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Awareness routing algorithm in vehicular ad-hoc networks (VANETs)

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Abstract

The behavior of a Vehicle Ad hoc Network (VANETs) is extremely unpredictable due to the high mobility and random network topology inherent to the nature of VANETs. Several problems, including frequent connection failures, scalability, multi-hop data transfer, and data loss, impact the performance of Transmission Control Protocols (TCP) in such wireless ad hoc networks. This study proposes using zone-based routing with consideration for mobility in VANETs as a means of avoiding this issue. A hybrid optimization approach is introduced and used to the routing process. Both Ant Colony Optimization (ACO) and Artificial Bee Colony Optimization (ABCO) are components of the hybrid algorithm (ABC). Link stability and Residual energy provide the basis of the fitness function. Several measures, including delivery ratio, time, and overhead, are used to evaluate the effectiveness of the suggested method. A comparison of the suggested method's efficiency with that of other algorithms.

Keywords: Vehicle ad hoc network, Transmission control protocol, Multi-hop data transmission, Ant colony optimization, Artificial bee colony optimization

Introduction

Vehicular Ad-Hoc Networks (VANETs) are a form of wireless networking technology that connects automobiles and fixed infrastructure along highways and in cities with the purpose of enhancing drivers' safety and convenience [1–3]. VANETs are a cutting-edge invention that blends Ad-Hoc networking, wireless LAN, and cell technology to create an intelligent vehicle communication framework; ITS relies heavily on VANETs. Unlike Mobile Ad-Hoc Networks (MANETs), VANETs cannot be easily distinguished [4–6]. The hybrid structure of a VANET distinguishes it from a MANET. A vehicle-to-vehicle network, or VANET, enables automobiles to exchange data with one another. Ad hoc networks are defined as those that have not yet established a permanent infrastructure, unlike association-based networks, which rely on things like routers and access points. Vehicles with onboard units [OBU], centralized stations, and vehicles known as roadside units [RSU] and base station units [BSU] at roadside junctions make up the backbone of VANET's fundamental structure. Next, the connected cars exchange information with one another via the OBU and Messages. In a similar vein, the OBU can have direct conversations with the RSU and the BSU [7–10].

In the last several years, there has been a great deal of study devoted to VANETs, primarily focusing on the development of new routing protocols and the distribution of information. The primary method of passenger amusement is target tracking, which makes use of the vehicle's own sensors [11]. Due to the ever-changing nature of a network like VANETs, it might be difficult to choose reliable metrics for tasks like cluster head election and cluster membership, as vehicles are constantly joining and departing the network's collective memory. In VANETs, vehicle clustering is accomplished in two ways: I static clustering, which relies on Vehicle-to-Infrastructure (V2I) communication and employs Road Side Units (RSUs) as static cluster heads [12, 13]. In order for the cars to be able to communicate and connect to the internet in real time, RSUs are installed in them. High-mobility vehicles aren't always linked to RSUs because of the great distance between them. Vehicle-to-vehicle (V2V) communication is the basis of dynamic clustering, in which cluster heads are selected from among the cluster's members. The idea of fixed cluster heads is modified by this approach [14–17]. When the dynamic clusters go down the route, cars join or depart the clusters based on their speeds in order to determine who the cluster heads are. In this scenario, the V2V communications are more adaptable and not dependent on the roadside circumstances [18–20]. Whilst they excel in cluster stability and overhead minimization, these algorithms fall short when it comes to providing a high level of service quality.

Related work

The concept of Mobility-aware zone-based Routing in VANETs has been studied extensively and implemented by several academics. Several of these studies are discussed below; for example, [21–23] optimized routing and clustering to provide a low-power data transmission mechanism for VANETs. In this study, we cluster the cars using the k-medoid technique. Effective communication nodes are then determined after clustering. The Improved Dragonfly Algorithm finds the best candidates for communication nodes to minimize energy consumption (EDA). By using this technique, we were able to enhance our level of interaction. In [24], an efficient and dependable three-stage method for determining the best routing path was published for use in network design. Poor quality of service (QoS) in communications was the result of the provision of jammers to disrupt transmissions between wireless nodes. Each node with a battery was able to have its transmission power limited so as to save electricity. In [25], a genetic algorithm was used to describe a routing protocol for VANETs that conserves energy. In this case, we employ a variant of AODV for routing. In this case, a genetic algorithm was used to improve the AODV. Routing variables include data transmission rate, availability of connections, delay, packet loss, and link reliability. A longer transmission lifespan can be achieved through the application of the optimum route selection technique.

Using a parallel evolutionary method, the authors of [26] demonstrated a fast energy-aware OLSR routing in VANETs. The standard OLSR-based routing in VANETs has challenges that have been addressed by this technique. Power usage metrics are used to assess how well the suggested approach performs. Energy and Time Efficient Routing Techniques for High-Speed Virtual Ad hoc Networks [27] have been described. In this study, the authors introduce two new protocols: CBLTR and IDVR. Using the newly adopted CBLTR protocol, we were able to increase route reliability and average throughput. CHs are chosen according on how long the nodes are expected to live. The IDVR protocol's goal was to decrease end-to-end time in a grid topology while increasing route reliability and average throughput. This algorithm took the quickest route possible given the protocols in place. The [28] work on VANET energy-efficient routing. In this context, GreeDi was first used for routing. greeDi, a reactive routing protocol, is used in VANETs to find the path between nodes that uses the least amount of energy. Using a city map as a basis, the described method was tested in a virtual autonomous network environment. When compared to the traditional AODV, the newly proposed approach performed better while using less energy. More VANET routing was provided in [29, 30]. To improve the routing process, a new cross-layer cluster-based routing (CCBR) protocol was developed to implement the cross-layer autonomous route recovery (CLARR) mechanism. The primary goal is to establish reliable clusters to lengthen the life of routing paths by reducing the frequency of connection failures, hence facilitating the more efficient distribution of multimedia data. To do this, we include the idea of clustering into the current CLARR by making use of mobility measures, and then use these to locate trustworthy relay trucks on the way to the destination. At various vehicle speeds, the simulation experiments in network simulator-2.34 are used to assess the efficacy of the proposed method and compare it to the currently used cross layer, which is based on the demand routing protocol [31, 32], researchers compiled a list of every VANET-related paper that discussed a QoS-aware routing technique. The protocols were analyzed to see how well they supported the infotainment services, how well they solved the multi-constraint path issue (MCP), how well they performed their intended functions, and how difficult or easy they were to build.

Structure of vehicular ad-hoc networks (VANETs)

Vehicles may talk to other cars (Vehicle-to-vehicle communication, or V2V) and can also talk to equipment on the sides of roads and highways to create Vehicular Ad hoc Networks (VANETs), a subset of Mobile Ad hoc Networks (MANETs) (Vehicle-to-infrastructure communication, V2I). Vehicle-mounted units are known as on-board units (OBUs), whereas roadside units (RSUs) are known for their presence on the highways (roadside units). The steps involved in VANETs communication are shown in Fig. 1.

Each OBU in V2V operates in ad hoc mode, relaying messages over a series of hops; however, in this configuration, network connection is heavily reliant on the number and movement pattern of vehicles. As cars are expected to adhere to transit standards, their trajectories should generally stick to road lines, making predictability in the network topology possible in a VANETs.

Proposed mobility aware zone-based routing in VANETs

Vehicle ad hoc networks, also known as VANETs, are characterized by extremely dynamic behavior, including high mobility and a random topology for the network. Transmission Control Protocols (TCP) suffer performance challenges in wireless ad hoc networks due to a number of factors, including frequent connection failures, scalability, multi-hop data transfer, and data loss. The mobility-aware zone-based routing in VANET that is presented in this chapter is an attempt to circumvent the difficulty. Under the framework of this idea, the ACO-ABC algorithm is used to determine the

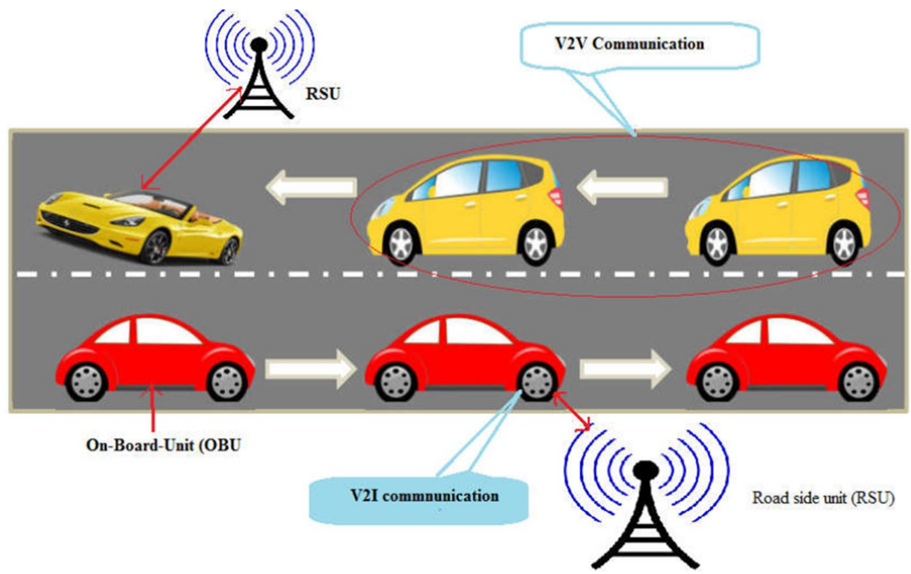

Fig. 1 Communication process of VANET

most effective routing pathways. The most efficient path is taken to cut down on the amount of time spent communicating and the amount of energy required. While building routing systems, it is vital to take into consideration a number of key aspects, including location management and connection management. In most cases, location management is carried out with the assistance of the Global Positioning System (GPS), which reveals both the location and the speed of moving vehicles. In this section, GPS will be discussed. Figure 2 depicts the general structure for your reference.

Design of fitness function

In this study, for routing multi-objective function is designed. The multi-objective function is a combination of Link stability and residual energy.

Link Stability: Location management and connection management are important issues to consider while designing routing algorithms. Commonly, location management is done by using the Global Positioning System (GPS), which provides the vehicle's position and speed. Connection management, which maintains stable routes between the vehicles, needs to be calculated. This translates to determining the link stability, an important parameter to making intelligent data forwarding decisions for overall routing performance.

Let us assume i and j are two vehicles on the road. Using GPS, the initial positions are obtained which are denoted as $(\boldsymbol{U}_{i0}, \boldsymbol{V}_{i0})$, and $\left(\boldsymbol{U}_{j0}, \boldsymbol{V}_{j0}\right)$ as well as their speed are denoted as $\boldsymbol{S}_{i0}$ and $\boldsymbol{S}_{j0}$. If the vehicles are in the same communication range, they will be treated by neighbors. Distance between two vehicles is denoted as D and the communication range is denoted as R. If D > R, the link between the vehicles will break. The lifetime $(\boldsymbol{\Delta t})$ of the link ij from current time $\boldsymbol{t}_1$ to initial time $\boldsymbol{t}_0$, when $\boldsymbol{D} = \boldsymbol{R}$ is $\boldsymbol{\Delta t}$. Given, the initial position of vehicles and speed information, the lifetime $(\boldsymbol{\Delta t})$ is calculated using the distance. The distance is calculated using the following Eq. (1).

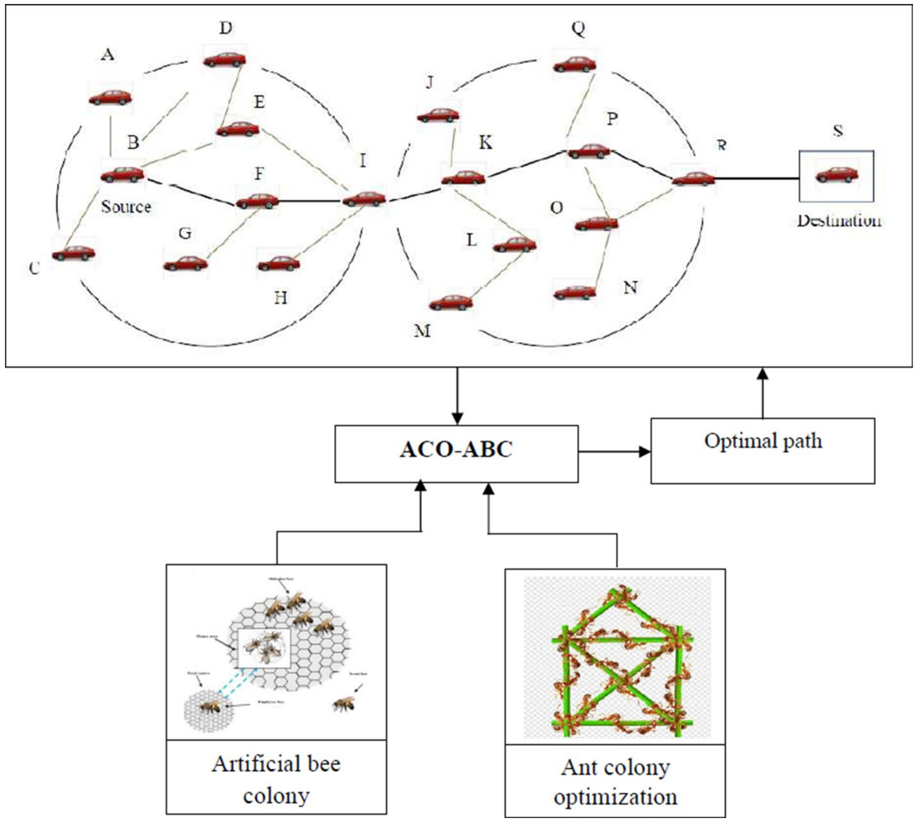

Fig. 2 Overall structure of mobility aware zone-based routing

$$D^2 = \|U\|^2 + \|V\|^2 \tag{1}$$

where;

$$U = (U_{i0} + Z_{i0}\Delta t) - \left(U_{jo} + Z_{jo}\Delta t\right) \tag{2}$$

$$V = (V_{i0} + Z_{i0}\Delta t) - \left(V_{jo} + Z_{jo}\Delta t\right) \tag{3}$$

The link stability (L^S)of ij can be calculated as follows;

$$L^S = \frac{\Delta t_{ij}}{t_{max}} \tag{4}$$

Here, tmax is a constant parameter and corresponds to the validity period of the time of the routing table.

Residual Energy: Energy is an important parameter for routing. A large amount of energy increases the cost. The Residual energy of each node can be calculated as follows;

$$R_i^{Energy} = R_i^{initial} - R_i^{consumed} \tag{5}$$

where $R_i^{initial} and R_i^{consumed}$ are characterized as initial and consumed energy of node i. Consumed energy can be calculated as follows;

$$R_i^{consumed} = u_i \times R^T + v_i \times R^R \tag{6}$$

where u_i *and* v_i are characterized as the number of transmitted bits and received bits in node $\boldsymbol{sR^T andR^R}$ are characterized as transmission energy and reception energy correspondingly and are calculated as

$$R^T = R_{radio}^R + R^A \times dis_{mn}^2 \tag{7}$$

$$\boldsymbol{R^R = R_{radio}^R} \tag{8}$$

where, $\boldsymbol{R_{radio}^T andR_{radio}^R}$ are is the energy that the radio requirements for the transmitter and the receiver correspondingly, $\boldsymbol{R^A}$ is signified as the energy of the transmit amplifier, and the distance within two nodes m and n is signified as dismn.

Fitness Calculation: The multi-objective function is utilized for the fitness function. The fitness is designed based on residual energy and link stability. the fitness can be calculated as follows;

$$Fitness_i = \alpha * R_i^R + \beta * L_i^S + \gamma * B_i \tag{9}$$

where,$\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are denoted as a weighting factor ranging from 0 to 1. B_i denotes the buffer occupancy of i^{th} a node. The solution with maximum fitness value is considered the best path.

Zone-Based routing on VANET

This article will save you time and resources by creating zones inside the network so that you may better organize your data. The distance between the vehicles is kept to a minimum in order to maximize their density. The transmission of packets makes use of both proactive and reactive routing at the same time. Whereas reactive transmission is used for data that is moving between zones, proactive transmission is used for data that is moving inside a zone. The hop count that was used to compute the buffer zone's radius also served as the basis for determining the size of the zone. It is possible for a vehicle to coexist inside two overlapping zones if those zones have different sizes. There are three unique locations in which a vehicle can be driven: within, outside, and on the border. These habitats are referred to as "inside," "outside," and "on." Any car that is placed inside of a zone in which the hop distance is shorter than a specific radius is referred to as a "interior vehicle," and this phrase can be used to refer to any vehicle. Vehicles that move within a zone whose radius is precisely equal to the hop distance are referred to as boundary vehicles. On the other hand, vehicles that go outside of the zone's radius are known as external vehicles. Using a method that is centered on zones, Fig. 3 illustrates the topology of the network. The boundary or border automobiles are represented by the letters A, D, and C in Fig. 3, while the inside vehicles are represented by the letters B, G, E, F, and H. The term "external" refers to locations or situations that are deemed to be "outside" of the restricted region.

There are two primary steps that may be completed in routing, and these are route discovery and route maintenance. This will take place either within the zone itself or between other zones. In order to accomplish this goal, we have made use of two distinct routing

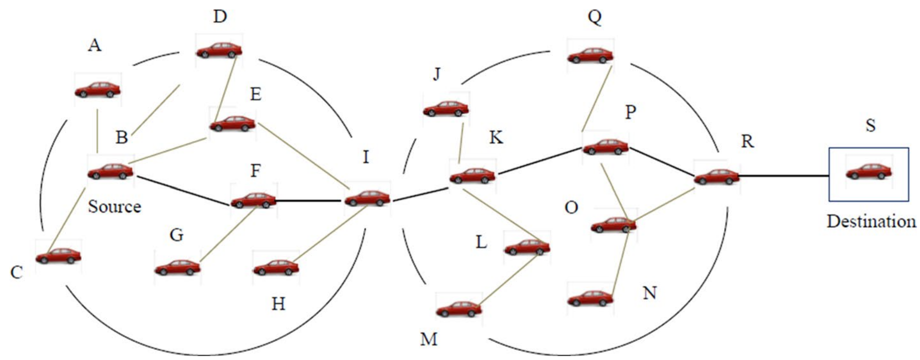

Fig. 3 Zone based routing

tables, namely the intra zone routing table and the inter zone routing table. The information included in the Intra zone routing table is kept up to date in a proactive manner, whereas the Inter zone routing database only tracks the information that is passed between the zones when it is requested. The source, the destination, the sequence number, the type, the hops, the speed, the location, and the path are all components of the routing data structure.

Optimal path selection using ACO-ABC algorithm

For routing, the ideal pathways are chosen so that the lifetime of the hub may be extended while simultaneously lowering the amount of power used. Within the context of this chapter, the ACO-ABC algorithm is applied for the process of selecting the best path. The ACO-ABC is a hybrid form that combines the ACO and the ABC. The procedure for the transfer of data is broken down into the following steps:

Step 1: *Solution Encoding* solution encoding is an important process for the optimal path selection process. Initially, the bees are initialized. The solution is considered a bee. The solution consists of a source node, destination node, sequence number, type, hops, speed, position, and path.

Source: the source node address is stored in the source field.

Destination: this field stores the destination address.

Sequence Number: each bee is tagged with a sequence number, stored under the sequence number field.

Type: which type of node is presented in this field.

Hops: it is used to indicate the number of hops between the node and all the nodes within its zone. This node helps distinguish between an outer node and an inner node.

Speed: it is stored the speed of the node.

Position: this field stored the present position of the vehicle.

Path: it stored the path between source and destination.

Step 2: *Fitness Calculation* After the solution initialization, the fitness of each solution is calculated. Here, a multi-objective function is utilized. The fitness function is given in Eq. (10).

$$Fitness_i = \alpha * R_i^R + \beta * L_i^S + \gamma * B_i \tag{10}$$

Step 3: *Employed Bee Operations* Here, the employed bee generates a modification on the position (solution) in its memory depending on local information (visual information) and tests the nectar amount (fitness value) of the new source (new solution). To generate a candidate food position from the previous one in memory, the employee bee utilizes the following expression (11).

$$S_{i,j} = z_{i,j} + \gamma_{ij}\left(z_{i,j} - z_{k,j}\right) \tag{11}$$

where, $k \in \{1, 2, ..., SN\}$ and $j \in \{1, 2, ..., D\}$ are randomly chosen indices. Although k is determined randomly, it is different from i, γ_{ij} is a random number between [1,-1]. It controls the production of neighborhood sources around i, γ_{ij}, and $S_{i,j}$ is the new value of the j^{th} position. Then the fitness value is computed for every newly generated solution of food sources. From the computed fitness value, the best solution parameter is obtained i.e. the solution parameter, which has the highest fitness value by applying the greedy selection process. After selecting the best solution parameter, the probability of the selected parameter is computed using the Eq. (12).

$$p_i = \frac{FF_i}{\sum_{n=1}^{SN} FF_n} \tag{12}$$

where, SN is the number of food sources equal to the number of employed bees, and FF_i is the fitness of the solution given in Eq. (12).

Step 4: *Onlooker Bee Phase* After computing the probability of the chosen parameter, the number of onlooker bees is estimated. After that, generate new solutions $(S_{i,j})$ for the onlooker bees from the obtained solutions $(z_{i,j})$ based on the probability value (p_i). Then the fitness function is calculated for the new solution. Subsequently, apply the greedy selection process to select the best parameter.

Step 5: *Scout Bee Phase* Determine the abandoned parameters for the scout bees. If any abandoned parameter is presented, then replace that with a new randomly obtained solution Z_{ij} for the scout using the Eq. (13).

$$z_{ij} = z_j^{min(0,1)\left(z_j^{max_j^{max}}\right)} \tag{13}$$

where z_j^{min} is the lower bound of the food source position in dimension and z_j^{max} is the upper bound of the food source position in dimension j. Then keep the best parameters obtained so far and then the process is continued until the final criterion is reached. Finally, the reduced dataset is discovered.

Step 6: *Ant colony operator* Then, further, improve the solution; the solutions are again updated using ACO algorithm. Using this way, easily find out the global optimum. Ant colony optimization is one of the population-based metaheuristic techniques based on the foraging behavior of real ants. They forage for food and establish the shortest paths from their nest to the food source. In ACO, two types of updations are available namely, local trail updation and global trail updation.

As the ant moves between nodes it updates the amount of pheromone on the edge by the following equation:

$$\tau_{ij}(t) = (1-\rho).\tau_{ij}(t-1) + \rho.\tau_0 \tag{14}$$

where, τ represent the evaporation constant. The value τ_0 is the initial value of pheromone trails and can be calculated as

$$\tau_0 = (n/L_n) - 1 \tag{15}$$

where, n is the number of nodes and Ln is the total distance covered between the total nodes, produced by one of the construction heuristics. When all ants have completed all the nodes that find the shortest path updates the edges in its path using the following equation:

$$\tau_{ij}(t) = (1-\rho).\tau_{ij}(t-1) + \frac{\rho}{L^+} \tag{16}$$

where L+ is the length of the best path generated by one of the ants. The steps are repeated until the optimal fitness function is attained. The selected path is given to the data transmission process.

Step 7: *Termination Criteria* The algorithm discontinues its execution only if the maximum number of iterations is achieved and the solution which is holding the best fitness value is selected and it is specified as the best path for transmission. Once the best fitness is attained employing ACO-ABC algorithm, the selected path is used for transmission.

Experimental results

The experimental result of the proposed mobility-aware zone-based routing in VANET is analyzed in this section. For simulation, an urban traffic scenario with random street conFigureuration is utilized. For experimentation, the number of vehicles has been set to 25, 50, 75, and 100 in the 1500×1500 m^2 area. The proposed methodology is implemented in NS2.

Experimental results

To prove the performance of the proposed methodology, the proposed method was compared with different two algorithms namely, AODV-based routing and AMODV-based routing. For performance analysis, four parameters are analyzed namely, end-to-end delay, packet delivery ratio, overhead, and throughput.

In Fig. 4, the performance of the proposed methodology is analyzed in terms of end-to-end delay. Here, the x-axis represents the number of vehicles and the y-axis represents the time. When analyzing Fig. 4, the proposed method produces better results compared to other approaches. This is because of the zone framework and ACO-ABC based optimal route selection process. The optimal path selection process helps to fast end-to-end data transmission process. The hybridization algorithm discards the broken paths. This reason allows the proposed method to produce an end-to-end delay output.

Comparative analysis based on packet delivery ratio by varying number of vehicles is given in Fig. 5. When there are fewer vehicles in the network, the proposed method did not show a good delivery ratio. A high delivery ratio is considered a good system. Here, as the network size increases and with more neighbors for a vehicle, the delivery ratio

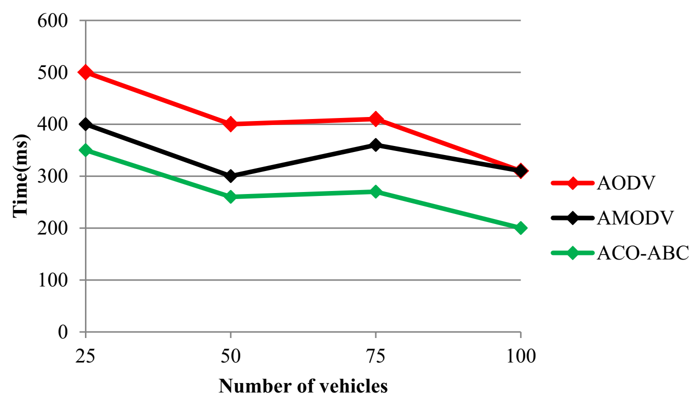

Fig. 4 Comparative analysis based on end to end delay by varying number of vehicles

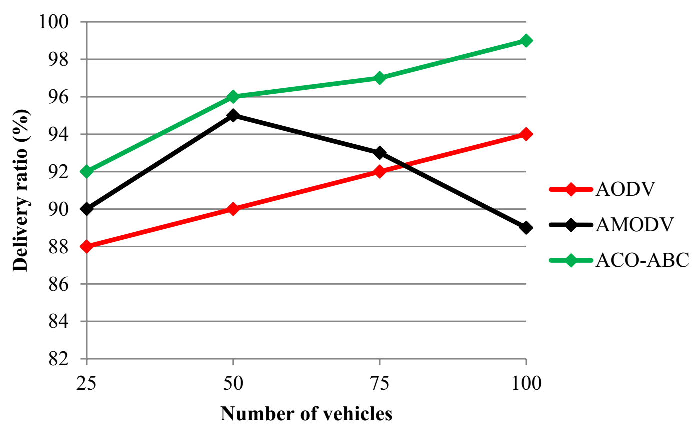

Fig. 5 Comparative analysis based on packet delivery ratio by varying number of vehicles

for proposed mobility-aware routing is better than other algorithms. This is because the bees can choose from multiple paths rather than a single path as in AODV and AMODV.

Figure 6 shows the routing overheads of proposed and other routing algorithms. AODV, AOMDV is a pure reaction protocol with no concept of the zone. Whereas, the proposed method is active within a zone. Routes within the zone are maintained by periodically sending control packets. This is a major reason for overhead in the proposed method. As the network size increases, there are more choices for routes to a vehicle destination, which proves the algorithm to be a multi-route path.

A comparative analysis of the number of different vehicles is given in Fig. 7. Here, the number of vehicles varies the radius of the simulation area and zones remain unchanged. Therefore, an increase in the number of vehicles increases the number of vehicles within a zone, creating a greater concentration of vehicles within a zone. These results are very similar to those discussed for packet delivery in Fig. 7, the higher the received packet rate, the higher the data performance.

In Fig. 8, a comparative analysis based on delivery ratio by varying zone radius is analyzed. In Fig. 8, the zone radius is increased from 2 to 10. As the number of vehicles increases, the delivery ratio also increases. From Fig. 8, 100 vehicles with a zone radius of 10 show a high delivery ratio.

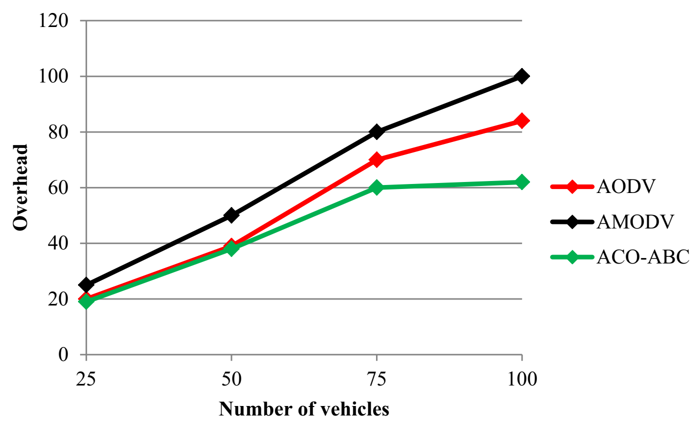

Fig. 6 Comparative analysis based on overhead by varying number of vehicles

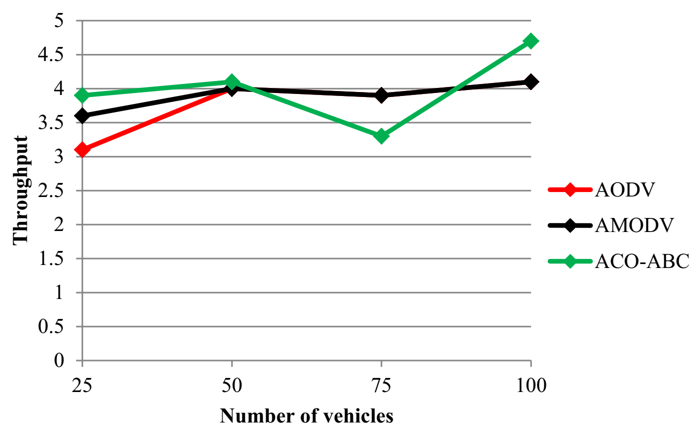

Fig. 7 Comparative analysis based on throughput by varying number of vehicles

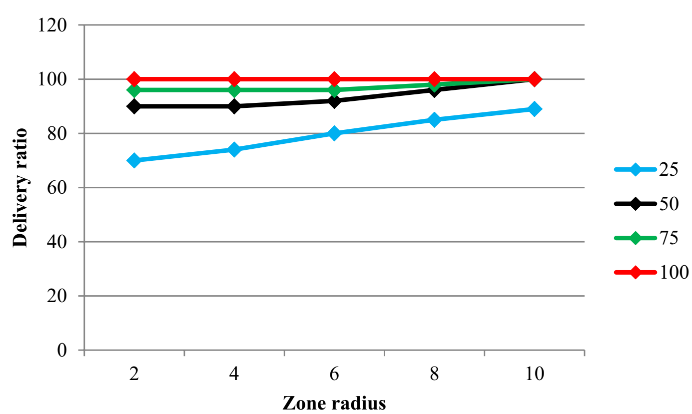

Fig. 8 Comparative analysis based on delivery ratio by varying zone radius

In Fig. 9, a comparative analysis based on end-to-end delay by varying zone radius is explained. When the number of vehicles is 100 and the zone radius is 2, it will take more time to send packets across the network. Whereas for 100 vehicles and a

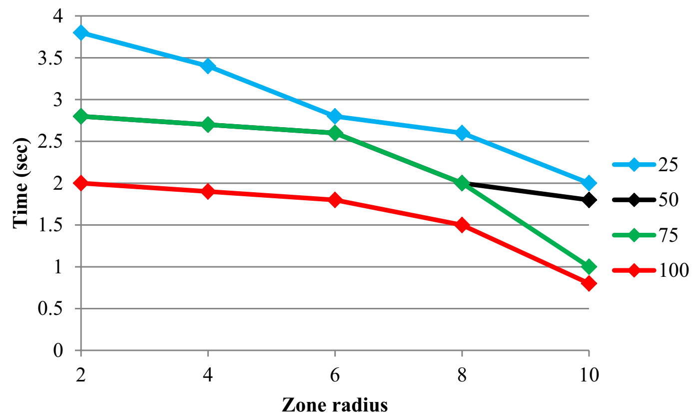

Fig. 9 Comparative analysis based on end to end delay by varying zone radius

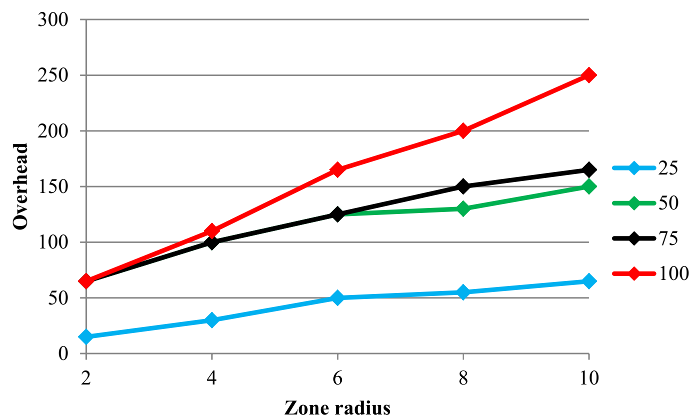

Fig. 10 Comparative analysis based on Overhead by varying zone radius

zone radius of 10, it would take less time to transport a packet. This is because the proposed mobility awareness zone-based routing allows a large number of vehicles to accept and operate within a zone. Therefore, Fig. 9 shows a larger number of vehicles and a larger zone radius, and it is better for an end-to-end delay than a smaller number of vehicles and a smaller zone radius.

Comparative analysis based on overhead by varying zone radius from 2 to 10 with varying vehicle count is given in Fig. 10. When the number of vehicles is 100 and the zone radius is 2, the proposed method attained less congestion on the network. On the other hand, if the zone radius is 10 and the numbers of vehicles are 100, the method produced more congestion due to more vehicles, which are constantly updating the routing table. Although the proposed routing method provides good network connectivity, it means more routes are available, which creates more controllable traffic. Therefore, from Fig. 10, it can be seen that there is a higher routing overhead as the number of vehicles and the zone radius increase.

Conclusion

The mobility-aware zone-based routing that has been recommended for implementation in VANETs has been explored in this paper. In this particular instance, the ACO-ABC algorithm was utilized in order to carry out the process of routing. A component-by-component breakdown of the mathematical analysis of the fitness function and the routing has been performed. It has been determined, with reference to a range of criteria, whether or not the plan that has been presented is effective. The technique that was proposed had been successful in obtaining both a higher delivery ratio as well as a shorter delay from the beginning to the completion of the process. Because of the multipath qualities it contained as well as the robust network connectivity it owned, the suggested approach was able to attain better performance than an existing one. This was possible due of its multipath features. We want to implement VANETs in the construction of a real-time traffic management system in the not too distant future.

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Ethics approval and consent to participate
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Consent for publication
Yes.

Competing interests
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