Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 1680507, 11 pages
https://doi.org/10.1155/2022/1680507

Research Article

A Novel Highway Routing Protocol in Vehicular Ad Hoc Networks Using VMaSC-LTE and DBA-MAC Protocols

Edris Khezri, Esmaeil Zeinali, and Hadi Sargolzaey

Faculty of Computer and Information Technology Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran

Correspondence should be addressed to Esmaeil Zeinali; zeinali@qiau.ac.ir

Received 24 October 2021; Accepted 23 December 2021; Published 25 January 2022

Academic Editor: Alireza Souri

The vehicular ad hoc networks (VANETs) are an example of mobile networks, which utilizes dedicated short-range communication (DSRC) to establish a wireless connection between cars, and their primary purpose is to provide more security and comfort for passengers. These networks utilize wireless communications and vehicular technology to collect and disseminate traffic information, and it is required to be delivered to all vehicles on the network reliably and quickly. One of the major challenges raised in VANETs is that the communication path between the source and destination nodes is disconnected due to the dynamic nature of the nodes in this network, and the reconnection process of nodes through the new path reduces the performance of network. This paper presents a highway routing protocol to overcome some of the challenges of these networks including routing cost, delay, packet delivery rate, and overhead. The NS2 is used for simulation, and the performance of the proposed protocol is compared with the VMaSC-LTE and DBA-MAC protocols. The results of the simulation indicated that the proposed protocol outperforms the other two protocols in terms of delay, packet delivery rate, and routing overhead.

1. Introduction

A vehicular ad hoc network is a wireless network in which the vehicles equipped with a wireless interface can communicate with each other or fixed roadside equipment [1–3] (Figure 1). These networks create wireless communication among moving vehicles utilizing dedicated short-range communications (DSRC) [2]. DSRC is, in fact, a version of IEEE 802.11a, improved as IEEE 802.11p for operations with low overhead [4]. VANET characteristics are mainly similar to mobile ad hoc networks (MANETs) [5, 6], which means both are self-organizing and self-management, have low bandwidth, and stay in the same position in case of sharing radio transmission. However, the most significant operational obstacle for VANETs (versus MANETs) is its high speed and the mobility of mobile nodes, alongside the routes, indicating that the appropriate design of routing protocols requires the improvement of MANET structure so that it can match itself to the rapid mobility of VANET nodes in an efficient way [7]. Vehicular ad hoc networks provide the context for diverse applications like security and welfare in a wide range of intelligent transportation systems (ITS) [8, 9]. Thus, the development of appropriate routing protocols has always been a challenge for researchers. For example, most routing protocols focus on urban environments and less on highways in communication environments. Other challenges to consider include dynamic topology and high mobility; alternative network disconnection, prediction and modeling of traffic path, and diverse communication environments; and sufficient energy and memory, distribution networks, security, and confidentiality [10–20]. In this paper, a highway routing protocol called "Greedy Highway Routing Protocol (GHRP)" is presented, which contributes to solving or minimizing any of the issues raised above. The main challenge that the suggested method is trying to solve is the global coverage of the routes to prevent the loss of the packages and reduce the delay. In order to solve this problem in the proposed method, it is attempted to minimize the number of fixed Roadside Units (RSUs) by identifying accident sites and installing fixed RSUs in those locations, minimizing the routing cost of purchasing and installing equipment, and covering the entire route using mobile

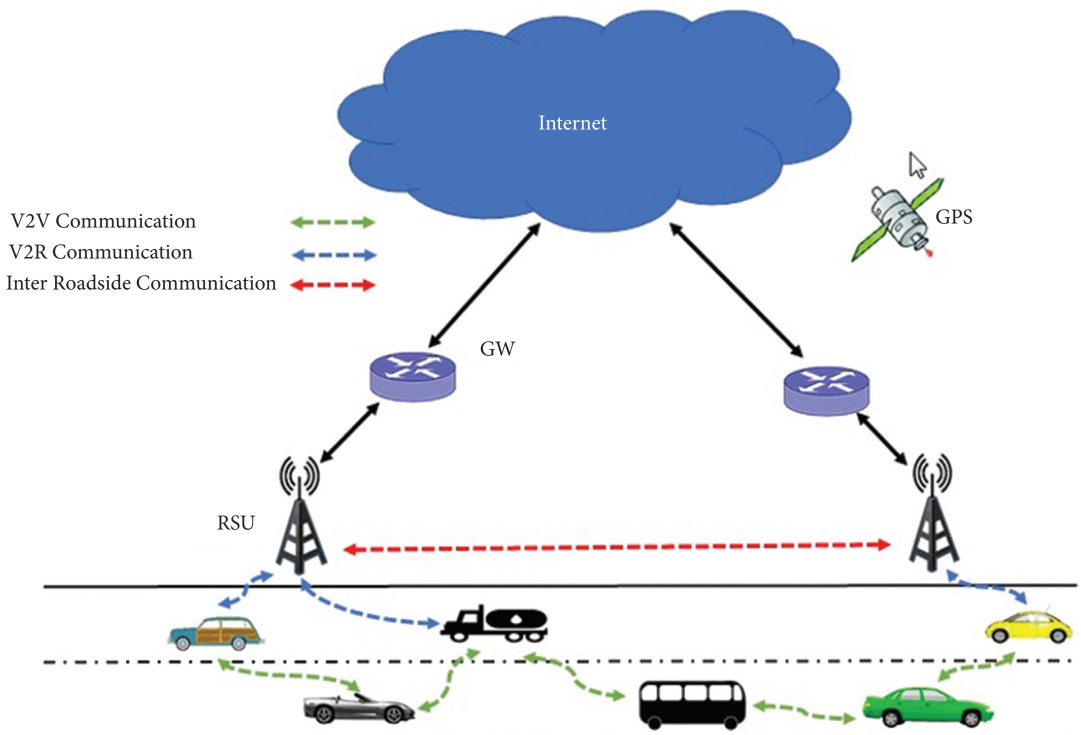

Figure 1: Vehicular ad hoc networks [1].

RSUs, which are public transport equipment. The packet delivery rate increases, and end-to-end delay decreases when covering the entire route with fixed and mobile RSUs. Ultimately, the primary purpose of VANETs, i.e., security and comfort of users, is obtained by collecting the entire information of route and distributing it between cars.

The main contributions of this paper are summarized as follows:

(i) suggesting an intercity routing protocol that attempts to cover the whole of the route and decrease the delay;

(ii) using fixed and variable RSUs; and

(iii) increasing the network efficiency concerning the transfer speed of the packages and reduction of the delay.

The following sections are organized: Section 2 provides DBA-MAC and VMaSC-LTE protocols. Section 3 examines the proposed protocol. Section 4 elaborates discussion, comparison, and simulation of the proposed protocol with other highway routing protocols. Finally, the conclusion, challenges, and future works are reported in Section 5.

2. Related Work

Since one of the main goals of intervehicle networks is to maintain the safety and comfort of occupants of cars [7, 21, 22] and most of the casualties occur in highways, attempts have been made to divide the intervehicle routing protocols into urban routing protocols and highway routing protocols (Figure 2) and focus more on highway routing protocols, which are less considered.

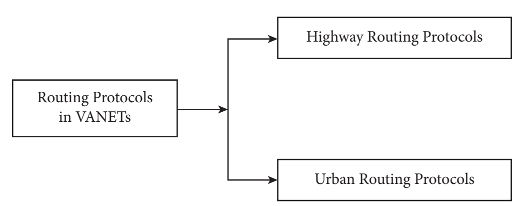

Figure 2: Proposed taxonomy of routing protocols in VANETs.

The highway routing protocols can also be divided into different categories depending on how the message is delivered, communication of cars with each other and the infrastructure, the use of fixed and mobile RSUs, and the like. Since the proposed protocol is a highway routing protocol, fixed and mobile RSUs are used. Simulations are performed on the MAC layer, and both DBA-MAC [23] and VMaSC-LTE [24] protocols are highway routing protocols and used fixed and mobile RSUs. Simulations are performed in the MAC layer, these two protocols are examined, and the proposed protocol is compared with them. Zhou et al. have designed a novel model based on Multilabel-Learning Network for RGB. The graded-feature Multilabel-learning network's suggested design performs state-of-the-art urban scene feature extraction approaches [25]. Zhou et al. have proposed a global feature learning for evaluating the quality of computer content and real scene photos in a blind manner [26]. Artin et al. have presented a new model for the prediction of traffic using ensemble NAS and linear regression in the network [27]. Sun et al. have generalized lifelong spectral clustering. In a lifetime learning paradigm called modified lifelong spectral clustering, this paper investigates the topic of fuzzy clustering [28]. Ahmadi et al. have presented a new classifier model regarding fuzzy regression and the wavelet-based ANN using machine-learning techniques [29]. According to Zhou et al. [30], in terms of increased income, numerous encoding optimization schemes have been presented (RDO). Liu et al. [31] have introduced a new heterogeneous domain adaptation based on an unsupervised model. The results show that the suggested model outperforms the current baselines. Ni et al. [32] have analyzed clustered faults using a framework of cobweb-based redundant. Ala et al. [33]have presented a novel method based on a genetic algorithm for solving the quality of fairness service. Ni et al. [34]have analyzed a new TDMA model regarding the fault tolerance method for the TSVs with the honeycomb network. Sui et al. [35]have studied interference cancellation systems based on the broadband cancellation technique. Guo et al. [36] have concentrated on spreading various sensors and a networked model-based issue for a geographically sizeable linear system. In another study, shifting fault current controls enabled by 5 g in distribution transformers has been investigated by Sun et al. [37]. Ahmadi et al. [38]have examined a new IMU-aided multiple GNSS fault method for solving the problem of environments. Ahmadi et al. [38] have presented a new hybrid method for choosing users federated learning using federated learning based on a novel clustering method. Lv et al. [39] have studied a novel architecture of machine learning for cooperative, smart transportation system security in digital twins. Lv et al. [40] have reviewed 6G-enabled topology based on the Internet of transport vehicles. Lv et al. [41] have checked on methodologies on the Internet of vehicles using intelligent edge computing. Sharifi et al. [42] have studied a survey paper about applying artificial intelligence in industry networks and energy during the pandemic. They have reviewed several articles during last year's. Lv et al. [40] have studied an artificial intelligence model regarding empowered transportation systems using innovative system vehicles. The result shows that the model has a high-accuracy [43]. Lv et al. [41] have analyzed the Security of the Internet of Multimedia Things. This study under the novel technological industry wave, the security performance of the Internet of multimedia things on the security protection of user identification, behavior trajectory, and preference have been done [44]. Varmaghani et al. [45] have optimized energy consumption in dynamic WSN regarding fog modeling and fuzzy MCDM. The methods have been used for clustering and routing network. Accordingly, the given optimum and blind approaches are increased by 28% and 48%, based on the difficulty results obtained [45]. Zhao et al. [46] have optimized macroscopic modeling and dynamic management of automated cars' on-street searching for parks in a cross urban road network. Ahmadi and Qaisari Hasan Abadi [47] have reviewed several papers about the application of programming in-network and industry. They have designed a simulation framework for the proposed model. Bie et al. [48] have investigated a scheduling modeling approach that considers random variances in trip travel duration and energy usage [48]. Rezaei and Naderi [49] have presented a signature verification model using a new hybrid convolution network model. Qiao et al. (2021) have studied a new classification using local wavelet acoustic with a whale optimization algorithm [50]. Qiao et al. [51] have studied coupled models in wavelet models to forecast PM10 concentration. Qiao et al. [52] have studied a combination model based on a wavelet network for forecasting the energy consumption of the USA. Qiao et al. [53] studied a fast-growing source forecasting for production using a novel hybrid wavelet. Peng et al. [54] investigated the effect of inverter blockage on metering efficiency during shale fracking. Peng et al. [55] have examined natural gas predicting regarding the wavelet threshold method.

2.1. DBA-MAC Routing Protocol. In 2009, Bononi et al. introduced the DBA-MAC protocol [23]. The DBA-MAC is presented for a multilane highway scenario, which is bidirectional. The vehicles are assumed to be equipped with GPS. Any emergency messages include dissemination direction, time to live (TTL), and risk zone. Only nodes in the risk zone are allowed to relay the message. The DBA-MAC protocol defines two priority classes to improve access to the channels: normal vehicles and backbone member (BM), where BMs are in higher priority. A node selects itself as BM to create a Backbone and then broadcasts a beacon message, which selects itself as BM. Vehicles that receive the beacon message calculate the remaining time the message can be disseminated (be released). Then, a car with a longer residual time than a threshold is selected as BM. When a BM_{N+1} receives a message from the BM_N, it immediately approves it and disseminates it with a SIFS delay for BM_{N+2}. If a Backbone needs to be repaired, the DBA-MAC will immediately replace a refreshed Backbone. Further, the protocol uses an infrastructure to avoid possible interruption of communication due to the low number of vehicles, in addition to vehicle-to-vehicle communication, where the locations of this infrastructure must be carefully selected.

2.2. VMaSC-LTE Routing Protocol. In 2016, Ucar et al. introduced the VMaSC-LTE protocol [24]. This protocol is a cluster-based technique that uses the IEEE 802.11p standard and selects the cluster head with a relative mobility metric, calculated using the average relative speed of neighboring vehicles. The average relative speed is obtained from $\mathrm{AVGREL\_SPEED}_i = \sum_{j=1}^{N(i)} |S_i - S_{i_j}| / N(i)$, where $N(i)$ is the number of neighbors having the same direction of cluster head for vehicle i, i_j is the id of node j, the neighbor of vehicle i, and Si is the speed of vehicle i. Other features of this protocol include periodically dissemination of the information of cluster members in hello packets, direct connection to the cluster with minimal overhead instead of multistep connection, and reactive clustering to maintain the cluster structure without overusing the network. In the cluster maintenance phase, a timer is used to control the communication between the cluster head and the other cluster members. If the cluster head does not receive packets from its members in the same cluster at a predefined time, it assumes that the node is lost.

3. Proposed Algorithm

In this paper, a new routing algorithm is presented to improve the weaknesses of previous methods such as delay, overhead, packet delivery rate, and the like. The routing mode uses both fixed and mobile RSUs. First, the accident sites are identified, and fixed RSUs are installed where it is intended to deploy the intervehicle network. However, as known, the whole route cannot be well covered just by using fixed RSUs installed at accident sites. Therefore, a combination of fixed and mobile RSUs is used in the proposed protocol. As mentioned, fixed RSUs are used at accident sites and mobile RSUs at other locations on the route. Public transit vehicles are used as mobile RSUs by installing OBUs. In the proposed protocol, each vehicle can use fixed and mobile RSUs to reduce sending steps and delays to send packets and warning signals to other vehicles. The routing steps are as follows:

(i) If there is a direct route from the source to the destination, i.e., the destination is within the coverage radius of the source, the package is sent directly to the destination.

(ii) If there is no vehicle or RSUs (fixed or mobile) near the source, the source vehicle transports the data packet to the first vehicle within its radius and then sends it.

(iii) If there are RSUs (fixed or mobile) near the source and destination, the source sends the packet to the RSUs (fixed or mobile). After receiving the packet, the RSU near the source sends it to the nearest RSU to the destination, and then it is sent to the destination.

(iv) If there is more than one vehicle near the source, but none of them are fixed or mobile RSUs, the source vehicle sends the packet to the farthest vehicle within its radius and the shortest distance with the fixed or mobile RSUs. After the packet arrives at the RSU, the RSU sends it to the nearest RSU to the destination, and then it is sent to the destination.

(v) If there is more than one route to send the data packet, a route with fewer steps and a longer route life is selected.

3.1. Assumptions. The following assumptions were made:

(i) Each vehicle using its GPS obtains its location, the location of neighboring nodes, the location, and direction of the destination, road information (such as traffic), as well as a map of its intended environment. This information is periodically transmitted as a Hello message to nearby vehicles within its range.

(ii) A digital map with the conditions of road traffic load is installed on the vehicle.

(iii) The On-Board Unit (OBU) in any vehicle used as a mobile RSU has an IEEE 802.11p and a 3G interface. The IEEE 802.11p interface is used to communicate with ordinary cars. The 3G interface communicates with RSUs (fixed and mobile).

20% of the nodes in the network are considered fixed and mobile RSUs, and the number of fixed and mobile RSUs is considered equal.

In addition, it is assumed that the entry time of ordinary vehicles and the mobile RSUs on the road follows the Poisson distribution (Figure 3). The distribution function of the vehicles and mobile RSUs is uniform along the entire road. It should be noted that the Poisson distribution is used here since the normal distribution is not suitable for n nodes more significant than 20, and where n is the number of vehicles which is much more than 20. The horizontal axis (X) in Figure 3 presents of entry time of ordinary vehicles and mobile RSUs in 24 hours with the number of vehicles per hour on the road, which can be used to estimate the number of steps and the arrival time to the accident site.

3.2. Estimating the Number of Steps and Transmission Time. As mentioned before, one of the features of the proposed algorithm is to reduce the delay by minimizing the number of steps between source and destination. For this purpose, if several routes are between the source and destination, the shortest route is selected by estimating the number of steps. In order to estimate the number of steps, the required parameters are defined as follows (Table 1):

Considering that the entry and exit rate of ordinary vehicles and mobile RSUs on the road follows the Poisson distribution, first the number of vehicles and RSUs on the road is calculated from Equations (1) and (2):

$$n = N \times P \times 10, \tag{1}$$

$$m = M \times P \times 10. \tag{2}$$

In the above case, it is multiplied by 10 because the probability is 1 at the best. Since the Poisson distribution is considered for $\lambda = 13$, and the maximum value is approximately 0.1 as shown in the graph, so it is multiplied by 10 to get 1.

Since fixed and mobile RSUs are used, and fixed RSUs are installed at the accident sites in the proposed algorithm, the route is divided into several sections (Figure 4). One part of the road L_j was considered. The L_j part was divided into two parts as L_{j1} and L_{j2}. Then, we have Equations (3) and (4):

$$N_{jk} = n_k \times \frac{L_j}{X_i} \quad k = 1, 2, \tag{3}$$

$$M_{jk} = m_k \times \frac{L_j}{X_i} \quad k = 1, 2, \tag{4}$$

where N_{jk} indicates the number of mobile RSUs and M_{jk} shows the number of ordinary vehicles in section L_j of the road. It is assumed that the source vehicle is in section j of the road and wants to send a packet. Since it can send the packet in the direction or in the opposite direction of itself, the jth part of the road is divided into two parts of $j1$ and $j2$.

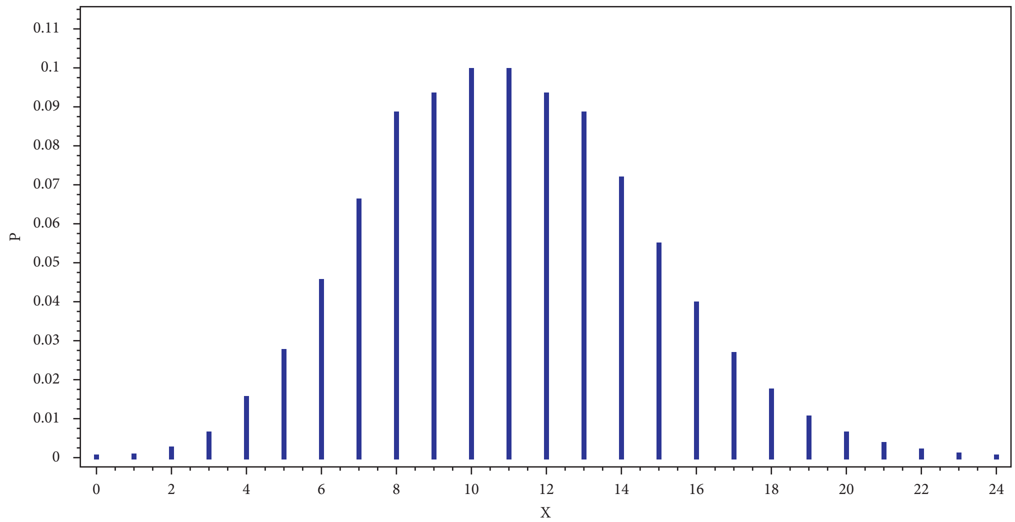

FIGURE 3: Diagram of entry time of ordinary vehicles and mobile RSUs in 24 hours.

TABLE 1: Parameters used in the proposed protocol.

Description	Name
The coverage radius of each vehicle	R
Packet delivery time between two source and destination vehicles	T
Delivery time between two vehicles	t_d
Speed of vehicle i	V_i
Speed of vehicle j	V_j
The distance between two vehicles i and j	d_{ij}
The whole length of the route	X_i
Total number of mobile RSUs in 24 hours	N
The number of mobile RSUs moving to the right of the road at a specific time	n_1
The number of mobile RSUs moving to the left of the road at a specific time	n_2
Total number of mobile RSUs at a specific time on the road	$n=n_1+n_2$
Total number of ordinary vehicles in 24 hours	M
The number of vehicles moving to the right of the road at a specific time	m_1
The number of vehicles moving to the left of the road at a specific time	m_2
Total number of ordinary vehicles at a specific time on the road	$m=m_1+m_2$
Poisson probability at a particular moment	P
The length of section j	L_j
The mobile RSUs in either L_{j1} or L_{j2} $(K=1, 2)$	N_{jk}
The ordinary vehicles in either L_{j1} or L_{j2} $(K=1, 2)$	M_{jk}

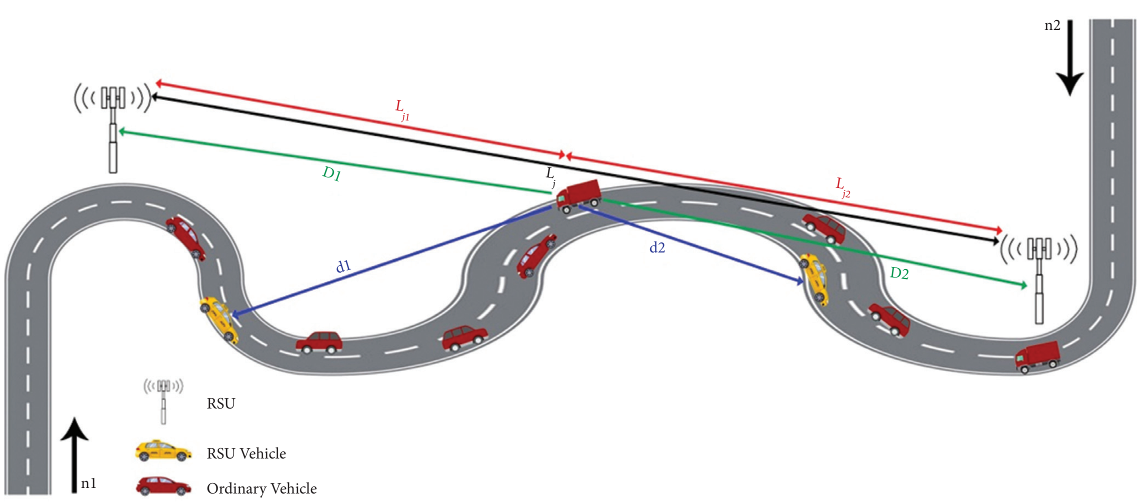

FIGURE 4: Network scenario.

The distance from the source vehicle to the fixed RSU behind it is called D_1, and the distance from the source vehicle to the fixed forward RSU is D_2. Now, suppose $D2 > D1$, $D2$ is selected for sending the packet because there is a higher probability of more mobile RSUs in this area. In that case, we have Equations (5)–(8):

$$N'_{j2k} = n_k \times \frac{L_j/D_2}{X_i} = n_k \times \frac{L_j}{X_i D_2} \quad k = 1, 2, \tag{5}$$

where N'_{j2k} is the number of RSU in L_{j2} section.

$$d = \frac{D_2}{N'_{j2k}} = \frac{D_2^2 \times X_i}{n_k \times L_j}, \tag{6}$$

where d is the distance from the source to the first RSU.

$$M'_{j2k} = m_k \times \frac{L_j/d_2}{X_i} = m_k \times \frac{L_j}{X_i d_2} \quad k = 1, 2, \tag{7}$$

where M'_{j2k} is the number of ordinary vehicles between the origin and the first RSU.

$$d' = \frac{d_2}{M'_{j2k}} = \frac{d_2^2 \times X_i}{m_k \times L_j} \quad k = 1, 2, \tag{8}$$

where d' is the average distance between ordinary cars from the origin to the first RSU.

In order to calculate the number of steps to get to the nearest fixed or mobile RSU:

(A) If $d' \leq R$. Then, we have Equations (9) and (10):

$$C_j = \frac{L_j}{N'_{j2k} \times R}, \tag{9}$$

$$T = C_j \times t_d, \tag{10}$$

where C_j is the number of steps to reach the nearest fixed, or mobile RSU and T is the time to reach the nearest fixed or mobile RSU.

(B) If $d' > R$. Then, we have (Equations (11) and (12)):

$$C_j = M'_{j2k} - 1, \tag{11}$$

$$T = \left(\sum_{i=1}^{M'_{j2k}-1} \frac{V_i}{d_{ij}} \right) + \left(C_j \times t_d \right). \tag{12}$$

If $D_1 = D_2$, since the number of steps will be equal, a route with the most extended lifespan will be selected among the available routes.

3.3. Calculating the Lifetime of the Route. The lifespan is calculated as follows:

(A) Both vehicles should be in the same direction, and the speed of the front vehicle should be more. In this case, the lifetime of the path is calculated by the following equation:

$$\text{LifeTime}_{link} = \frac{R - |d_{ij}|}{|V_i - V_j|}, \tag{13}$$

(B) Both vehicles should be in the same direction, and the speed of the front vehicle must be less. In this case, the lifetime of the route is calculated by the following equation:

$$\text{LifeTime}_{link} = \frac{R + |d_{ij}|}{|V_i - V_j|}. \tag{14}$$

(C) Vehicles move in the opposite direction. In this case, the lifetime of the route is calculated by the following equation (15):

$$\text{LifeTime}_{link} = \frac{R + |d_{ij}|}{V_i + V_j}, \tag{15}$$

where R is the transmission range between the vehicles, d_{ij} represents the distance between vehicles i and j, V_i is the speed of vehicle i, and V_j is the speed of vehicle j.

4. Result and Discussion

In this section, the performance of the proposed protocol is compared through various factors. NS2 simulator is used to simulate the proposed protocol and compare its performance parameters with other protocols [56]. In this simulation experiment, a highway scenario with a length of 8 km and 25 to 200 vehicles was considered. IEEE 802.11 with a transmission rate of 2 Mbps and a transmission range of 250 m is used as the underlying MAC protocol. The data packet's time to live (TTL) is set to 100 hops. All simulation results are averaged over 20 runs. The parameters used in the simulations are summarized in Table 2.

4.1. Performance Parameters. The parameters such as packet delivery rate, overhead, end-to-end delay, and several dropped packets were used to evaluate the performance of the proposed protocols and compare them with other protocols. Each of these parameters is explained in this section, and all three proposed protocols, DBA-MAC and VMaSC-LTE, are compared.

4.1.1. Packet Delivery Rate. The ratio of total packets received by the destination node to the total packets sent by the source is obtained using Equation (16):

$$\text{PDR} = \frac{\text{number of packets received by the destination}}{\text{number of packets sent by the source}}. \tag{16}$$

Packet delivery rates give information on how successful the protocol is in delivering data packets. The higher PDR means that the protocol has been more efficient in delivering packets.

Table 2: Simulation parameters.

Parameters	Value
Network simulator	NS2
Simulation time	1000s
Highway length	8 Km
Vehicles speed (min)	20 m/s
Vehicles speed (max)	33 m/s
Number of vehicles	25, 50, 100, 200
Phy/Mac protocol	IEEE 802.11p
Data message size	512 bytes
Traffic	CBR
Transmission range	250 m
Transmission power	1 mW

The breaking of the communication link between vehicles due to the high speed of the vehicles is regarded as one of the main concerns in intervehicle networks is. As observed in Figure 5, the communication links between the vehicles are less likely to be broken when the number of vehicles increases, resulting in fewer dropped packets and higher packet delivery rates. Furthermore, the proposed protocol performs better than the other two protocols.

Figure 6 illustrates the effect of increasing the number of RSUs on the packet delivery rate for the proposed protocol in different modes. In the proposed protocol, 20% of the vehicles are RSU. However, the packet delivery rate is examined for the modes with 10%, 20%, 30%, 40%, and 50% of the total RSU network vehicles and four modes with 25, 50, 100, and 200 vehicles. As observed, the higher the number of RSUs, the higher is the packet delivery rate.

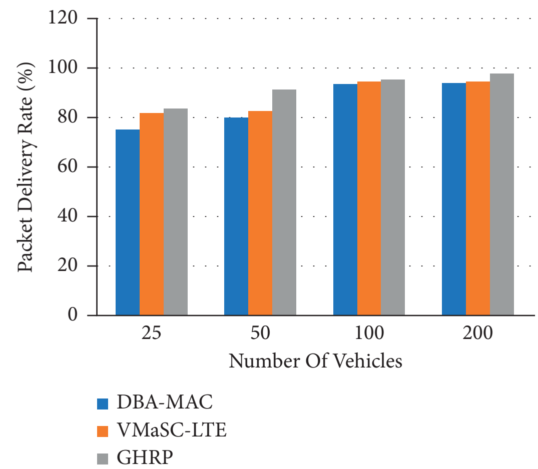

Figure 5: The effect of increasing the number of vehicles on the percentage of packet delivery rate.

4.1.2. Average End-to-End Delay. The average end-to-end delay is defined as the average delay in transmitting a packet between two end nodes. This parameter is calculated using Equation (17):

$$\mathrm{AED} = \frac{\sum_{i=0}^{n}((\text{time of receiving the } i-\text{th packet})-(\text{time of sending the } i-\text{th packet}))}{\text{total number of packets received by the destination}}. \tag{17}$$

Figure 7 shows the average end-to-end delay between the suggested algorithm and the two other algorithms. With the number of vehicles, the end-to-end delay decreases due to the number of routers between the source and destination. As Figure 7 shows, the suggested protocol outperformed the two other protocols when the network was quiet and busy.

As explained, the use of RSUs in the proposed protocol for intervehicle networks reduces the number of routing steps between the source and the destination. As the number of RSUs shown in Figure 8 increases, the number of packet sending steps decreases between source and destination, resulting in a lower end-to-end delay.

4.1.3. Number of Dropped Packets. This parameter indicates the percentage of packets dropped during the simulation and not reached their destination. The NDP can be calculated by:

$$\mathrm{NDP} = \frac{(\text{sent packet} - \text{received packet})}{100}. \tag{18}$$

Increasing the number of vehicles makes it less likely for links to break between vehicles. Thus, the number of dropped packets is lower.

In the section related to packet delivery rates, it was argued that the links are less likely to be broken due to the high speed of vehicles in intervehicle networks. Thus, the packet delivery rate is higher when the number of vehicles increases. Since the packet delivery rate and the number of dropped packets in the network are correlated inversely, the number of dropped packets is lower when the packet delivery rate increases. Figures 9 and 10 indicate the obtained results. The number of dropped packets in the network decreases by increasing the number of vehicles and RSUs.

4.1.4. Normalized Routing Load (NRL). This parameter is defined as the ratio of routing packets sent to the number received and can be calculated using Equation (19):

$$\mathrm{NRL} = \frac{\text{number of routing packets sent by the source}}{\text{number of packets received by the destination}}. \tag{19}$$

The higher the NRL, the lower is the performance and efficiency of the protocol.

An increase in the number of vehicles leads to an increase in the routing overhead since the operations performed by vehicles on packets increase. However, as shown in Figure 11, the routing overhead of the proposed protocol is less than the other two protocols.

As shown in Figure 11, the overhead increases by increasing the number of vehicles and thus the number of

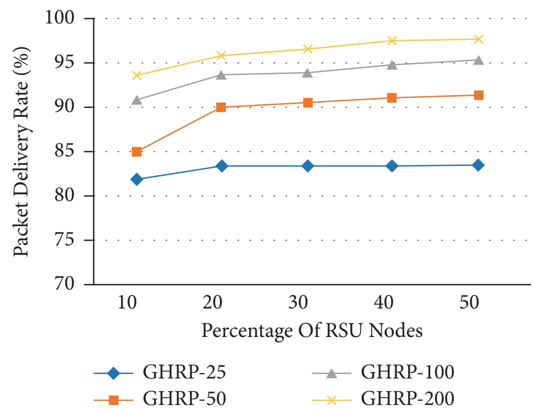

Figure 6: The effect of increasing the number of RSUs on packet delivery rate percentages.

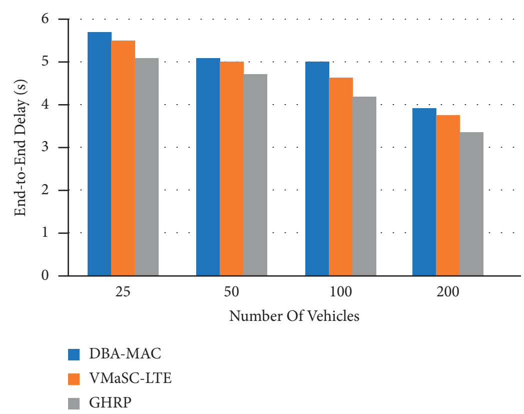

Figure 7: The effect of an increasing number of vehicles on end-to-end delay.

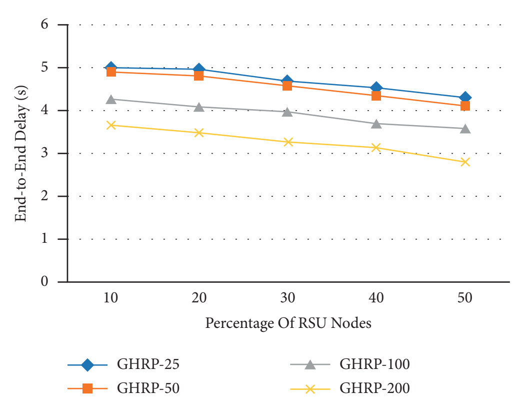

Figure 8: The effect of increasing RSUs on end-to-end delay.

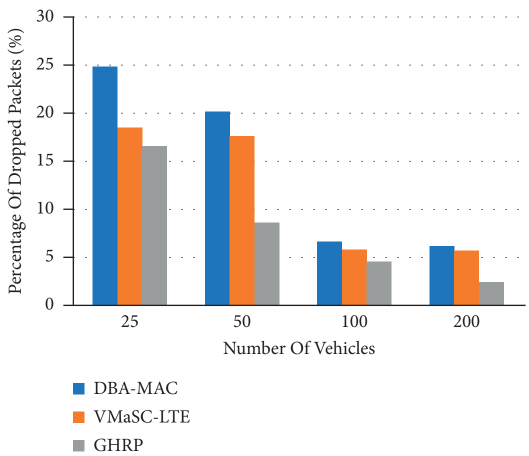

Figure 9: The impact of an increasing number of vehicles on the dropped packet amount.

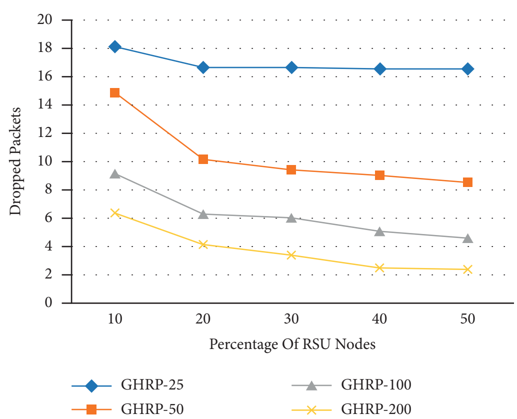

Figure 10: Increasing the number of RSUs on the amount of dropped packets.

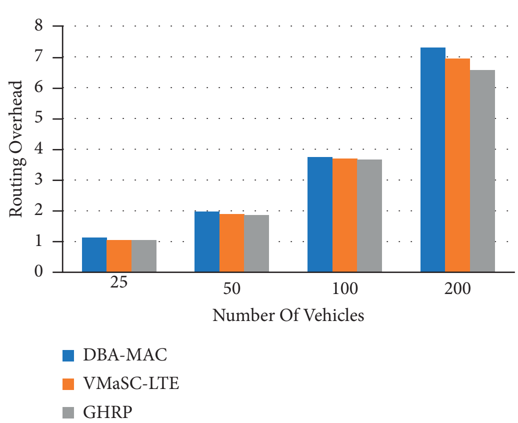

Figure 11: The effect of an increasing number of vehicles on the routing overhead.

vehicles performed on routing packets. However, as illustrated in Figure 12, an increase in the number of RSUs leads to an increase in the number of steps to reach the destination, resulting in fewer routing operations and eventually lower overhead.

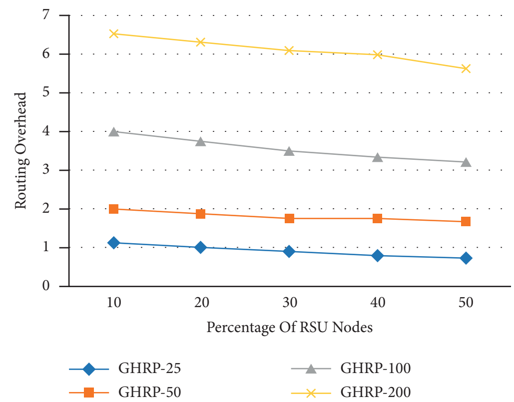

Figure 12: Effect of increasing RSUs on routing overhead value.

5. Conclusion

The main challenges in VANETs are the dynamic topology and constant network disconnection, which lead to delays in packages' arrival [57]. In the present paper, an intercity protocol was suggested, which attempts to solve this problem by global coverage of the vehicles' routes and reduction of delay to achieve the primary goal of VANETs, which is the safety and comfort of passengers. In the suggested protocol, fixed and variable RSUs were used to route packages, and an ns2 simulator was employed to simulate. The suggested protocol was compared with two intercity routing protocols, i.e., DBA-MAC and VMaSC-LTE. It was found that the suggested protocol outperformed the two other ones in terms of delay, packet delivery rate, and routing overhead. We follow two main goals in future works. First, investigation and implementation of the suggested protocol in an urban environment will also focus on efficient energy consumption and the issues mentioned above [58]. Second, since the information exchanged between cars is essential.

In some cases, even humans' life may depend on this information, and the issue of security can be of great importance [59]. Thus, it must be robust against different types of attacks like fake information, service denial, and black holes. Therefore, we will work on the security aspect of the suggested protocol to make it a safe protocol against different types of attacks to the information can safely and accurately reach the destination.

Data Availability

Data are available and can be provided over the emails querying directly to the author at the corresponding author (zeinali@qiau.ac.ir).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] E. Khezri and E. Zeinali, "A review on highway routing protocols in vehicular ad hoc networks," *SN Computer Science*, vol. 2, no. 2, pp. 1–22, 2021.

[2] J. Cui, W. Xu, Y. Han, J. Zhang, and H. Zhong, "Secure mutual authentication with privacy preservation in vehicular ad hoc networks," *Vehicular Communications*, vol. 21, p. 100200, 2020.

[3] S. Kumar and A. K. Verma, "Position based routing protocols in VANET: a survey," *Wireless Personal Communications*, vol. 83, no. 4, pp. 2747–2772, 2015.

[4] J. Noh, S. Jeon, and S. Cho, "Distributed blockchain-based message authentication scheme for connected vehicles," *Electronics*, vol. 9, no. 1, p. 74, 2020.

[5] I. Ali, A. Hassan, and F. Li, "Authentication and privacy schemes for vehicular ad hoc networks (VANETs): a survey," *Vehicular Communications*, vol. 16, pp. 45–61, 2019.

[6] Y. Ming and H. Cheng, "Efficient certificateless conditional privacy-preserving authentication scheme in VANETs," *Mobile Information Systems*, vol. 2019, Article ID 7593138, 19 pages, 2019.

[7] B. T. Sharef, R. A. Alsaqour, and M. Ismail, "Vehicular communication ad hoc routing protocols: a survey," *Journal of Network and Computer Applications*, vol. 40, pp. 363–396, 2014.

[8] H. Galeana-Zapién, M. Morales-Sandoval, C. A. Leyva-Vázquez, and J. Rubio-Loyola, "Smartphone-based platform for secure multi-hop message dissemination in VANETs," *Sensors*, vol. 20, no. 2, p. 330, 2020.

[9] M. Ma, D. He, H. Wang, N. Kumar, and K.-K. R. Choo, "An efficient and provably secure authenticated key agreement protocol for fog-based vehicular ad-hoc networks," *IEEE Internet of Things Journal*, vol. 6, no. 5, pp. 8065–8075, 2019.

[10] C. Suthaputchakun and Z. Sun, "Routing protocol in inter-vehicle communication systems: a survey," *IEEE Communications Magazine*, vol. 49, no. 12, pp. 150–156, 2011.

[11] C. Tripp-Barba, A. Zaldívar-Colado, L. Urquiza-Aguiar, and J. A. Aguilar-Calderón, "Survey on routing protocols for vehicular ad hoc networks based on multimetrics," *Electronics*, vol. 8, no. 10, p. 1177, 2019.

[12] D. Antolino Rivas, J. M. Barceló-Ordinas, M. Guerrero Zapata, and J. D. Morillo-Pozo, "Security on VANETs: privacy, misbehaving nodes, false information and secure data aggregation," *Journal of Network and Computer Applications*, vol. 34, no. 6, pp. 1942–1955, 2011.

[13] E. Fonseca and A. Festag, "A survey of existing approaches for secure ad hoc routing and their applicability to VANETS," *NEC network laboratories*, vol. 28, pp. 1–28, 2006.

[14] F. Li and Y. Wang, "Routing in vehicular ad hoc networks: a survey," *IEEE Vehicular Technology Magazine*, vol. 2, no. 2, pp. 12–22, 2007.

[15] G. Karagiannis, O. Altintas, E. Ekici et al., "Vehicular networking: a survey and tutorial on requirements, architectures, challenges, standards and solutions," *IEEE Communications Surveys & Tutorials*, vol. 13, no. 4, pp. 584–616, 2011.

[16] M. Zhou, L. Han, H. Lu, and C. Fu, "Distributed collaborative intrusion detection system for vehicular Ad Hoc networks based on invariant," *Computer Networks*, vol. 172, p. 107174, 2020.

[17] S. Dhankhar and S. Agrawal, "VANETs: a survey on routing protocols and issues," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 3, no. 6, pp. 13427–13435, 2014.

[18] S. Zeadally, R. Hunt, Y.-S. Chen, A. Irwin, and A. Hassan, "Vehicular ad hoc networks (VANETS): status, results, and challenges," *Telecommunication Systems*, vol. 50, no. 4, pp. 217–241, 2012.

[19] A. Ram and M. K. Mishra, "Density-connected cluster-based routing protocol in vehicular ad hoc networks," *Annals of Telecommunications*, vol. 75, no. 7, pp. 319–332, 2020.

[20] M. A. Mimi and M. M. Elahi: A Stable Clustering Architecture for Efficient Routing in Vehicular Ad Hoc Networks.

[21] Y. Jiang and X. Li, "Broadband cancellation method in an adaptive co-site interference cancellation system," *International Journal of Electronics*, pp. 1–21, 2021.

[22] F. J. Martinez, C. K. Toh, J.-C. Cano, C. T. Calafate, and P. Manzoni, "A survey and comparative study of simulators for vehicular ad hoc networks (VANETs)," *Wireless Communications and Mobile Computing*, vol. 11, no. 7, pp. 813–828, 2011.

[23] L. Bononi, M. Di Felice, and S. Pizzi, "Dba-mac: dynamic backbone-assisted medium access control protocol for efficient broadcast in vanets," *Journal of Interconnection Networks*, vol. 10, no. 04, pp. 321–344, 2009.

[24] S. Ucar, S. C. Ergen, and O. Ozkasap, "Multihop-cluster-based IEEE 802.11 p and LTE hybrid architecture for VANET safety message dissemination," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 4, pp. 2621–2636, 2015.

[25] W. Zhou, J. Liu, J. Lei, L. Yu, and J.-N. Hwang, "GMNet: graded-feature multilabel-learning network for RGB-thermal urban scene semantic segmentation," *IEEE Transactions on Image Processing*, vol. 30, pp. 7790–7802, 2021.

[26] W. Zhou, L. Yu, Y. Zhou, W. Qiu, M.-W. Wu, and T. Luo, "Local and global feature learning for blind quality evaluation of screen content and natural scene images," *IEEE Transactions on Image Processing*, vol. 27, no. 5, pp. 2086–2095, 2018.

[27] J. Artin, V. Amin, M. Ahmadi, S. A. P. Kumar, and A. Sharifi, "Presentation of a novel method for prediction of traffic with climate condition based on ensemble learning of neural architecture search (NAS) and linear regression," *Complexity*, vol. 2021, Article ID 8500572, 13 pages, 2021.

[28] G. Sun, Y. Cong, J. Dong, Y. Liu, Z. Ding, and H. Yu, "What and how: generalized lifelong spectral clustering via dual memory," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, p. 1, 2021.

[29] M. Ahmadi, F. Dashti Ahangar, N. Astaraki, M. Abbasi, and B Babaei, "FWNNet: presentation of a new classifier of brain tumor diagnosis based on fuzzy logic and the wavelet-based neural network using machine-learning methods," *Computational Intelligence and Neuroscience*, vol. 2021, Article ID 8542637, 13 pages, 2021.

[30] Y. Zhou, G. Xu, K. Tang, L. Tian, and Y. Sun, "Video coding optimization in AVS2," *Information Processing & Management*, vol. 59, no. 2, p. 102808, 2022.

[31] F. Liu, G. Zhang, and J. Lu, "Heterogeneous domain adaptation: an unsupervised approach," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 31, no. 12, pp. 5588–5602, 2020.

[32] T. Ni, D. Liu, Q. Xu, Z. Huang, H. Liang, and A. Yan, "Architecture of cobweb-based redundant TSV for clustered faults," *IEEE Transactions on Very Large Scale Integration Systems*, vol. 28, no. 7, pp. 1736–1739, 2020.

[33] A. Ala, F. E. Alsaadi, M. Ahmadi, and S. Mirjalili, "Optimization of an appointment scheduling problem for healthcare systems based on the quality of fairness service using whale optimization algorithm and NSGA-II," *Scientific Reports*, vol. 11, no. 1, pp. 19816–19819, 2021.

[34] T. Ni, Z. Yang, H. Chang et al., "A novel TDMA-based fault tolerance technique for the TSVs in 3D-ICs using honeycomb topology," *IEEE transactions on emerging topics in computing*, vol. 9, no. 2, pp. 724–734, 2021.

[35] T. Sui, D. Marelli, X. Sun, and M. Fu, “Multi-sensor state estimation over lossy channels using coded measurements,” *Automatica*, vol. 111, p. 108561, 2020.

[36] L. Guo, C. Ye, Y. Ding, and P. Wang, “Allocation of centrally switched fault current limiters enabled by 5G in transmission system,” *IEEE Transactions on Power Delivery*, vol. 36, no. 5, pp. 3231–3241, 2021.

[37] R. Sun, J. Wang, Q. Cheng, Y. Mao, and W. Y. Ochieng, “A new IMU-aided multiple GNSS fault detection and exclusion algorithm for integrated navigation in urban environments,” *GPS Solutions*, vol. 25, no. 4, 2021.

[38] M. Ahmadi, T. Ali, D. Javaheri, A. Masoumian, and Y. Pourasad, “DQRE-SCnet: a novel hybrid approach for selecting users in federated learning with deep-Q-reinforcement learning based on spectral clustering,” *Journal of King Saud University-Computer and Information Sciences*, 2021.

[39] Z. Lv, Y. Li, H. Feng, and H. Lv, “Deep learning for security in digital twins of cooperative intelligent transportation systems,” *IEEE Transactions on Intelligent Transportation Systems*, pp. 1–10, 2021.

[40] Z. Lv, L. Qiao, and I. You, “6G-Enabled network in box for internet of connected vehicles,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 8, pp. 5275–5282, 2021.

[41] Z. Lv, D. Chen, and Q. Wang, “Diversified technologies in internet of vehicles under intelligent edge computing,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 4, pp. 2048–2059, 2021.

[42] A. Sharifi, M. Ahmadi, and A. Ala, “The impact of artificial intelligence and digital style on industry and energy post-COVID-19 pandemic,” *Environmental Science and Pollution Research*, vol. 28, no. 34, pp. 46964–46984, 2021.

[43] Z. Lv, R. Lou, and A. K. Singh, “AI empowered communication systems for intelligent transportation systems,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 7, pp. 4579–4587, 2021.

[44] Z. Lv, L. Qiao, and H. Song, “Analysis of the security of internet of multimedia things,” *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 16, no. 3s, pp. 1–16, 2021.

[45] A. Varmaghani, M. Ali, M. Ahmadi, A. Sharifi, and Y. Pourasad, “DMTC: optimize energy consumption in dynamic wireless sensor network based on fog computing and fuzzy multiple attribute decision-making,” *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 9953416, 14 pages, 2021.

[46] C. Zhao, F. Liao, X. Li, and Y. Du, “Macroscopic modeling and dynamic control of on-street cruising-for-parking of autonomous vehicles in a multi-region urban road network,” *Transportation Research Part C: Emerging Technologies*, vol. 128, p. 103176, 2021.

[47] M. Ahmadi and M. Qaisari Hasan Abadi, “A review of using object-orientation properties of C++ for designing expert system in strategic planning,” *Computer Science Review*, vol. 37, p. 100282, 2020.

[48] Y. Bie, J. Ji, X. Wang, and X. Qu, “Optimization of electric bus scheduling considering stochastic volatilities in trip travel time and energy consumption,” *Computer-Aided Civil and Infrastructure Engineering*, vol. 36, no. 12, pp. 1530–1548. In Press, 2021.

[49] M. Rezaei and N. Naderi, “Persian signature verification using fully convolutional networks,” 2019, https://arxiv.org/abs/1909.09720.

[50] W. Qiao, M. Khishe, and S. Ravakhah, “Underwater targets classification using local wavelet acoustic pattern and Multi-Layer Perceptron neural network optimized by modified Whale Optimization Algorithm,” *Ocean Engineering*, vol. 219, p. 108415, 2021.

[51] W. Qiao, Y. Wang, J. Zhang, W. Tian, Y. Tian, and Q. Yang, “An innovative coupled model in view of wavelet transform for predicting short-term PM10 concentration,” *Journal of Environmental Management*, vol. 289, p. 112438, 2021.

[52] W. Qiao, W. Liu, and E. Liu, “A combination model based on wavelet transform for predicting the difference between monthly natural gas production and consumption of U.S,” *Energy*, vol. 235, p. 121216, 2021.

[53] W. Qiao, Z. Li, W. Liu, and E. Liu, “Fastest-growing source prediction of US electricity production based on a novel hybrid model using wavelet transform,” *International Journal of Energy Research*, 2021.

[54] S. Peng, Y. Zhang, W. Zhao, and E. Liu, “Analysis of the influence of rectifier blockage on the metering performance during shale gas extraction,” *Energy & Fuels*, vol. 35, no. 3, pp. 2134–2143, 2021.

[55] S. Peng, R. Chen, B. Yu, M. Xiang, X. Lin, and E. Liu, “Daily natural gas load forecasting based on the combination of long short term memory, local mean decomposition, and wavelet threshold denoising algorithm,” *Journal of Natural Gas Science and Engineering*, vol. 95, p. 104175, 2021.

[56] T. Issariyakul and E. Hossain, *Introduction to Network Simulator 2 (NS2)*, Springer, Berlin, Germany, 2009.

[57] H. Shahwani, S. Attique Shah, M. Ashraf, M. Akram, J. Jeong, and J. Shin, “A comprehensive survey on data dissemination in Vehicular Ad Hoc Networks,” *Vehicular Communications*, p. 100420, 2021.

[58] F. Safara, A. Souri, T. Baker, I. Al Ridhawi, and M. Aloqaily, “A priority-based energy-efficient routing method for IoT systems,” *The Journal of Supercomputing*, vol. 76, pp. 1–18, 2020.

[59] P. Wang, C.-M. Chen, S. Kumari, M. Shojafar, R. Tafazolli, and Y.-N. Liu, “HDMA: hybrid D2D message authentication scheme for 5G-enabled VANETs,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, 2020.