Increasing the scalability and reliability of AODV routing protocol in mobile vehicular ad hoc networks using multi-verse meta-heuristic Algorithm

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Abstract
Vehicular network is a type of ad hoc wireless network that plays a significant role in reducing traffic and preventing accidents. Hence, the increased scalability in routing is regarded as one of the basic challenges in vehicular networks. AODV protocol is one of the standard protocols in vehicular networks. This protocol has the minimal control and processing overhead. In addition, this protocol reacts to the topology changes and route failure. However, AODV routing protocol suffers from the route request messages overhead and lack of attention to the black-hole attacks. The overhead of route request messages along with the rapid changes in topology greatly reduce the scalability of the network.
Clustering is a technique commonly used to increase network scalability in vehicular networks. We try in this research to provide a mechanism for clustering of the vehicular network. We also intend to increase the stability of links, considering the parameters of vehicles' distance, speed and acceleration in the cluster head fitness function. We also tend to prevent from selecting black-hole vehicles as the gates by using the vehicles' demolition value in gate selection. This causes the black-hole vehicles not to be able to delete or broadcast the transmitted data messages.
Key words:
vehicular network, clustering, increasing scalability, Vanet, Aodv, Mvo

Introduction

The exchange of information among vehicles and the roadside equipment in vehicular networks have been emphasized in recent years. The high mobility of vehicles and various decision-makings of drivers bring about rapid changes in the network topology. Rapid changes in the network topology affect the network scalability so severely. The network throughput is directly related with scalability. This is why the increased scalability in the vehicular network routing has been emphasized in recent years.

On the other hand, route stability is one of the most important factors in increasing the throughput and reducing the message transmission delay. Therefore, route stability should be particularly stressed in routing protocols of vehicular networks.

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The black-hole vehicle is a vehicular that claims that it has a route to send messages to the target vehicle. Therefore, it sends a route response message to the source vehicle as soon as it receives a route request message. Then, the source vehicle sends the message to the black-hole vehicle. The black-hole vehicle also deletes the message (reducing the throughput) or broadcast it (increasing the delay) as soon as it receive the message.

1. Problem Statement

Exchange of information among vehicles is related to traffic and road conditions, such as the freezing of the road, and weather conditions. The delay in the transmission of messages or the reduction of network throughput has a significant impact on the safety and comfort of passengers and drivers. Hence, the black-hole vehicles attacks should be considered in order to improve the routing protocols.

AODV protocol is one of the standard routing protocols. This protocol has the minimal control and processing overhead. In addition, this protocol reacts to the topology changes and route failure. Furthermore, because of the sequence number in its request and reply messages, this protocol prevents looping during the route discovery process. However, AODV routing protocol suffers from the route request messages overhead and lack of attention to the black-hole attacks. Besides, no attention has been given to the route stability in AODV standard protocol AODV.

2. Theoretical foundations and research history

The authors provided a routing protocol in order to improve AODV protocol in mobile ad hoc networks and named it EO-AODV. EO-AODV. The EO-AODV protocol has high performance in cases where there are high topology changes. However, the proxy route request overhead has increased the EO-AODV protocol overhead.

In addition, the presence of black-holes and the stability of the discovered nodes (route) have been neglected in the EO-AODV protocol

(Mahajan &et al,2014,2).

Scholars offered a routing protocol to increase the AODV protocol route stability in vehicular networks. The results indicated that the route stability in the proposed routing protocol is higher than that in AODV protocol. The evaluation also shows that the route request broadcast message overhead and the route request unicast is lower in the proposed routing protocol than in the AODV protocol. However, the proposed routing protocol has not considered the traffic load of links and the black-hole vehicles' attacks (Ding & et al,2011,3).

The authors in [6] offered a cluster-based routing protocol in order to detect the black-hole vehicles in vehicular networks, which they called DMV. In this proposed protocol, the black-hole vehicles are detected and prevented from being selected as the cluster heads. Besides, since this is a cluster-based protocol, the route request and response message overhead has reduced in it. However the speed and acceleration of vehicles has been ignored in this routing protocol (Daeinabi and Rahbar,2014,326).

The authors used the concept of sequence number to identify black-hole nodes. This is why there is no need in this protocol for any additional messages and only a sequence number field is added to the route request and response messages. This routing protocol not only detects the black-hole nodes, but also isolates them from the network. The mechanism of detecting the black-hole nodes is executed only in the source nodes. That is why there is considerable processing overhead on source nodes in this protocol. Moreover, there is high route request message overhead in this protocol, because the source node broadcasts the route request message twice in order to identify the black-hole nodes (Banerjee & et al,2014,350).

Bing Bang theory holds that our universe is made of a massive explosion .According to this theory, Big Bang refers to a substance prior to which there is nothing in the universe. The multi-verse theory is a popular and well-known theory among physicists. The term multi – verse is in contrast with the single-verse theory, holding that there are several universes other than the universe in which we live.

Three concepts of multi-verse theory have been used in this algorithm to design the multi-verse algorithm: white-hole, black-hole and wormhole.

White-hole has never been seen yet, but physicists believe that there initially existed white-holes, each creating a universe with a Big Bang. According to this theory, the Big Bang is made by the collision of several white-holes against one another. Nothing, even light, may penetrate the white-hole. White-holes, as observed too often, are unlike black-holes and can absorb anything, even light, with high absorbing power. Wormholes are also holes that connect different parts of the world. Wormholes are regarded as time / space tunnels, which can transfer anything from one corner of the world to the other corner of it (or even from one corner of a world to another corner of another world). The conceptual models of the three key concepts of white-hole, black-hole and wormholes are shown in Figure (1) (. Mirjalili & et al,2015,89).

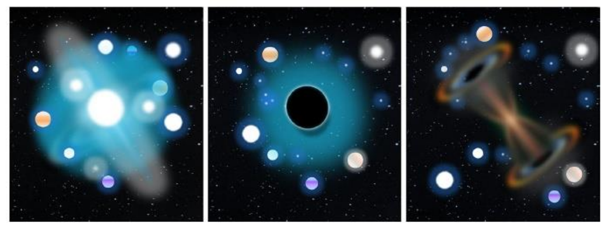

Fig. 1 A view of a white-hole, black-hole and wormhole from left to right

Like the genetic meta-heuristic algorithm, the multi-verse meta-heuristic algorithm is a swarm-based algorithm. Thus, a collection of candidate solutions is obtained at each stage of the algorithm implementation. The search process in a swarm-based Algorithm is divided into two phases: 1. discovery, 2. extraction.

The concepts white-hole and black-hole have been used in the discovery phase, but the concept wormhole has been used in the extraction phase. We assume that each candidate solution is considered as an object of the world. The author has also assumed that each candidate solution has an inflation rate that is proportional to the efficiency value of that candidate solution. The more the efficiency value increases, the more the inflation rate increases. The following points are applied in the multi-verse meta-heuristic algorithm:

- The higher inflation rate increases the probability of being a black-hole.
- The universe with a higher inflation rate tends to send out its objects via black-holes.
- The universe with a lower inflation rate tends to absorb further objects via black-holes.
- Objects throughout the world are moving toward the optimal universe randomly without regard to the inflation rate.

3. Discussion

The proposed protocol is composed of four operational phases including 1. Initiation, 2. Clustering, 3. Cluster-based route detection, 4. The data transmission and clustering-support phase. The initiation phase is executed only once, whereas the data transmission and clustering-support phase is executed repeatedly. The other phases are also executed when needed depending on the number of the vehicles that get out of the cluster head.

A: The initiation phase

In this phase, the techniques proposed in [6, 8] have been used in order to identify and prevent the penetration of the black-hole vehicles in the routing process. In the first phase, each RSU unit makes an RND1, in which it puts its own IP. Then, it broadcasts the RND message to all of its neighbors. Each RSU that receives the RND message puts the transmitter's identification number in the table of the neighboring RSU units.

Then in the second phase, each RSU initializes several spurious route requests (SRREQ) with a spurious different random destination IP and broadcasts to all its neighbors. The distance between the spurious messages is a short period of time. If the vehicle receiving the SRREQ message is a normal N vehicle, it transmits an RTR message to the source vehicle. When a UN non-normal vehicle receives the SRREQ message, it claims that it has a route to the destination vehicle. Therefore, it creates an RREP message, in which it puts its own IP and transmits a spurious message to the transmitter's RSU. The RSU also receives the REEP message and searches its IP in the white table (RWT). If its IP already exists in the white table, it removes it and add it to the black table. Otherwise, it puts it in the black table of the RSU unit and creates a BHD2 message. The BHD message is composed of the binary field and the IP address field. The RSU unit first puts the non-normal W vehicle in the BHD message, the RSU unit broadcasts the BHD message to all its neighbors.

Upon receiving a BHD message, each vehicle detects the W non-normal vehicle as the black-hole vehicle and removes it from neighboring vehicles Table (NVT). By so doing, we isolate the W black-hole vehicle from the network.

[1] . RSU Neighbor Detection
[2] . Black-hole Detection

B: Clustering phase

In this phase, the vehicles' movement direction plays a significant role in the cluster head selection. At first, each vehicle calculates its own efficiency S value using Equation (3-6). Then, it creates an EN 3 package and broadcasts it all its one-hop neighbors. The EN package contains the sending vehicle's IP, efficiency value and movement direction (a two-bit binary number).

$$\text{Clustering\_Eff(i)} = R-\left(\frac{\text{NoNV(i)}}{M} \times \sum_{j=1}^{\text{NoNV(i)}} \alpha dis_{ij} + \beta |v_i - v_j|\right)$$

Equation (1-1): Clustering_Eff (i) represents the efficiency value of Vehicle i in the clustering phase. NoNV (i) shows the number of vehicles in the one-hop neighborhood of the vehicle I, and M represents the total number of vehicles in the network. Disij represents the distance between vehicles i and j. vi and vj represent the speed of vehicles i and j respectively. α and β represent the distance effect and absolute value coefficients of the difference between the speed of vehicles i and j respectively. R is a fixed number that changes the problem into the optimization problem.

Each vehicle that receives the EN package first compares its movement direction with the existing movement direction in the EN package. If it has the same movement direction as that in the EN package, it saves the sending vehicle's identification number in the neighbor vehicle table (NVT). NVT consists of two columns. The first column shows the identification number of the neighboring vehicle and the second column shows its corresponding efficiency value.

Each vehicle waits for a period of time. Then it compares its own efficiency value with that of the neighboring vehicles in NVT. If it has a higher efficiency value than the neighboring vehicles, it selects itself as the cluster head. Then, it creates a CHN4 message and broadcasts it to all its neighbors. Each vehicle receiving the CHN message first checks whether it has chosen itself as the cluster head. If it has not done so, it puts the IP contained in the message in the neighboring cluster head table (NCHT) and executes the multi-verse meta-heuristic algorithm in order to achieve the optimum cluster head.

This algorithm is composed of two operational phases:

Initiation phase: At first, the vehicles that execute the multi-verse meta-heuristic algorithm initialize the variables num_iter = 0, i=0, then they select the m number from the neighboring cluster heads randomly, where m

[3] . Efficiency Notification
[4] . Cluster Head Notification

represents the size of the ecosystem. These selected cluster heads show the initial set of candidate solutions. Then, like the multi-verse algorithm, each vehicle with a candidate solution initializes the fixed parameters Max, Min and WEP as 1, 2 and 0 respectively.

Candidate solution optimization phase: In this phase, each vehicle with a candidate solution puts i = 1, and updates $\text{clustering\_num\_iter}$ using Equation (1-2).

$$\text{clustering\_num\_iter} = \text{clustering\_num\_iter} + 1$$

Equation (1-2): This equation adds one unit to the value of clustering_num_iter at each stage of optimization. Then, each vehicle with a candidate solution gets the efficiency of its candidate solutions using Equation (1-3).

$$\text{Clustering\_Eff1}(z_i) = \sum_{j=1}^{m} \sum_{i=1}^{CH_i} \text{Clustering\_Eff}(j,i)$$

Equation (1-3): Routing_Eff (zi) represents the efficiency value of the Zi candidate solution. m represents the size of the eco-system. Clustering_Eff (j, i) shows the efficiency of i-th cluster head in the j candidate solution and is obtained using Equation (1-1).

Then, each vehicle with a candidate solution obtains the optimal candidate solution. The optimal candidate solution is a candidate solution that has greater efficiency than the rest of the candidate solutions. As it was mentioned in the multi-verse algorithm, the first candidate solution in the SZ ordered collection is the best candidate solution. Thus, we do the following for each szi candidate solution except for sz1:

- ✓ First, we consider the sz_i candidate solution as the black-hole answer.
- ✓ Then, we do the following for each sx_i and sy_i position corresponding to sz_i :
- ➢ First, we obtain a random number r_1 in the closed range [0,1].
- ➢ Then, we update the values of sx_i and sy_i using Equations (1-4) and 1-5).

Equation (1-4): $$sx_i = \begin{cases} sx_k, & \text{if } r_1 < NI(Z_i) \\ sx_i, & \text{if } r_1 \geq NI(Z_i) \end{cases}$$

Equation (1-5): $$sy_i = \begin{cases} sy_k, & \text{if } r_1 < NI(Z_i) \\ sy_i, & \text{if } r_1 \geq NI(Z_i) \end{cases}$$

In Equations (1-4) and (5-1), xk and yk represent the values of the sxk and syk of szk candidate solution. Szk is obtained by the forward movement of NI(Zi), because the problem is of optimization type.

- ➢ Next, we obtain a random number r2 in the closed range [0,1].
- ➢ Then, if r_2<WEP :
- ➢ we obtain two random numbers r_2 and r_4 in the closed range [0,1].
- ➢ We update the values of the variables of sx_t_i and sy_t_i vectors from the temporary candidate solution using Equations (1-6) and (1-7).

$$sx\_t_i = \begin{cases} best\_sx + ((TDR \times ((ux - lx) \times r_4) + lx), & \text{if } r_3 < 0.5 \\ best\_sx - ((TDR \times ((ux - lx) \times r_4) + lx), & \text{if } r_3 \geq 0.5 \end{cases}$$

Equation (1-6): This equation shows the temporary position of sx ti on the x-axis.

$$sy\_t_i = \begin{cases} best\_sy + ((TDR \times ((uy - ly) \times r_4) + ly), & \text{if } r_3 < 0.5 \\ best\_sy - ((TDR \times ((uy - ly) \times r_4) + ly), & \text{if } r_3 \geq 0.5 \end{cases}$$

Equation (1-7): This equation shows the temporary position of sy ti on the y-axis.

- ➢ We update the value of the j- th variable from the sx t_i and sy t_y position vectors using Equation (1-8) and (1-9).

$$sx\_t_i = \begin{cases} lx, & \text{if } sx\_t_i < lx \\ ux, & \text{if } sx\_t_i > ux \end{cases}$$

Equation (1-8): This equation puts the value obtained from the sx ti position in the allowable range of search.

$$sy\_t_i = \begin{cases} ly, & \text{if } sy\_t_i < ly \\ uy, & \text{if } sy\_t_i > uy \end{cases}$$

Equation (1-9): This equation puts the value obtained from the sy ti position in the allowable range of search.

- ➢ Each vehicle with candidate solution obtains the sx t_i and sy t_i new position of the selected vehicles in the z_i candidate solution by using the nearest vehicle technique and the sx t_i and sy t_i position.

In the nearest vehicle technique, the vehicle that has the least Euclidean distance from the sx ti and sy ti position is selected for each zi new candidate solution. Assume that xj and yj have the j-th position among the neighboring vehicles. Euclidean distance djj is obtained using the following equation:

$$d_{ij} = \sqrt{(sx\_t_i - x_j)^2 + (sy\_t_i - y_j)^2}$$

Equation (1-10): This equation obtains the Euclidean distance between the j- th vehicle among the neighboring vehicles from the SX_Ti and SY Ti temporary position.

Then the vehicle with a candidate solution checks whether whether Equation (1-11) is met or not. If the equation is met, the optimization step is executed again. Otherwise, the algorithm will terminate.

$$clustering\_num\_iter \leq Max\_clustering\_iter$$

Equation (1-11): Max_clustering_iter represents the maximum stage of execution.

After the algorithm ends, the optimal candidate solution s are selected as the optimum cluster heads in vehicles with candidate solution.

C: The cluster-based route discovery phase

In this phase, each source vehicle transmits a routing request RREQ to its cluster head. This request contains the source and destination IP addresses. Upon receiving the PREQ message, the cluster head obtains the IP address of the target vehicle. Then, it checks whether the target vehicle exists in the list of the cluster member vehicles or not, and whether there is a route to the target vehicle in the Cluster Routing Table or not. If one of the above conditions is met, the cluster head creates a reverse route toward the source vehicle in the routing table. Next, it creates an RREP message. The RREP message is shown from the IP address field and the field of the EV route efficiency value. The route efficiency value field is initially zero. The cluster head puts its own IP address in the IP Address field of RREP message and puts its own cluster head efficiency value in the EV route efficiency value. Then, it sends the RREP message to the next vehicle in the opposite direction toward the source vehicle. Otherwise, the cluster head first creates a reverse route toward the source in the routing table and sends an RREQ message to the gates of the cluster. The gates send the received RREQ message to the cluster heads existing in the NCHT (Neighboring Cluster head Table). This continues until the RREQ message reaches a cluster in which one of the above conditions is met. In this case, when one of the above conditions is met, the cluster head creates an RREP message in which it puts its own IP address.

Then, it makes the value of the variable E as equal to the efficiency value of its cluster head and sends the RREP message to the next vehicle in the opposite direction toward the source vehicle. Each vehicle of the central overhead which receives the RREP message adds the efficiency value of its cluster head to the previous value of the EV route efficiency in the RREP, next, it sends the RREP message to the next vehicle in the opposite direction. This continues until the RREP message reaches the source vehicle. After the RREP message reaches the source vehicle, the EV route efficiency value field is checked and its value is put in the REV column corresponding to the next hub of the route.

D: The phase of data transmission and support of the discovered routes

This phase consists of two stages: As the first stage, the vehicles transmit data over the discovered routes. At the second stage, each cluster head vehicle sends a Hello message to its members. Any cluster member vehicle which is still within the cluster range transmits an Ack message to the cluster head vehicle as soon as it receives the Hello message. Then, it waits for a short period of time. Now, there may be three cases:

1. The CH vehicle v may receive no Ack message from a cluster member vehicle during a period of time, in which case the cluster head vehicle removes the IP of the cluster member vehicle from the list of its members.

2. The cluster member vehicle W may receive no Hello message from the cluster head vehicle during a period of time, in which case the cluster member vehicle first checks whether there is at least one cluster head other than itself in the neighborhood:

- If there is at least one neighboring CH: The cluster head with the greatest efficiency is selected as the new cluster head. Then, the initial route discovery and the optimized route discovery phases are implemented on the destination vehicles from the routes requested in the cluster member.
- If there is no neighboring cluster head vehicle: The cluster member broadcasts a message requesting the implementation of the clustering phase. Each vehicle receiving this message broadcasts the message to all neighboring vehicles if it has not already received that message from that cluster member. In other words, the cluster head vehicles transmit the clustering phases, the initial route discovery and the optimized route discovery in this case.

3. Each CH v vehicle and cluster member w vehicle have received the Ack and Hello messages respectively:

• The transmitted phase and support of the discovered routes are implemented again.

We use the Omnet++ Simulation Software Version 4,4 in order to evaluate the proposed algorithm and compare it with the standard AODV routing algorithm. The evaluation criteria include: packet delivery, throughput and packet loss.

4. Evaluation parameters

- ✓ Direction: If two vehicles are within the transmission range of each other and are in the same direction, they can participate in the clustering operation.
- ✓ The speed difference between the cluster member vehicle and the cluster head vehicle: The less the speed difference, the higher the efficiency.
- ✓ The distance between the cluster head vehicle and the cluster member vehicle: The lower the distance, the higher the efficiency. Assuming (x_{CH}, y_{CH}) and (x_{Mem}, y_{Mem}) as the Euclidean coordinates of the cluster head and cluster member respectively, the Euclidean distance between them is calculated using equation 1-12:

$$d(CH,Mem)=\sqrt{(x_{CH}-x_{Mem})^2+(y_{CH}-y_{Mem})^2}$$

Equation (1-12): d represents Euclidean distance between the cluster head vehicle and cluster member vehicle.

5. Results

The proposed cluster-based routing algorithm and the standard routing algorithm AODV are implemented and the evaluation criteria are examined in this part.

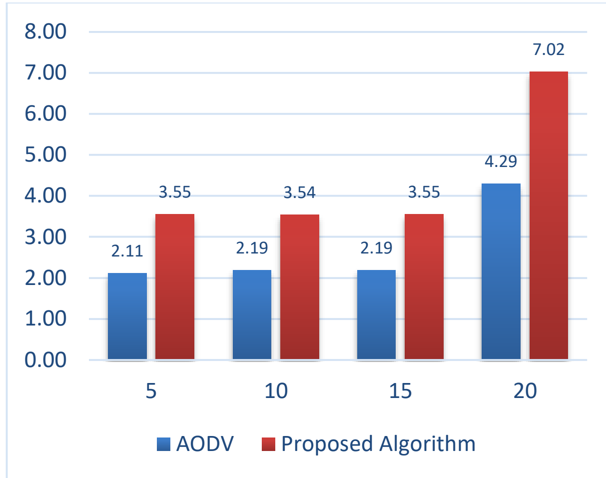

Diagram. 1 the average throughput of the proposed algorithm and AODV Algorithm, with the assumption of 5, 10, 15, and 20 vehicles per route

As shown in the diagram 1, the larger the number of nodes, the higher the average throughput of the proposed routing algorithm in comparison with the AODV routing algorithm.

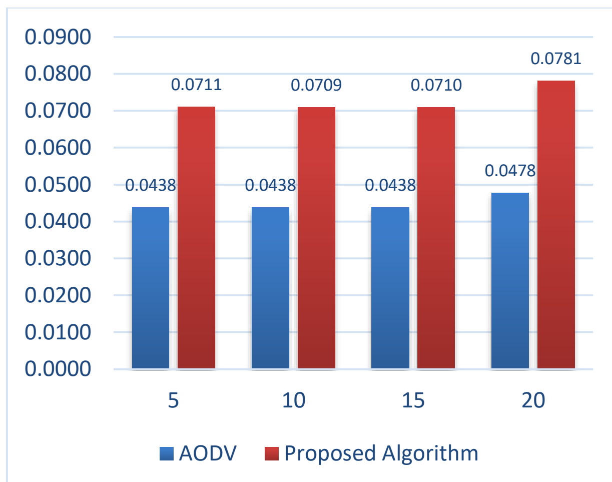

Diagram. 2 the average packet delivery in the proposed routing algorithm, and the AODV, algorithm, assuming 5, 10, 15 and 20 vehicles per route

As shown in the diagram 2, the packet delivery in the proposed routing algorithm increases significantly as the number of nodes increases. This is due to the reduced traffic overhead of the AODV route request message, because, as noted above, the cluster heads are responsible for implementing the routing algorithm in the proposed routing algorithm.

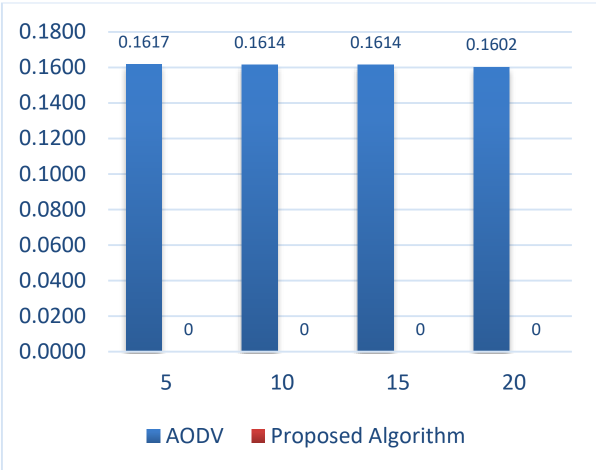

Diagram. 3 the packet loss in the proposed routing algorithm, and the AODV algorithm AODV, with the assumption of 5, 10, 15 and 20 vehicles per route

As shown in the diagram 3, the packet loss in the proposed algorithm is zero and the network has been isolated with regard to the presence of black-hole vehicles.

6. Conclusion

According to what was said, we tried in this study to increase the scalability and throughput of AODV routing protocol by using clustering and detecting non-normal vehicles. The evaluation shows that the multi-verse meta-heuristic algorithm has more efficiency than the Genetic Meta-heuristic Algorithm, the Particle Swarm Algorithm and twenty six other algorithms in nineteen functions (F1-F19).

In the proposed cluster-based routing algorithm, only the cluster heads and the source vehicle are responsible for implementing the routing algorithm. This greatly reduces the traffic overhead of the route request messages and increases the scalability. The simulation results show that the proposed cluster-based routing algorithm has managed to increase the AODV routing algorithm scalability and throughput considerably. One of the significant advantages of this algorithm compared to the standard routing algorithm AODV is its full attention to non-normal vehicles. At the initiation phase, each RSU detects the non-normal vehicles and notifies the normal vehicles. This is why the normal cars remove them from their neighborhood and exclude them from the clustering and routing operations. This minimizes the number of lost messages and increases the network's throughput.

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