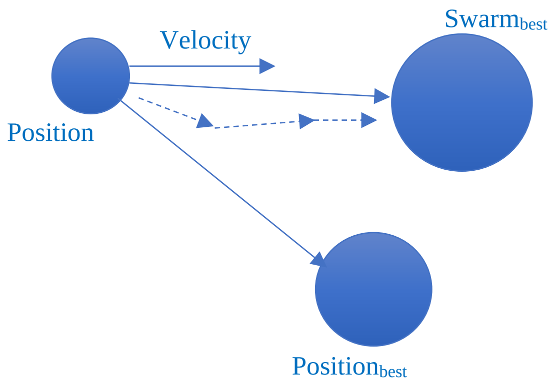


Fig. 8 Position and Velocity update of each individual

The updated position and velocity are represented in equations (10) and (11).

$$position_{update} = position_{current} + C_1 \times r_1 \times (position_{best} - position_{current}) + C_2 \times r_2 \times (Swarm_{best} - position_{current}) \tag{10}$$

$$velocity_{update} = velocity_{current} + position_{update} \tag{11}$$

Where,

C_1&C_2 are cognitive paremeters varies in between[0,1] and r_1&r_2 are random paremeters varies in between[0,1]

5.2. PSO Implementation

PSO is implemented to the multicasting in VANET as follows:

5.2.1. Step-1

This step is algorithm initialization. In this initial step, RSU is considered at road side which has a range capacity of 100m. as shown in Fig.9.

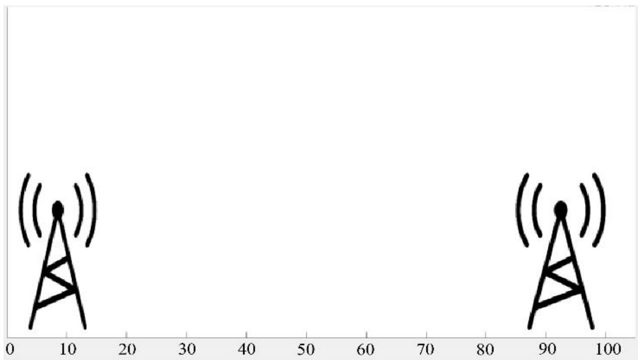


Fig. 9 RSU installed at roadside with the range of 100m

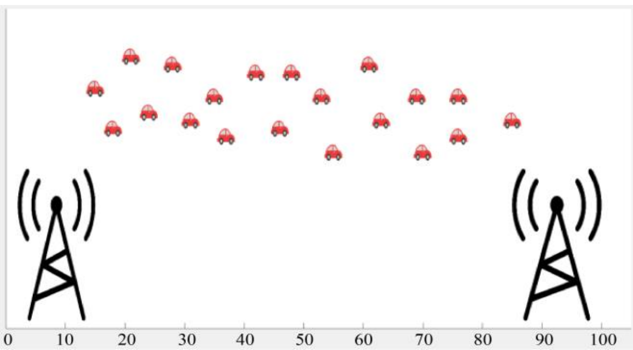


Fig. 10 Number of vehicles identified in the RSU range

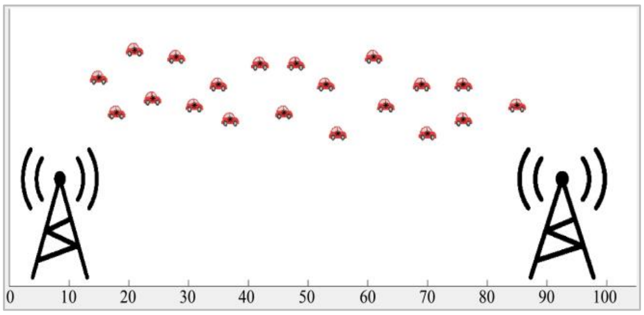


Fig. 11 Position representation of vehicles in the RSU range

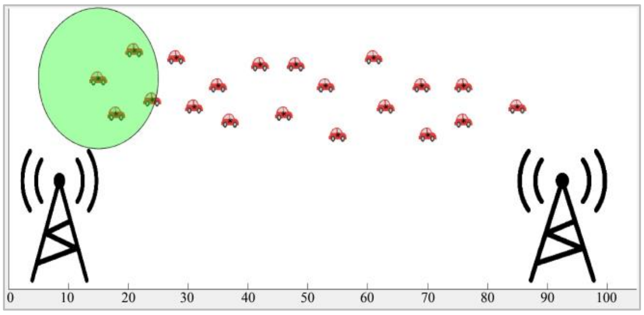


Fig. 12 Representation of the number of vehicles in the first vehicle OBU range

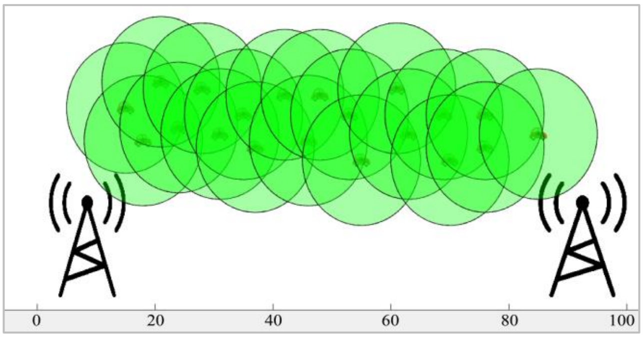


Fig. 13 Representation of OBU range of vehicles in RSU

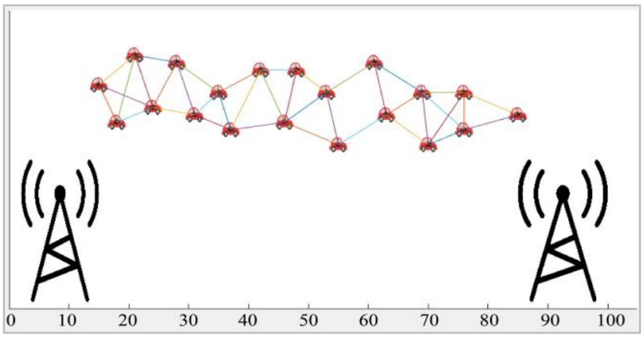


Fig. 14 Network Formation among the vehicles in the of RSU

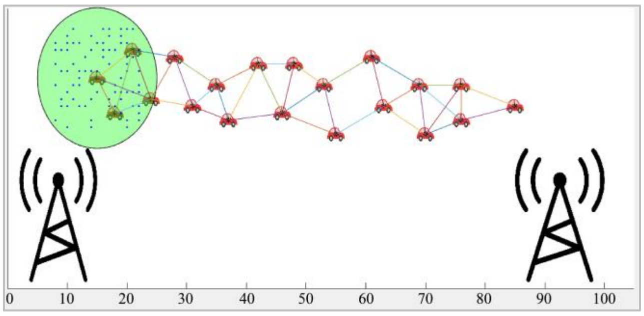


Fig. 15 Swarm generation in the source vehicle's OBU range

5.2.2. Step 2

In this range, number of number of vehicles will be treated as nodes to form the network as represented in Fig.10.

5.2.3. Step-3

Each of the vehicles is supposed to be installed with one On-Board-Unit (OBU) and GPS unit such that the position of the vehicle is familiar, and the same is represented in Fig.11

5.2.4. Step-4

The details of the vehicle, such as OBU range, beacon data, energy stored in the unit, etc., will be transferred to RSU for network formation. The range of the first vehicle is represented in Fig.12. Similarly, each vehicle is occupied with its own OBU range, as represented in Fig.13.

5.2.5. Step 5

Once the communication between RSU and OBU is completed, a network will be formed among the vehicles, as shown in Fig.14.

5.2.6. Step 6

Once the network is created, PSO will be activated. In this step, 100 number of the population is generated at the source node within its OBU range, as represented in Fig.15.

5.2.7. Step-7

Once the swarm is generated in the OBU range, each particle will be evaluated for the fitness value according to the equations (3) and (6).

5.2.8. Step 8

Each particle's current position is treated as its $position_{best}$ until $Swarm_{best}$ is identified. $Swarm_{best}$ is the particle that has a minimum fitness value.

5.2.9. Step-9

The vehicle which is closer to the $Swarm_{best}$ will be considered as the node for forwarding messages to the source node. Accordingly, the position and velocity of each individual will be updated based on the equations (10) and (11).

5.2.10. Step-10

Steps 7 to 9 will be repeated until the $Swarm_{best}$ is equal to the destination node.

Table 2. VANET parameter consideration

S.No.	Description	Value
1	Number of vehicles	20
2	RSU Antenna range	100 m
3	OBU Range	10 m
4	Packet size	64 bytes
5	Mobility Model	Random waypoint
6	Traffic model	Constant bit rate
7	Propagation model	Two-way Ground
8	MAC protocol	IEEE 802.11

6. Results and Discussion

The proposed methodology is implemented for the scenario which has the following parameter settings [19] as illustrated in Table 2.

The environment is considered in the MATLAB 2022 version to validate the proposed methodology. At a specific instant, it is assumed that RSU identified 20 number of vehicles (N). Since each vehicle has its OBU range of 10m. it generates 39 number of edges (E), as represented in Fig.16.

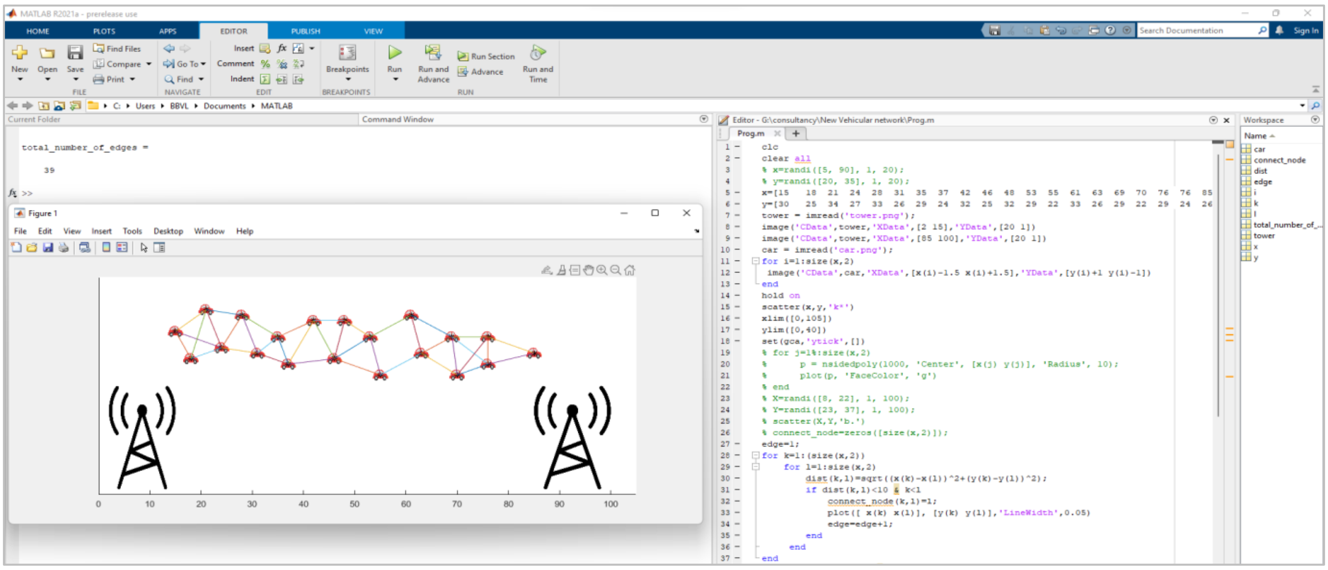


Fig. 16 Representation of number of edges in VANET

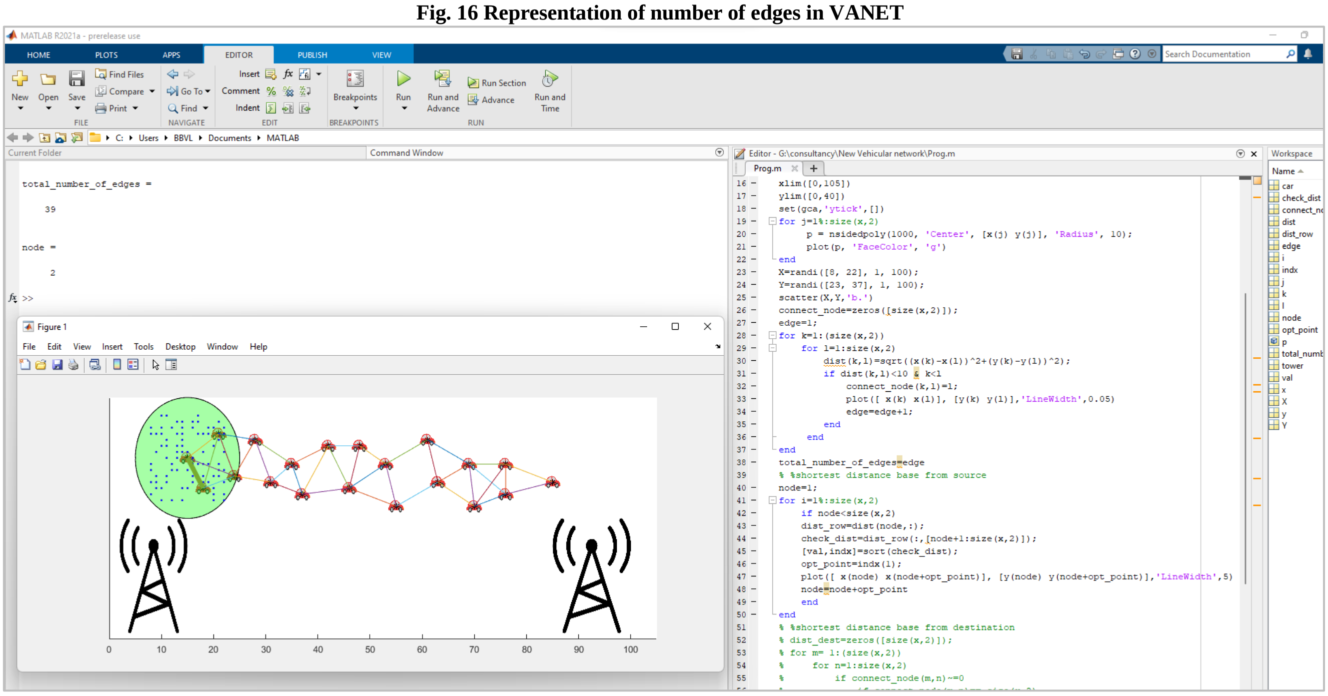
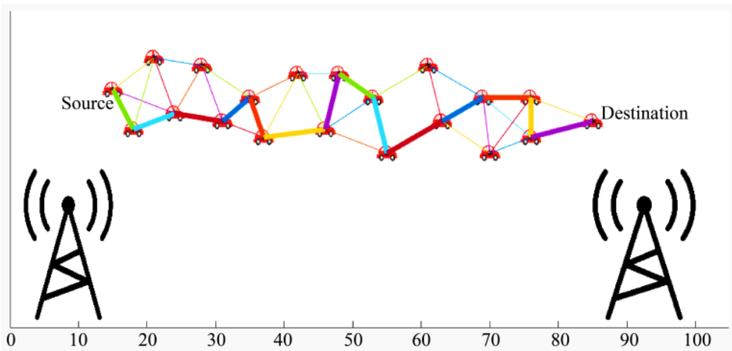
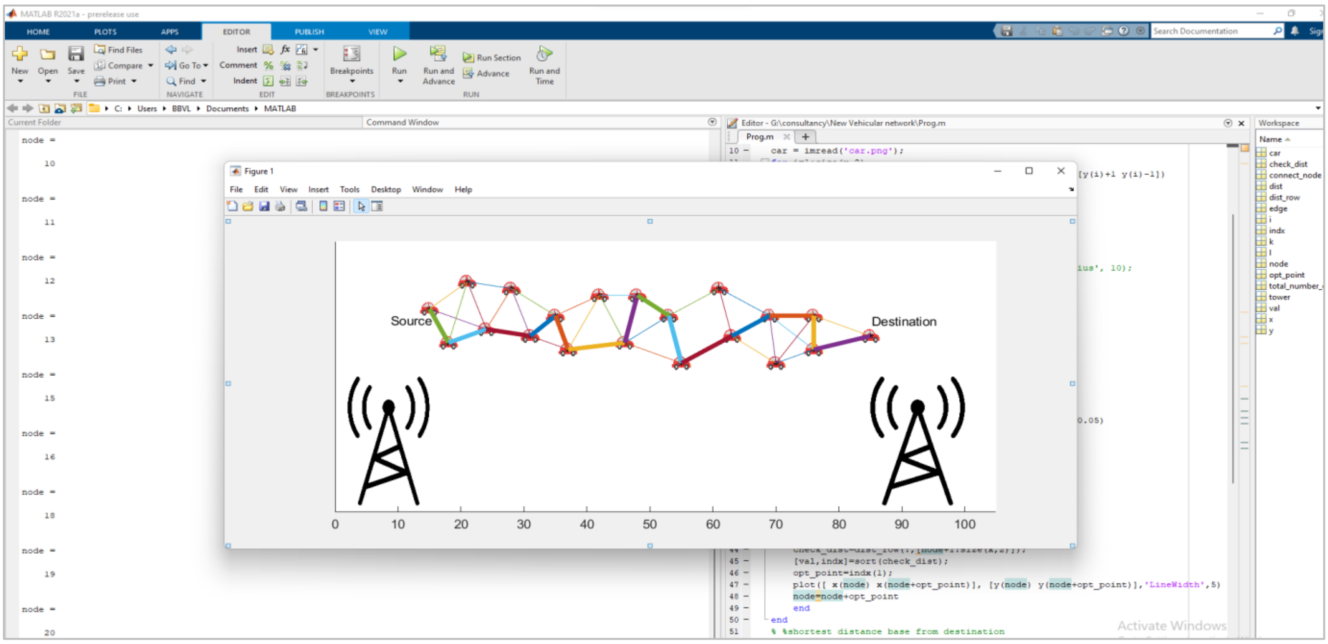


Fig. 17 Optimal node identified by the algorithm



(a) Identified message transmission tree by PSO



(b) Node identification

Fig. 18 (a,b) PSO solution for case-1

Table 3. PSO parameters consideration

S.No.	Description	Value
1.	Population Size (n)	100
2.	Cognitive Parameters	$C_1 = C_2 = 1$
3.	Random Parameters	$r_1 = r_2 = 1$
4.	$position_{best}$	Position of swarm in the next iteration
5.	$Swarm_{best}$	Particle position with a minimum fitness value

6.1. Case-1: Minimize Energy-Aware Forwarding and Packet Delivery Rate PSO Implementation

Once the network is formed and source and destination nodes are identified, a message transmission tree should be generated. In this case, two optimal criteria are considered, i.e., i) Minimize Energy-Aware Forwarding and ii) Maximize Packet Delivery Rate. These two criteria will be satisfied when the source node identifies the consecutive nearest nodes for message transmission. The fitness is calculated according to equation (1) for the considered PSO parameters, as illustrated in Table 3.

Once the $Swarm_{best}$ is identified, the node that is closer to the $Swarm_{best}$ will be treated for message transmission. During the first iteration, the best node is selected as the 2nd vehicle, as represented in Fig.17.

The iterations will be continued until it reaches its destination node, i.e., the 20th node. Fig.18 represents the MATLAB platform where the optimal node is generated in each iteration.The results of each parameter are represented in Table 4. Observing the results, it is noticed that the total energy consumed by the transmission tree in the VANET is 2.12558 /sec with a packet delivery rate of 1.50 sec. It means the beacon message is transmitted in 1.5 sec. from its destination node to the source node.

Table 4. Quantitative results of Case-1

Iteration	Edge	Fitness	Energy	Packet Delivery Rate
1	1 - 2	5.83095	0.1715	0.091108623
2	2 - 4	6.32456	0.15811	0.098821177
3	4 - 6	7.07107	0.14142	0.110485435
4	6 - 7	5	0.2	0.078125
5	7 - 8	5.38516	0.1857	0.0841432
6	8 - 10	9.05539	0.11043	0.141490393
7	10 - 11	7.28011	0.13736	0.113751717
8	11 - 12	5.83095	0.1715	0.091108623
9	12 - 13	7.28011	0.13736	0.113751717
10	13 - 15	8.94427	0.1118	0.139754249
11	15 - 16	6.7082	0.14907	0.104815686
12	16 - 18	7	0.14286	0.109375
13	18 - 19	5	0.2	0.078125
14	19 - 20	9.21954	0.10847	0.144055382
Total Value			**2.12558**	**1.498911202**

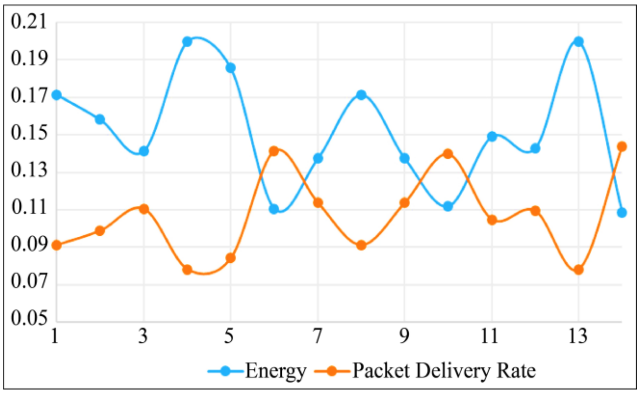


Fig. 19 Variation in Energy consumed and Packet Delivery Rate at each edge

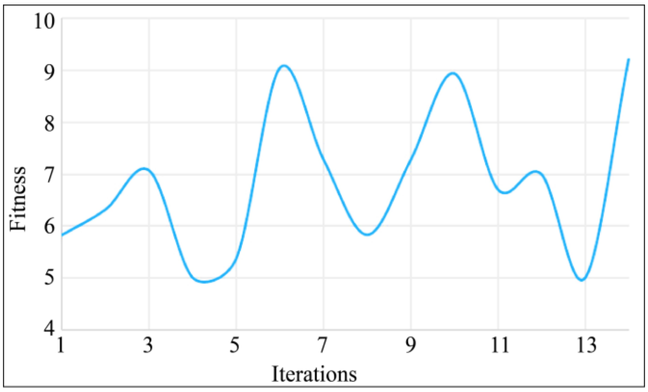


Fig. 20 Variation in fitness value at each edge

The variation in Fitness, Energy consumed, and Packet Delivery Rate at each edge corresponding to each iteration is represented in Figs.19 & 20.

6.2. Case-2: Minimize Delay and Number of Hops

Once the network is formed and source and destination nodes are identified, a message transmission tree should be generated. In this case, two optimal criteria were considered, i.e., i) Minimize Delay and ii) Minimize Number of Hops. These two criteria will be satisfied when the source node identifies the nearest nodes towards the destination for message transmission. The fitness is calculated according to equation (4) for the considered PSO parameters, as illustrated in Table 3. Once the $Swarm_{best}$ is identified, the node that is closer to the $Swarm_{best}$ will be treated for message transmission. During the first iteration, the best node is selected as the 4th vehicle, as represented in Fig.21.

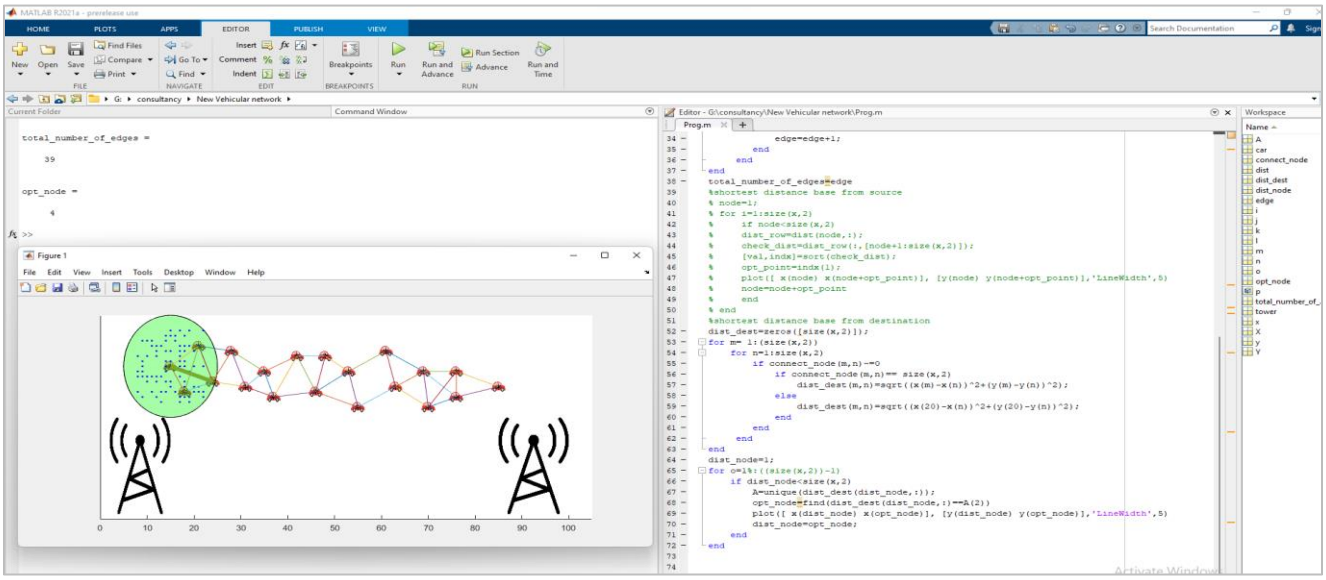


Fig. 21 Optimal node identified by the algorithm for case-2.

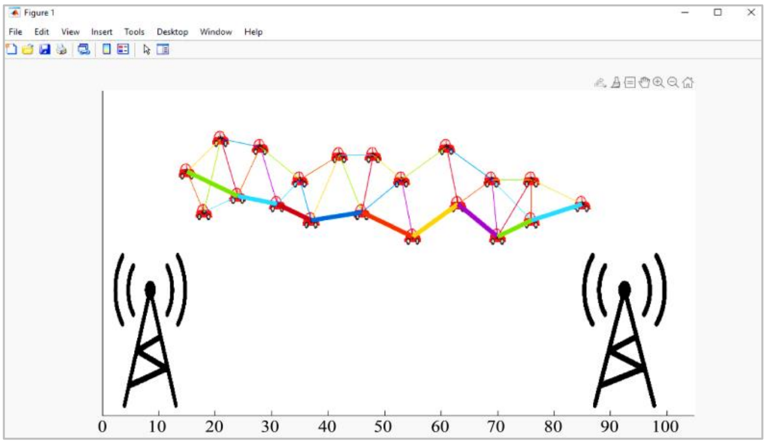


Fig. 22 Identified message transmission tree by PSO

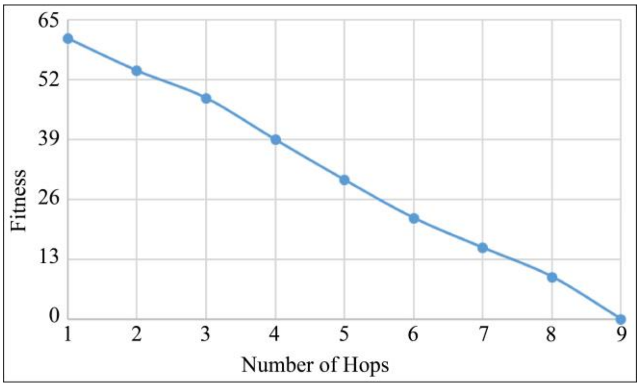


Fig. 23 Variation in fitness value at each hop

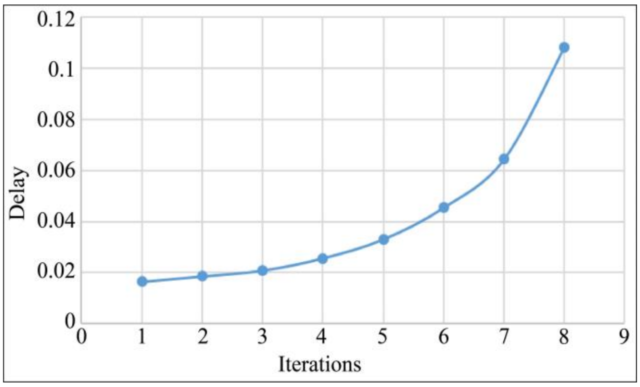


Fig. 24 Variation in Delay at each hop

Table 5. Quantitative results of Case-2

Iteration	Edge	Fitness	Delay
1	1 - 4	61.0082	0.016391
2	4 - 6	54	0.018519
3	6 - 8	48.04165	0.020815
4	8 - 10	39.01282	0.025633
5	10 - 13	30.26549	0.033041
6	13 - 15	22	0.045455
7	15 - 17	15.52417	0.064416
8	17 - 19	9.219544	0.108465
9	19 - 20	0	0

The iterations will be continued until it reaches its destination node, i.e., the 20th node. Fig.22 represents the MATLAB platform where the optimal node is generated in each iteration. The results of each parameter are represented in Table 5. Observing the results, it is noticed that the total number of hops for the transmission tree in the VANET is reduced from 14 to 9.

Further, the delay of the transmission tree was found to be 0.3sec. It means the beacon message is transmitted in 0.3 sec. from its destination node to the source node.

The variation in Fitness value and delay in Packet Delivery at each edge corresponds to each iteration, which is represented in Figs.23 and 24.

7. Conclusion

In this research work, intelligent multicast routing is implemented in vehicular communications using particle swarm optimization. Multicast routing is performed based on various objective criteria, such as minimizing energy-aware forwarding, delay, and the number of hops while maximizing the packet delivery rate. Two forms of fitness functions are considered subject to the said optimization criteria. Later, PSO was implemented in order to find the transmission tree to forward the beacons from the destination node to the source node. Finally, two case studies were presented in order to validate the performance of the proposed methodology. Results showed that both fitness functions exhibit various advantages such as energy efficiency, minimum delay, fast transmission of packets, etc.

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