A Survey on Routing Protocols in Vehicular Ad hoc Networks

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***Abstract*— Vehicular ad hoc networks (VANETs) are a subclass of mobile ad hoc networks (MANETs) that have inherited some of this type of network's features. Due to road accidents, these networks are a promising technology to increase passengers' comfort and safety and increase road safety and provide traffic information. In vehicular ad hoc networks, it is challenging to design an efficient routing protocol for data routing in vehicles due to rapid topology changes and frequent disconnections. Applications in these fields require efficient routing protocols. The design of a routing protocol must be done both in terms of useful information dissemination and under the information dissemination environment's actual conditions. In this paper, we overview the existing VANET routing protocols; As there are different routing protocols in VANET, we need to do detailed research on various routing protocols and their strengths/weaknesses. The routing protocols essentially concentrate on delay, packet delivery magnitude relation, information measure utilization, and plenty of alternative factors. However, there are challenges to select a routing protocol to a dynamic topology and special characteristics of VANETs. VANET is extremely advantageous because it helps in up the road safety through reducing the amount of accidents by warning drivers regarding the danger before they really face it and different facilities to comfort drivers.**

***Index Terms*— Vehicular ad hoc networks, Routing, Safety, Mobile ad hoc networks.**

I. Introduction

THE vehicular ad hoc network is an effective subset of mobile ad hoc networks and is an example of a mobile network. This Network is designed to communicate between adjacent vehicles as well as between vehicles with an adjacent fixed equipment, which is usually road-side equipment. The vehicular ad hoc network's main purpose is to provide safety and comfort for passengers [1]. A special electronic device is embedded in each vehicle, allowing wireless communication between passengers to achieve this goal [2]. The vehicular ad hoc network is based on IEEE 802.11 short-range wireless communication, which is superior to intelligent transportation systems in terms of network design [3]. The fact is that the high mobility of nodes in these networks leads to a dynamic network structure. It should be noted that in the vehicular ad hoc networks, due to the vehicles' high speed, it is difficult to establish the route, which will cause the packet to be sent again [4]. Researchers have studied routing in vehicular ad hoc networks in one-dimensional, two-dimensional, and three-dimensional environments. These networks have some challenges due to their characteristics, such as data routing, scalability, data propagation, security, and quality of services [5]. In vehicular ad hoc networks, vehicles are moving as high-speed mobile nodes; speed changes will cause some challenges to data routing and data propagation and failure to provide the desired quality of service. For example, at high speeds, the rate of topological changes will be greater, while there may be density and increased collisions at low speeds. On the other hand, different road patterns will affect the mobility of vehicles [6]. The different nature of node movement on highways and urban environments will lead to many challenges in routing published data, scalability, and more. In some vehicular ad hoc network applications, vehicles need to be aware of their location. Given the characteristics of vehicular ad hoc networks, having the vehicle's location is another challenge of these networks.

Many research has been done to find the root causes of accidents, and the results all agree on one factor as the main cause of accidents: information error. In other words, because the driver receives the necessary information late, he\she cannot take the appropriate reaction to prevent the accident. As a result, if the driver's level of information about his/her surroundings and information range can be expanded, there will be a prodigious change in transportation safety. Many unexpected accidents can be avoided if the driver has the vehicle status information up to a certain distance. It will be possible by exchanging information using radio equipment, and vehicular ad hoc networks can be a solution to this problem [7].

The rest of this paper is organized as follows. In section II, routing in the vehicular ad hoc networks is described, and the classification of various routing methods in these networks is presented. In section III, the proposed methods for routing in vehicular ad hoc networks are reviewed. Section IV presents the evaluation and comparison of methods and describes the advantages and disadvantages of each method, and finally, in section V, the conclusion is presented.

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II. Routing in Vehicular Ad Hoc Networks

Routing protocols will be considered as an essential part of network communication. Routing protocols are defined as a set of rules in which nodes in a network can communicate with each other. Due to the major differences between mobile ad hoc networks and vehicular ad hoc networks, such as movement pattern, vehicle density, and vehicle speed, the routing protocols used in mobile ad hoc networks are not suitable for vehicular ad hoc networks. Generally, vehicular ad hoc network routing protocols will be divided into five main categories, which are as follows [8]:

1) Topology-based routing protocols
2) Position-based routing protocols
3) Broadcast-based routing protocols
4) Geographic-based routing protocols
5) Clustering-based routing protocols

Figure 1 shows the types of routing protocols. In the following, we will examine each of the mentioned methods.

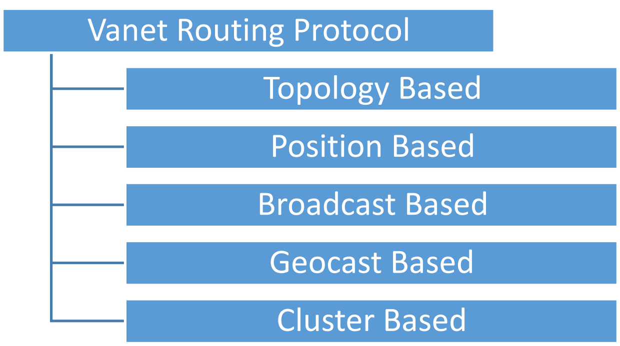

Fig. 1: Types of routing protocols in vehicular ad hoc networks

1. Topology-based routing protocols

In vehicular ad hoc networks, topology-based routing protocols attempt to find a route from source to destination. All information about the links between nodes in this type of routing will be stored in each node [9]. Topology-based protocols are divided into three categories as follows:

Active Routing Protocol (Table-Based): In Active Routing Protocols, information about network links is stored in the node routing table. This information is updated after a specified period. This type of routing protocol will have a high cost in routing overhead and reduces network performance.

Reactive Routing Protocol (on-Demand): In Reactive Routing Protocol, routing will be done on-demand. In these protocols, control packets will be sent from source to destination to find the route. However, due to their request-based nature, these protocols have a high delay.

Hybrid Routing Protocols: Hybrid routing protocols will attempt to improve vehicular ad hoc networks' characteristics using the benefits of both reactive and active methods.

2. Position-based routing protocols

In vehicular ad hoc networks, position-based routing is an important issue due to topological changes. Compared to topology-based protocols, position-based routing will route with node positioning information. Using positioning information will make better routing decisions. Position-based routing protocols will select the next sender based on geographic information. Therefore, every vehicle needs information about its geographical location and that of its neighbors. This routing method uses the Global Positioning System (GPS) embedded on the vehicles to find each vehicle's position information. This routing method also uses road information and on-board unit (OBU) to decide on route selection [10].

3. Broadcast-based routing protocols

Broadcast routing is generally used to transmit data such as weather conditions, warning messages, and road condition information. In this method, a packet will be flooded to all vehicles in the Network. The multi-hop transfer mechanism will be used when a message needs to be propagated to an area outside its transmission area. Using a simple broadcasting mechanism in which all vehicles broadcast the packet leads to a broadcasting storm problem. The broadcasting storm problem will occur when multiple nodes attempt to transmit simultaneously, resulting in collisions and delays in the media access layer. Using a simple broadcasting protocol without considering mechanisms to deal with broadcasting storms will cause problems such as inefficient use of bandwidth, increased collision, and further loss of packets [11].

4. Geographic-based routing protocols

In multicast routing, the source node will send the packet to a specific area. Sending packets to the target area using the geographic information of the vehicles is called GeoCast routing. The purpose of this method is to deliver packets to a specific geographical area. Vehicles that are not in this area will not consider the packet. In this routing method, packets are sent as multicast [12].

5. Clustering-based routing protocols

This method refers to the grouping of vehicles based on the area in which they are located. These vehicles have direct communication with each other. A cluster head in each group will be selected to manage the communication between the clusters. Also, clustering will act as an infrastructure. In this method, however, the overhead of cluster formation is an issue that needs to be addressed. Clustering protocols and using this method will lead to efficient management and organization and create a hierarchical routing method in the Network. This method will also make the vehicular networks more efficient and manageable [13].

A comparison of the strengths and weaknesses of routing methods is shown in Table I.

TABLE I
Comparison of Strengths and Weaknesses of Routing Methods

Routing method	Subcategory	Strengths	Weaknesses
Topology-based routing protocols	Active	Predefined routes that reduce delay and do not require route discovery.	High storage overhead due to routing table maintenance on all network nodes, high communication overhead due to constant updates of routing tables.
	Reactive	Routes are created on-demand and stored in the routing table, which reduces overhead and network traffic.	The route discovery phase from source to destination imposes a long delay on the Network.
Position-based routing protocols	-	Routing tables are not used, so storage costs are reduced. Due to the hop-to-hop transmission, there is no need for a route discovery phase, and the delay is reduced.	GPS and location information and location detection services are required, which can sometimes cause errors.
Broadcast routing protocols	-	Simplicity of execution	It is not suitable for large networks due to excessive bandwidth use, and the large amount of messages sent causes congestion and interference in the Network.
Geographic routing protocols	-	Due to the multicast method, the collision is less than the broadcast method.	GPS, location information and location services are required, and these services may occasionally fail.
Clustering-based routing protocols	-	This method will make the vehicular ad hoc networks more efficient and manageable. The clustered Network will be more scalable.	The overhead of cluster formation is high.

III. ROUTING METHODS

In this section, we will have an overview of routing methods in vehicular ad hoc networks.

In [14], using beacon messages, a network backbone called BBR is created, and packets will be sent through the backbone. An algorithm based on fuzzy logic, which combines information about the direction, speed, and density of vehicles, is presented to select the Network's backbone. The BBR will not need to store all the topology information, so it will be without additional control overhead. In [14], focusing on end-to-end delivery in vehicular ad hoc networks, a new method for delivering data using backbone creation is proposed. The backbone of the data transmission path will be created by considering the quality of the link and the dynamics of vehicle mobility. The BBR method generally includes three main goals of reducing routing overhead, reducing end-to-end delay and high reliability. As shown in Figure 2, the data packets are sent using fuzzy logic through the nodes of the backbone using the vehicle density calculation, moving direction, the speed of the nodes and the height of the antenna.

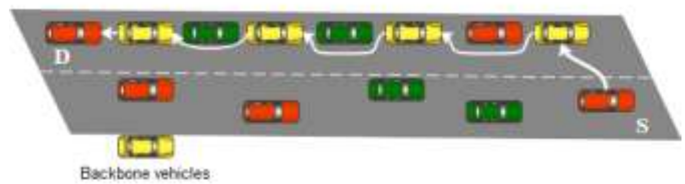

Fig. 2: Sending data packets using the backbone in the BBR

In the BBR method, vehicles traveling at the same relative speed are used as the Network's backbone. In this way, the data relay node will have better stability than the surrounding nodes. In this method, due to the exchange of beacon messages, each node will have its own set of local neighbors (one-time). Using the list of neighboring nodes and their characteristics such as speed, position, and movement direction, the data relay node will be selected as the Network's backbone.

Chang et al. [15] improved the hierarchical function in the A* route programming algorithm named VBA*. The authors considered two planning criteria, the shortest transit time and the lowest fuel consumption, to find the route from the source to the destination. In this study, there are two sources of information, including the Global Positioning System and the electronic road database. When vehicles start moving on the road, they can identify the location of their current global positioning device and record information in their memory. The Global Positioning System indicates whether it is the end of the road section when passing through an intersection by tracking the vehicle. The advantage of the proposed method in this research is reducing time and fuel consumption in the planning routes. This reduction is significant compared to route planning algorithms in dense routes and periods of low congestion.

In [16], in order to counteract the effect of traffic flow and reduce the delivery rate, an opportunistic geographical routing protocol considering the road traffic flow called ORRIS is presented. This method uses geographical location, motion vector, and traffic flow to make decisions during routing. ORRIS also considers vehicles moving in the opposite direction to the sender vehicle. This method uses digital maps that have two modes of sending in Straight-Way and sending in the intersection. This routing method uses a greedy strategy to reach the destination while sending in the Straight-Way, as shown in Figure 3. In this case, the node that is less distant from the destination will be selected as the next hop among the neighbors.

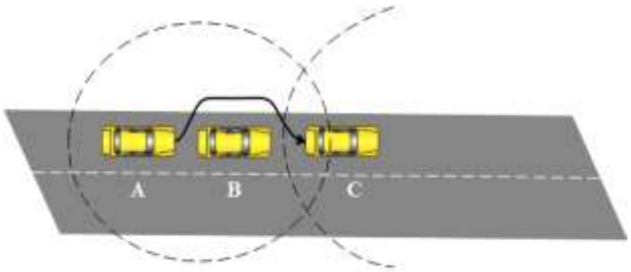

Fig. 3: Sending packets in a Straight-Way using ORRIS

Intersection routing should also be considered in the movement direction, considering that the candidate node may have different directions to reach the destination. Also, in the intersection routing, a density estimation function is used to consider the direction of vehicles' movement and is shown in Figure 4.

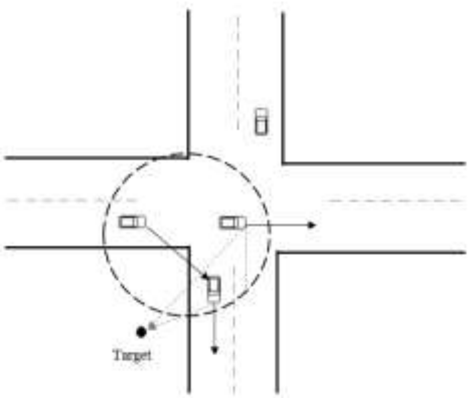

Fig. 4: Sending packets at intersections based on the ORRIS protocol

In [17], the Network consists of several nodes and road-side units (RSU) along the road. Here, a concept called waiting time is used, which means that a neighboring node farther from the sender is closer to the destination and has a shorter waiting time. First, when the node decides to send its packet to the destination, it broadcasts the packet to its neighbors. If the destination is between them, the routing ends. Otherwise, because all nodes are equipped with a global positioning system, the sender calculates its distance to all neighbors and specifies the waiting time for all of them. It then sends the data packet to the node with the shortest waiting time. The receiver also performs the act of broadcasting. The nodes that received this packet in the previous step drop this packet, and the routing operation is performed between the remaining nodes. If the sender node does not have a neighbor, it sends the packet to the RSU, which is in its range. This packet is moved between different RSUs to reach the RSU where the destination is in its communication range and then delivers it.

Sachdev et al. [18] proposed a routing and clustering algorithm in vehicular ad hoc networks using the firefly algorithm. Clustering in vehicular ad hoc networks is equal to a group of nodes in which the communication between different nodes is continuous. These nodes select the cluster head node to coordinate the communication. Vehicles receive their neighbor relationships using data embedded position in messages. Vehicles usually share their current stage with all other nodes in the same range. The main purpose of designing this routing algorithm is clustering based on routing vehicular ad hoc networks and route discovery. Finding the optimal route and maintaining the route, delay, energy, packet delivery ratio has been done using the firefly algorithm. The routing algorithm works well to find routes and send signals or data to other vehicles. The firefly algorithm is nature-inspired, an optimization algorithm based on fireflies' flashing behavior or lightning bugs used for routing in vehicular ad hoc networks.

Bousbaa et al. [19] developed a new routing protocol for the vehicular ad hoc network in urban scenarios. This method started by building a strong framework on the road sections and connecting them by nodes as bridges at intersections. Then, based on the collected information, these weights are assigned to different parts of the road. In this research, two different applications, including applications related to road safety in highways or urban environments and other items for comfort on the roads, have been considered, which shows the comprehensiveness of the research. The proposed method presents two robust ground pattern routing protocols for the two applications. The first algorithm is a robust routing protocol for safety software designed for road safety applications.

Lin et al. [20] developed a mobile-based routing protocol using vehicle-to-vehicle communications in vehicular ad hoc networks named MoZo. This study presents a new area-based architecture and a corresponding routing protocol for propagating messages across vehicular ad hoc networks. This is the first study to use moving object methods in vehicular ad hoc networks. The methods of marking and drawing the moving object have been used in various tasks such as construction and maintenance of the area and propagating of information. Reducing communication costs and increasing the rate of sending messages compared to other existing methods is the advantage of the proposed method.

Li et al. [21] proposed an adaptive multiple fuzzy method for routing in vehicular ad hoc networks (AFMADR). In this method, packets are sent to vehicles with higher fuzzy rates. This study has made this work more practical and less costly by considering the movement of multiple vehicles in an area without a roadside unit involved in transportation and sending packets. Vehicle movements are based on maps and are performed in the shortest distance. Packets are randomly generated from a vehicle and sent to vehicles in an adjacent hop. The four essential characteristics of identifying candidate vehicles to represent a multiple adaptive fuzzy scheme are distance, direction, density, and deadlock. One of the advantages of the proposed method is that it has the highest reception ratio and the lowest reception delay on a reasonable number of hops among the protocols in all simulation scenarios. The disadvantage of the proposed method is the number of features used; because in designing routing protocols, more features of vehicular ad hoc networks are used.

Hadded et al. [22] developed a TDMA-aware routing protocol for multi-hop communication in vehicular ad hoc networks (TRPM). Figure 5 shows the message propagation information in TDMA. In occasional vehicular ad hoc network security applications, messages must be delivered promptly and reliably. The advantage of the proposed method is the design of a multi-purpose communication protocol for packet delivery due to rapid changes in network topology and lack of infrastructure. The proposed TDMA-aware routing protocol allows the vehicle to send a packet over long distances by relay nodes to multiple vehicles. The packet is delivered from the source vehicle to the destination vehicle using geographic location and time gap information from the TDMA schedule.

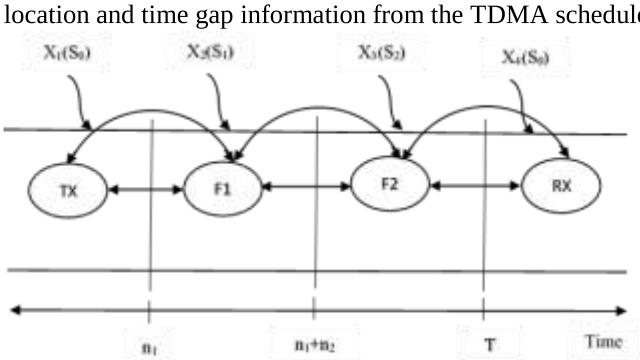

Figure 5: Message propagation information in TDMA

Qin et al. [23] developed a routing protocol for connecting to the road network for vehicular ad hoc networks. This protocol, called Traffic-Light considered Road Network Connectivity Aware Routing (TCAR), provides traffic-aware routing at a traffic light. The protocol examines the effects of vehicle density and traffic lights on road network communications and uses a greedy macroscopic selection strategy to select the next transport segment. The advantage of the proposed method is that the routing protocol creates more precise selection decisions to ensure low time delay, high efficiency, and high throughput in the data transmission process. In segmentation, the proposed protocol still considers vehicle density as an indicator of road-aware communication. When sections are in segmentation mode, assuming constituent links, there will be more distance between vehicles, longer network communication routes, and a lower degree of network segmentation; therefore, the distance between vehicles and the density of vehicles are essential factors to show the performance of network communications.

In [24], a probability prediction-based reliable and efficient opportunistic routing algorithm called PRO is proposed for vehicular ad hoc networks. This method can predict changes in network parameters such as signal-to-noise ratio (SINR) and packet queue length (PQL) of the receiver. The prediction results are used to determine the utility of vehicles in the candidate set. Because the PRO algorithm is a geographical routing method, only neighboring vehicles that are less distant from the destination vehicle and moving toward the destination can be selected as relay candidates. The set of the candidate relaying vehicles is defined as the candidate set. When the sender vehicle wants to send the data packet, it first selects the candidate set based on its neighbors' geographical information. The sender vehicle predicts each vehicle's necessary parameters in the candidate set and calculates the candidate relay vehicles' usefulness. In this method, a candidate set optimization algorithm is introduced, the candidate set is optimized. The sender vehicle then distributes the data packet to all relay vehicles in the optimized candidate set. This data set includes the candidate set and relay priorities of the relay vehicles in this set.

Goudarzi et al. [25] proposed a position-based routing algorithm for vehicular ad hoc networks suitable for urban environments. This algorithm is an advanced version of the GSR routing algorithm. The proposed algorithm, called efficient GSR, uses an ant colony-based algorithm to find the optimal network connectivity path. It is assumed that each vehicle has a digital map of the streets that includes junctions and street segments. Using the available information, in small control packets called ants, the vehicles calculate each street section's weight based on that segment's network connection. The vehicle selects the street with the minimum total weight to find the optimal route between a source and a destination. In this way, using a digital map of the streets, each vehicle can obtain an adjacency matrix that models the city. Figure 6 shows a part of a city map. Figure 6 shows intersections with circles and streets with lines between intersections. Figure 7 shows the adjacency matrix corresponding to Figure 6.

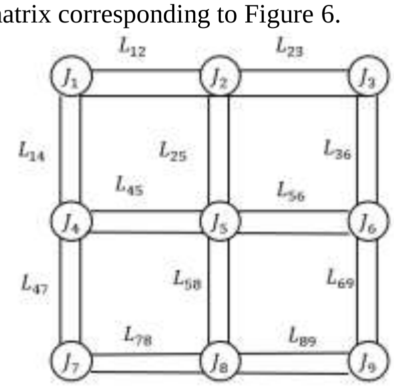

Fig. 6: Street model in EGSR method

In the EGSR, like the GSR, the source vehicle calculates a regular list of route intersections and stores it into the packet's header. The list of connections is calculated using the Dijkstra algorithm in a graph representing a city map, in which the weight of each edge (street) is proportional to the connection of that part of the street.

	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9
J_1	∞	L_{12}	∞	L_{14}	∞	∞	∞	∞	∞
J_2	L_{12}	∞	L_{23}	∞	L_{25}	∞	∞	∞	∞
J_3	∞	L_{23}	∞	∞	∞	L_{36}	∞	∞	∞
J_4	L_{14}	∞	∞	∞	L_{45}	∞	L_{47}	∞	∞
J_5	∞	L_{25}	∞	L_{45}	∞	L_{56}	∞	L_{58}	∞
J_6	∞	∞	L_{36}	∞	L_{56}	∞	∞	∞	L_{69}
J_7	∞	∞	∞	L_{47}	∞	∞	∞	L_{78}	∞
J_8	∞	∞	∞	∞	L_{58}	∞	L_{78}	∞	L_{89}
J_9	∞	∞	∞	∞	∞	L_{69}	∞	L_{89}	∞

Fig. 7: Adjacency matrix of EGSR method

In [26], a reliable self-adaptive routing algorithm based on a heuristic service algorithm called RSAR is proposed. The main purpose of this paper is to propose a reliable and adaptive routing algorithm. This method has achieved good performance by combining the parameters of reliability and adjusting the heuristic function. The authors analyzed vehicles' motion characteristics in detail and the reasons that cause links to go down to design a reliable routing protocol. In this method, link reliability is evaluated and used as a key parameter to design a routing protocol. After calculating the probability of link reliability, it is used as a Q-Learning algorithm parameter to design the RSAR algorithm.

AMGRP [27] is a geographical unicast multi-hop routing protocol for vehicle-to-vehicle (V2V) communication. This protocol assumes that vehicles are equipped with a global positioning system and wireless communication devices to facilitate communication between vehicles. It then enhances the data transfer mechanism geographical routing using four routing metrics: mobility, link lifetime, node density, and node status. Vehicles have a neighbor table to record the one-hop neighbor information, such as position, speed, buffer queue length, and node density. The neighbor table is updated at predefined intervals after receiving information from neighbors via beacon packets. The source node calculates the average distance, average moving speed, link lifetime, and moving angle between the neighbors and stores it along with other neighbor information on receiving the beacon packets. The AHP process uses these routing metrics to calculate the weight for all nodes in the source node table during the transfer process. Finally, the packet carrier node forwards the packet to the neighbor node with the minimum weight. If the packet carrier node faces the local optimum problem, i.e., if it has the least weight among its neighbor nodes, then the packet is switched to the perimeter mode of routing until a neighbor with less weight is identified.

Liu et al. [28] proposed a spider web-based routing protocol for parking environments for emergencies in a vehicular ad hoc network in a city environment called PASRP. This method assumes that the spider web and the urban roadmap have a similar structure. The goal is to create a GIS and a digital map to create a spider model in the vehicular ad hoc network. Parked vehicles can help transfer data; so, a spider model is created with the help of the parking space. In order to obtain the end-to-end emergency data transmission route, two control messages called spider request, and spider verifier are considered. The source node sends the spider request to the destination node, and the destination node sends the spider verifier to the source node. Each of these messages includes the source vehicle ID, the destination vehicle ID, the parking area ID, and information about the priority of the packet. After obtaining the end-to-end emergency data transfer route, a greedy multi-mode algorithm has been adopted to transfer information according to the characteristics of the parking area. Spider webs are made up of fins, hypotenuses and intersection points. In the real world, mobile vehicles are considered as common nodes, parking areas are considered as parking intersections in the model, hypotenuse is the line that connects the intersection points of the same layer, and chord is the edge of an urban road. This model is shown in Figure 8.

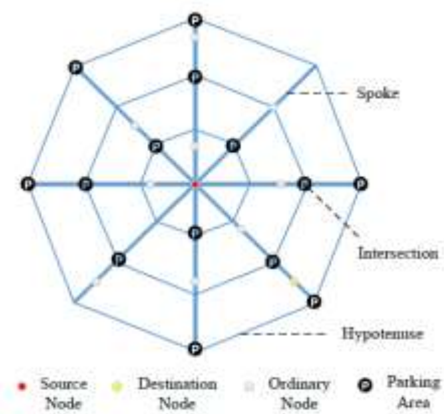

Fig. 8: Spider model of parking

Mamatha [29] presents a clustering-based routing method in vehicular ad hoc networks. A combination of two clustering methods, Fuzzy C Means (FCM) and Quadrature Low Energy Adaptive Cluster Hierarchy (Q-LEACH), is used in this method. This method first clusters the network nodes using FCM and then optimizes the clusters by the Q-LEACH algorithm. The Q-LEACH algorithm reduces energy consumption and increases the vehicular ad hoc networks lifetime.

This method, called FCM-Q LEACH-VANET, generally involves seven steps: setting up mobile nodes, clustering by using the FCM and Q-LEACH algorithm, selecting the cluster head, transmitting data from cluster member nodes to the cluster head, receiving data by cluster heads, transmitting data from the cluster head to the road-side unit and transmitting data from the road-side unit to the base station by the IEEE 802.11p protocol. An overview of this method and how to send the data is shown in Figure 9.

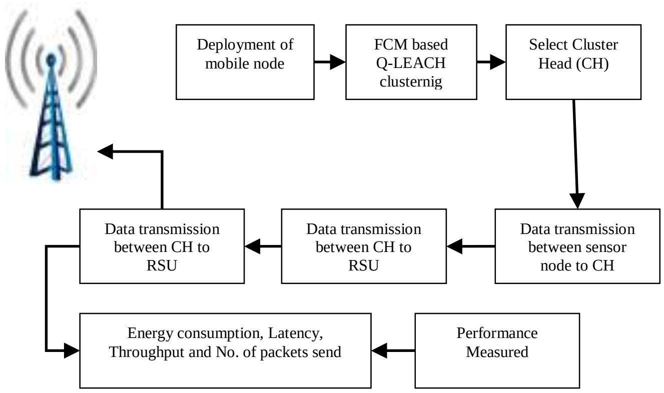

Fig. 9: Sending data in the FCM-Q LEACH-VANET protocol

Tang et al. [30] developed a centralized routing approach for end-to-end unicast communications in vehicular ad hoc networks. The advantage of the proposed routing method is predicting and selecting the optimal route based on general information. The proposed routing method can choose vehicle-to-vehicle or vehicle-to-infrastructure communications to adapt to the dynamic change of network topology. The most important innovations of the proposed method are the lack of constant control of vehicle locations, increasing the probability, and minimizing the overall vehicle delay in the vehicular ad hoc network. In this method, the NP-hard routing problem is solved by implementing a two-part matching algorithm and designing a request delivery algorithm to improve network performance. In addition, they have considered the RSU / BS service capability. The simulation results show that the Centralized Routing Scheme with Mobility Prediction (CRS-MP) performs better than other routing methods in total vehicle delay. The proposed method is also very powerful when changing the speed of vehicles. The disadvantage of the proposed method is the lack of implementation of a practical vehicle entry model to predict the correct mobility to improve the routing efficiency in the vehicular ad hoc network.

Haider et al. [31] developed a method called Direction Aware Best Forwarder Selection (DABFS), a robust routing protocol for sending warning messages across vehicular ad hoc networks. Avoiding collisions with vehicles first relies on sending warning messages to prevent road accidents. Delaying or deleting packets while sending warning messages may cause an accident between vehicles. To this end, a new protocol for Direction Aware Best Forwarder Selection (DABFS) has been proposed. In addition to the distance parameter, the proposed protocol considers two other parameters to provide the dynamic nature of the two-way highway environment and efficient route selection. The first parameter contains the moving direction of a node, which is determined by the Hamming distance. In contrast, the second parameter is the relative positions of the source and destination nodes. These parameters are critical for selecting the next hop in two-way traffic. This study shows that using these parameters for routing warning messages leads to increased throughput, reduced packet loss, and delay and allows topological changes during transmission, which is an advantage of the proposed method. Analytical and simulation results show a significant improvement in the performance of DABFS over important routing protocols. The disadvantage of the proposed method is that DABFS does not extend to urban environments with the location without global positioning. In addition, the effect of channel conditions on the delivery of alert messages and secure sending has not been determined.

Zang et al. [32] proposed a routing protocol called LCGL for vehicular ad hoc networks, which was formed using connection analysis based on geographical location to overcome common vehicular ad hoc network routing problems in urban areas. Vehicles have access to digital city maps, LCGL manages node location information and link connections. The LCGL selects the shortest connected path to send packets by calculating the path length and links' connectivity. In the LCGL routing protocol, factors such as route length and traffic congestion that may affect routing are considered as effective parameters in the connection. The link connectivity means the path weight for route planning. Higher connectivity leads to a lower path weight. Then the cost-appropriate function of the path weight is calculated according to the link connectivity. Determining random variables shows the distance between two neighbor nodes. The simulation results show that LCGL performs better in providing end-to-end communication in terms of packet delivery rate and the average number of hops.

Srivastava et al. [33] developed a location-aware routing protocol called RLARP, in which each vehicle is equipped with a Global Positioning System and a digital roadmap; therefore, a vehicle can get its position on the road map. If the forward sender vehicle is present at the intersection, the data transmission will start on the road with the highest weight. The weight factor is calculated based on the vehicle's distance, direction, and density on that road. On the other hand, when the vehicle is placed between intersections, the two-step process is applied to obtain a reliable data transmission. This two-stage process helps vehicles send data without getting stuck in an optimal local state. This protocol works in two modes: the first mode is when the vehicle is found in the middle of the intersection, and the second mode is when the vehicle is found at the intersection. In the middle of the intersection, the forwarder selection process occurs, and at the time of relocation, the road selection process occurs. In the sender selection process, the source vehicles' neighbors are placed in a semicircle of the transmission area and move to the next destination or intersection in the first step. The semicircle is toward the area closest to the destination. In the second stage, the neighbors of the vehicles in the previous stage are examined. In this case, the vehicle with the maximum number of neighbors moving towards the destination (when the destination is on the same road) or the neighbor intersection (when the hole is on different roads) is selected. How a sender is selected in this method is shown in Figure 10.

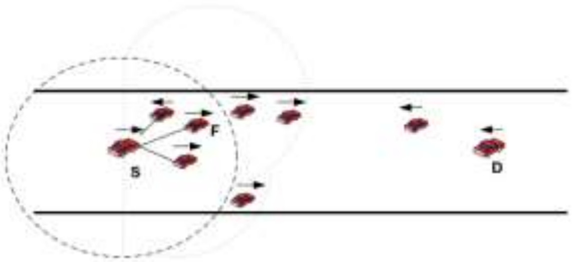

Fig. 10: select a sender in RLARP

In [34], a reactive routing method called FBAODV is presented. In this method, the AODV algorithm is improved by adding the received signal strength parameter. This method includes network formation, neighbor discovery, and performance estimation using the fitness function and routing process. After the Network is formed, the routes between the source node and the destination node are discovered with all the "Hello" packet broadcasts. Then, by calculating the Euclidean distance, the nearest neighboring nodes are identified. In this method, using the fitness function, reliable nodes are estimated and selected based on QoS parameters. As a result, the routing process will be established by finding the cost of the routes. Secure nodes are selected to send packets from source to destination by using this amount of cost.

WU et al. [35] proposed a Q-learning-based traffic-aware routing protocol named QTAR. QTAR takes advantage of the benefits of the geographic routing paradigm and also uses the RSU to send the packet to the destination. The Q learning algorithm in QTAR is used to data transfer vehicle-to-vehicle (V2V) and RSU-to-RSU (R2R). For vehicle-to-vehicle routing, the packets and the vehicles are assumed the agents, and the states. For RSU-to-RSU routing, the hello packets and the neighboring RSUs are considered as the agents, and the states. In QTAR, two types of hello packets are used for V2V and R2R communication. QTAR assumes the existence of an RSU in every road segment. Thus this protocol applicable to only urban areas. In this method, vehicles use the SCF mechanism to transfer data if the next hop is not available. QTAR is a traffic-aware urban routing protocol that considers road intersections.

Roh et al. [36] proposed a load balancing routing protocol for VANET called Q-LBR. This routing protocol is assisted with UAV to enable communication for the vehicles. The load balancing mechanism in Q-LBR is established in three main ways. First, an overhead vehicles' load estimation technique using of the UAV proposed. Second, the Q-learning technique used for establishing the load balancing data communication. Third, a reward function is applied for quicker convergence. This method used three types of packets. Urgent service messages with highest priority, real-time service with medium priority, and connection-oriented protocol with low priority. The Q-LBR consist of two phases. In the first phase, the UAV detect the congestion level by collects the vehicles' congestion conditions. In the second phase the information about the nodes' congestion information and also the UAV's congestion information are broadcasted. The route discovery process in Q-LBR is similar to the on-demand routing protocols. The RREP packet include the optimal and near-optimal solutions. When the best route is unavailable, other routes can be used.

Chenguang He et al. [37] proposed a two-level communication routing algorithm that considered the vehicle attribute information and clustered the vehicles on the road. This method dynamically select the cluster heads according to their attribute information. In the proposed method the nodes will communicate with each other through the cluster heads by the two-level communicating algorithm. This method is much more suitable for the large-scale VANET because the cluster heads do not need a gateway to help them communicate. Routing in the proposed method is based on the AODV routing algorithm. The route established by the proposed method is much more stable and efficient. And the latency is also lower than the former.

Abdur Rashid Sangi et al. [38] to alleviate the spectrum handover packet drops, proposed a “spectrum handover-based AODV routing protocol in CRAHNs”. In the proposed work, channel-route control messages of cognitive AODV routing protocol are updated with the support of spectrum handoff which helps to provide the backup opportunistic channel during PU active and helps to reduce the end-to-end spectrum handoff packet drops. Simulation results reveal that the overall performance of the vehicular cognitive TCP protocol with the proposed spectrum handoff aware cognitive AODV routing protocol is enhanced as compared to the existing cognitive TCP protocol. With the proposed packet buffering and forwarding mechanism, the achievable end-to-end average throughput is enhanced as compared to the existing CR-AODV routing protocols.

IV. Evaluation and compression

In this section, the reviewed methods are evaluated. Table II summarizes the methods reviewed. This table shows each of the methods along with the parameters used to select the next-hop and the route discovery process.

TABLE II
SPECIAL FEATURES OF THE EXISTING ROUTING PROTOCOLS

Protocol	REF	Year	Special feature
BBR	[14]	2013	Velocity, Directional Traffic Density, Antenna Height, Backbone nodes
VBA*	[15]	2013	Average driving speed, Speed retrieved from GoogleMaps, and observed driving speed of time zone
ORRIS	[16]	2014	Geographical location, Motion vector, and Traffic flow
VTARA	[17]	2015	Waiting time
Schdev et al. method	[18]	2016	Average settling time
Bousbaa et al. method	[19]	2016	Velocity,distance,location

MoZo	[20]	2016	Moving zones and the Vehicle Movement
AFMADR	[21]	2017	Distance, direction, road density, and location
TRPM	[22]	2017	Position and the time slot information from the TDMA scheduling
TCAR	[23]	2017	Traffic flow information
PRO	[24]	2018	Signal to Interference plus Noise Ratio (SINR) , Packet queue length (PQL)
EGSR	[25]	2018	Adjacency Matrix
RSAR	[26]	2019	Link reliability, Bandwidth
AMGRP	[27]	2019	Distance, Link lifetime, Speed
PASRP	[28]	2019	Intersection grade, Priority grade, Movement direction
FCM-Q LEACH	[29]	2019	Degree of vehicle, Cluster center, Threshold value
Tang et al. method	[30]	2019	Mobility prediction
DABFS	[31]	2019	Directions, relative positions of nodes, distance
LCGL	[32]	2020	Link Connectivity, Road weight
RLARP	[33]	2020	Weight value, Weight factor
FBAODV	[34]	2020	RSSI, Distance, QoS parameter (Throughput, Delay, and Error rate)
QTAR	[35]	2020	Road segment traffic information
Q-LBR	[36]	2020	Network load, Convergence of Q-learning.
Chenguang He et al method	[37]	2021	Vehicle attribute information
Sangi et al. method	[38]	2021	Spectrum handoff, opportunistic channel

Table III shows an overview of the proposed routing methods along with the advantages and disadvantages of each method. As shown in Table III, the proposed routing methods use different routing vehicular ad hoc networks. Due to the high mobility of vehicles in these networks, fewer delay methods are more appropriate. The network topology is very dynamic so that the movement will break the links of vehicles.

TABLE III
SPECIAL FEATURES OF THE EXISTING ROUTING PROTOCOLS

Protocol	Main categories	Advantage	Disadvantage
BBR	Position based	Reduce routing overhead and end-to-end delay and High reliability	As the number of senders increases, the probability of a collision increases.
VBA*	Position based and geographic based	Reduce time and reduce fuel consumption in planning routes	High Overhead
ORRIS	Geography based	It is suitable for roads with a large number of vehicles.	congestion is not considered in route selection, which increases latency and the rate of packet loss
VTARA	Position based and broadcasting based	Increase package delivery rate	Increase latency with increasing number of vehicles, High overhead
Schdev et al. method	Cluster based	Uses prominent data by increasing and decreasing transmission range in a way that gives better dissemination.	High end to end delay
Bousbaa et al. method	Geographic based	Comprehensive research	High end to end delay at high number of nodes
MoZo	Cluster based	Reduce communication costs and increase the amount of sending messages compared to other existing methods	Only the delivered rate is evaluated
AFMAD R	Geographic based	High reception ratio and the low reception delay.	The number of features used is small
TRPM	Geographic based and position based	Designing a multi-purpose communication protocol for packet delivery due to rapid changes in network topology and lack of infrastructure	It doesn't support multichannel operation
TCAR	Position based	Low delay, high efficiency, and high throughput in the data transmission process.	High overhead

Protocol	Main categories	Advantage	Disadvantage
PRO	Geographic based	improve packet delivery rate	High computational overhead, created due to probability calculations
EGSR	Position based	Increase package delivery rate	High control overhead, high end to end delay
RSAR	Broadcasting based	Increase package delivery rate	High end to end delay, increase number of hops
AMGRP	Geographic based and topology based	Improved package delivery rate, reduced number of hops and end to end delays	Routing overhead is high at low number of nodes. High control overhead
PASRP	Geographic based and position based	Improved package delivery rate for emergency packages	High overhead
FCM-Q LEACH-VANET	Cluster based	High throughput	High Overhead, High end to end delay and hop count
Tang et al. method	Position based	Ability to predict and choose the optimal route based on general information	Failure to implement a practical vehicle entry model in order to predict correct mobility to improve routing efficiency
DABFS	Geographic based	Increases throughput and reduces packet loss and latency, and allows topological changes during transmission	No expansion of DABFS for urban environments with GPS-free location
LCGL	Geographic based and topology based	Improved package delivery rate	High end to end delay, increase number of hops
RLARP	Position based and topology based	Improved package delivery rate and high throughput	High end to end delay, it is not suitable for vehicles with high mobility.
FBAODV	Topology based	Improved package delivery rate	High Overhead, High end to end delay
QTAR	Geographic based	The implementation of Q-learning for the selection of the next hop increases the throughput and PDR.	QTAR does not estimate the vehicle's direction, which will impair the performance of the protocol in real life.
Q-LBR	Geographic based	Q-LBR has multipath support, which ensures less route discovery packets to be transmitted. This procedure also reduces the number of broadcast messages	The addition of UAV is a bottleneck of the Q-LBR.
Chenguang He et al method	Cluster based	Low the rate of packet loss, low the average transmission delay	High overhead
Sangi et al. method	Broadcasting based	High end-to-end average throughput	Packets drops are high when the node handover from one base station to another base station

Table IV deals with the evaluations presented in each of the articles and the software used to simulate the articles' method. Given the importance of packet delivery rates and end-to-end delay in routing methods in vehicular ad hoc networks, these two parameters were common in evaluating all the studied methods.

TABLE IV
EVALUATED PERFORMANCE METRICS OF THE EXISTING ROUTING PROTOCOLS

Protocol	REF	Simulator	Evaluated performance metrics
BBR	[14]	NS 2.34	Packet delivery ratio, Control overhead, End-to-end delay
VBA*	[15]	ONE simulator	Travelling distance, time, and fuel consumption
ORRIS	[16]	ONE simulator	Success time, Success ratio
VTARA	[17]	NS 2.34	End-to-end delay, Average overhead, Packet delivery ratio, Number of hops, Average delivery ratio, Average delay ratio and Average success ratio.
Schdev et al. method	[18]	NS 2.34	Energy consumption, End-to-end delay, Packet deliver ratio
Bousbaa et al. method	[19]	NS2	Number of Sent Packets, Number of Retransmission Packets, Packets Delivery Ratio, End-to-End Delay, Throughput Utilization, Protocol Overhead
MoZo	[20]	NS2	Data delivery rate

Protocol	REF	Simulator	Evaluated performance metrics
AFMADR	[21]	ONE simulator	Delivery rate, end to end delay, average hops
TRPM	[22]	NS2	Average end-to-end delay, average number of relay vehicles and the average delivery ratio
TCAR	[23]	NS2	Data transfer rate, end-to-end time delay
PRO	[24]	-	Packet delivery ratio, End-to-end delay, Network throughput
EGSR	[25]	OMNeT++ and SUMO	Packet delivery ratio, Routing protocol overhead, End-to-end delay
RSAR	[26]	NS 2.34	Packet delivery ratio, End to end delay, Number of hops , Transmission overhead
AMGRP	[27]	SUMO and OMNET++	Packet delivery ratio, End-to-end delay, Normalized routing overhead, Average hop count
PASRP	[28]	NS 2.34	Packet delivery ratio, End-to-end delay, normalized routing overhead
FCM-Q LEACH-VANET	[29]	MATLAB 2015b s	Energy consumption, Throughput, Latency, Total packet send
Tang et al. method	[30]	-	Delay, successful transmission probability
DABFS	[31]	-	Throughput, End-to-end delay, Average packet loss rate
LCGL	[32]	Python	Packet delivery rate, Average forwarding hops, Packet loss rate, Average delay, Throughput
RLARP	[33]	NS 2.34	Packet delivery ratio, Throughput, End to end delay
FBAODV	[34]	NS 2.35	Packet delivery ratio, Packet rate, Overheads, and End-end delay
QTAR	[35]	Qualnet	Performance, Average packet delivery ratio, Aerage end-to-end delay.
Q-LBR	[36]	Riverbed Modeler	total network utilization, total latency,Packet Deilvery rate
Chenguang He et al method	[37]	NS2	Rate of packet loss, the average transmission delay, and the proportion of normalized routing overhead
Sangi et al. method	[38]	NS2	Local channel-route discovery, average end to end throughput

In this paper, we present a comprehensive investigation of VANET routing protocols. As indicated in the criteria presented in Table V, the VANET protocol is categorized based on the various strategies used by each protocol. From the study and comparison among the characteristics of the listed VANET routing protocols, we can identify several relevant issues such as QoS awareness, security awareness, link prediction, traffic awareness, and communication environments.

TABLE V
COMPARISON AMONG VARIOUS VANET ROUTING PROTOCOLS

Protocol	REF	Qos awareness	Security awareness	Link prediction	Traffic awareness	Communication environments
BBR	[14]	Yes	No	No	Yes	Highway
VBA*	[15]	No	No	No	Yes	Urban
ORRIS	[16]	No	No	No	Yes	Highway
VTARA	[17]	Yes	No	No	Yes	Urban/Highway
Schdev et al. method	[18]	No	No	No	No	Highway
Bousbaa et al. method	[19]	No	No	No	No	Urban
MoZo	[20]	Yes	No	Yes	No	Urban
AFMADR	[21]	No	No	No	Yes	Urban
TRPM	[22]	Yes	No	No	Yes	Urban
TCAR	[23]	Yes	No	No	Yes	Urban
PRO	[24]	Yes	No	Yes	Yes	Urban
EGSR	[25]	Yes	No	No	Yes	Urban
RSAR	[26]	Yes	No	No	Yes	Highway
AMGRP	[27]	No	No	Yes	Yes	Urban
PASRP	[28]	No	No	No	Yes	Urban
FCM-Q LEACH	[29]	No	No	No	No	Highway
Tang et al. method	[30]	Yes	No	No	Yes	Urban
DABFS	[31]	No	No	Yes	Yes	Highway
LCGL	[32]	Yes	No	No	Yes	Urban

Protocol	REF	Qos awareness	Security awareness	Link prediction	Traffic awareness	Communication environments
RLARP	[33]	No	No	Yes	Yes	Urban
FBAODV	[34]	Yes	No	Yes	No	Highway
QTAR	[35]	Yes	No	No	Yes	Urban
Q-LBR	[36]	Yes	No	No	Yes	Urban
Chenguang He et al method	[37]	No	No	No	No	Highway
Sangi et al. method	[38]	No	No	No	Yes	Highway

V. Conclusion

In this paper, routing methods in vehicular ad hoc networks are extensively reviewed and compared. Based on the study, it can be found that most routing protocols for vehicular ad hoc networks cover minor objectives rather than the entire aspects of routing. Many of the proposed protocols do not consider energy performance. Most of the proposed routing protocols focus on improving packet delivery rates in vehicular ad hoc networks. Less attention has been paid to the discussion of delay, one of the major challenges of vehicular ad hoc networks. Some of the studied methods do not consider road intersection and mobility. Considering the vehicle's direction is very important in designing an efficient routing algorithm that has been considered in many of the studied methods.

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