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Electrical and Computer Engineering

EFFICIENT ROUTING IN VANET NETWORK USING METUHEURISTIC BASED MODIFICATION OF MAODV PROTOCOL

Haider Mohammad Saadi AL-BEDER

Master's Thesis

Supervisor

Prof. Galip CANSEVER

Istanbul, 2022

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The thesis titled EFFICIENT ROUTING IN VENT NETWORK USING METUHEURISTIC BASED MODIFICATION OF MAODV PROTOCOL prepared by HAIDER MOHAMMAD SAADI AL-BEDER and submitted on 08/08/2022 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering.

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Haider Mohammad Saadi Al-beder

Signature

DEDICATION

I devote and pledge this research work to my supervisor who is salient for guiding me through the whole research work as well as my family for always assisting me in my hard time.

PREFACE

First and foremost, I would like to thank my supervisor Prof. Dr. Galip CANSEVER for guiding and helping me along the way in writing this dissertation. Discussing my progress, problems, and ideas with my supervisor Prof. Dr. Galip CANSEVER a couple of times every week helped me tremendously in understanding the logic behind the research. It made me better realize the technical need for this research work.

ABSTRACT

EFFICIENT ROUTING N VANET NETWORKS USING METAHEURISTIC OPTIMIZATION AND MAODV PROTOCOL

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VANET (Vehicular Ad hoc Network) is a new technology that uses vehicles as nodes to create a mobile network. These vehicles are equipped with wireless interfaces allowing them to communicate with each other. Indeed, VANETs can be used to extend the scope of safety information (alert messages, information on anomalies, etc.) or other types of applications (multimedia, etc.). On the basis of previous remark, we propose in this thesis solutions based on metaheuristics. heuristic algorithms make it possible to find feasible solutions having an acceptable spatial and temporal complexity. It is a technique to improve the time to determine an optimal solution for NP-difficile problems. First, we analyze the applicable heuristics for NP-hard problems. We detail the performance and characteristics of each. Next, we use the most appropriate for the vehicular routing problem.

Keywords: VANET, NP-Hard, ADHOC, Optimization

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ABBREVIATIONS

AI	: Artificial Intelligence
IoT	: Internet of Things
PAN	: Personal Area Network
FSK	: Frequency Shift Keying
TDMA	: Time Division Multiple Access
OFDM	: Orthogonal Frequency Division Multiplexing

1. INTRODUCTION

VANET (Vehicular Ad hoc Network) is a new technology that uses vehicles as nodes to create a mobile network. These vehicles are equipped with wireless interfaces allowing them to communicate with each other. Indeed, VANETs can be used to extend the scope of safety information (alert messages, information on anomalies, etc.) or other types of applications (multimedia, etc.). Vehicle networks are a projection of Intelligent Transportation Systems. Vehicles can communicate with each other via as well as with road facilities via Equipment-to-Vehicle (Roadside-to-Vehicle) communication. In this type of network, all vehicles play the role of routers by allowing information to be relayed from one vehicle to another until it arrives at the destination vehicle. The communication range in VANETs can reach 300m. As the vehicles can get out of signal range and abandon the network, other vehicles can join the vehicular network, connecting the vehicles to each other so that a mobile internet is created. We believe that the first system that incorporated this new technology is the police vehicular network which allows the vehicles that compose it to communicate with each other for security needs. The vehicular ad-hoc networks are supposed to implement a variety of wireless technologies such as (Dedicated Short Range Communications) [2] which is a type of Wi-Fi. Other wireless technologies are as follows: cellular, satellite and WiMAX. They can be considered as a component of Intelligent Transport Systems [3].

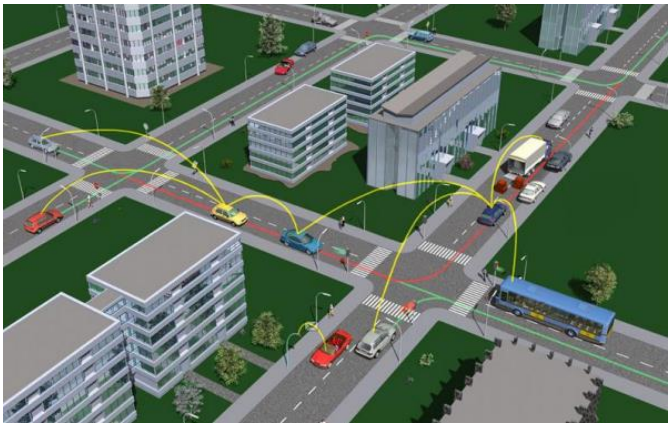

Figure 1.1: Example of VANET network

1.1 PROBLEM STATEMENT

In VANETs, the high mobility of nodes leads to frequent changes in the topology of the network. This mobility is limited by the types of roads and traffic rules. Under these conditions, car manufacturers and researchers have launched several projects and research to develop robust and reliable intelligent transport systems. The basic idea behind these solutions is to allow vehicles to exchange accident and traffic alert messages to help drivers make proactive decisions. Despite the variety of approaches proposed and the development of communication technologies, exact algorithms cannot solve the problem of routing in VANETs in polynomial time [4].

1.2 MOTIVATION

According to the WHO, road accidents will become by 2030 the seventh leading cause of death in the world. Almost 1.3 million people die from this scourge each year. Likewise, between 20 and 50 million suffer from serious injuries and permanent disabilities [5]. In most countries, these accidents cost nearly 3% of gross domestic product (GDP). In this context, ad hoc networks of vehicles, called VANETs, can be deployed to save lives and provide more comfort to passengers. VANETs belong to a class of mobile ad hoc networks (MANETs) with specific characteristics. Each vehicle is considered a node equipped with sensors and cameras for data collection. Using dedicated software, this data will be processed to identify obstacles, accidents, service stations, road signs, etc. Then, this extracted information will be transmitted from one vehicle to another via wireless transmitters to form a vehicular network. Knowing that the transmission range of each vehicle is limited to a few hundred meters, multi-hop communication is necessary for messages to be broadcast to remote areas.

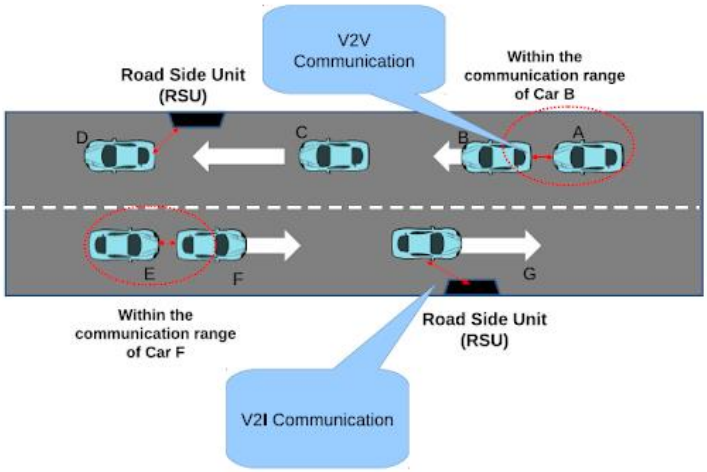

Figure 1. 2: Vanet communication example [6]

1.3 CONTRIBUTION

On the basis of previous remark, we propose in this thesis solutions based on metaheuristics. heuristic algorithms make it possible to find feasible solutions having an acceptable spatial and temporal complexity. It is a technique to improve the time to determine an optimal solution for NP-difficile problems. First, we analyze the applicable heuristics for NP-hard problems. We detail the performance and characteristics of each. Next, we use the most appropriate for the vehicular routing problem.

1.4 THESIS ORGANIZATION

The thesis is structured as follows: Chapter 2 is where we review some of the previous work and implementation on smart grids. Chapter 3 is where we give a background about all the components. Chapter 4 is where we explain our model in details and implementation of that model in details, Chapter 5 is where we simulate our model and record the results obtained. Chapter 6 is where we conclude our work and put a future scope into perspective.

2. LITRITAURE REVIEW

A. Md. Humayun Kabir (2016) had It was described in connection to its numerous aspects how VANET, a special wireless ad hoc network with high node mobility and quick topology changes, differs from other networks. The VANET has been the focus of research, standardization, and development activities because of the immense potential it has to improve safety for motorists and bicycles, traffic flow and efficiency, as well as passenger comfort, among other things. Additionally, VANETs will serve as a powerful communication tool for its users, helping researchers and developers to better understand and discern the key characteristics of VANETs.

B. Jain Sapan Kumar and Badhe Vivek (2017), had The distinctions between Wireless Sensor Networks and Heterogeneous Networks are discussed in detail here. In the wireless sensor network, hundreds of sensor nodes are used to collect data. Heterogeneous networks are defined as networks that have varied degrees of energy consumption, range, and hardware capabilities, among other characteristics. Sensors have a certain amount of energy to work with. This paper describes the development of a secure multi-hop reactive protocol for heterogeneous wireless sensor networks with clustering, which is intended to increase the lifetime of the network.

C. Gaur Saurabh Kumar et al (2017), had It was necessary to take into account the most critical elements while choosing a networking infrastructure for future automotive applications. The development of reactive research is essential in order for VANETs to become a reality in the not too distant future. When anything goes wrong with your car, you may use a VANET as an alert system to warn you of the problem. This is the mechanism through which we are alerted of traffic congestion. It shortens travel time by distributing traffic loads more evenly. Utilize this technology to send an emergency signal to drivers of other cars involved in an accident after a collision has occurred. It is also beneficial to send a message to the ambulance and traffic police in the case of a traffic emergency.

D. Jaiswal Siddhant and Dr D. S. Adane (2018), had the approach was designed to function in both a static and dynamic infrastructure environment. It is described in detail below. Cluster-

based routing has been devised, which allows packet transfer even in networks with low vehicle densities due to the use of clusters of vehicles.

E. Tejpreet Singh et al (2019), had It been possible that this dynamic nature will have a detrimental influence on network security and communication due to nodes' mobility and the constant altering of the network architecture. The VANET is susceptible to a variety of attacks, but wormhole attacks are among the most detrimental to the network's security. This is due to the fact that wormholes may be used to launch DDoS, data manipulation, and masquerade attacks. Throughput, end-to-end latency, and jitter were only a few of the metrics utilized to assess the performance of the different routing protocols tested. The performance of AODV, OLSR, and ZRP was evaluated in two scenarios: one without wormholes and another with wormholes. It was discovered that the performance of AODV, OLSR, and ZRP was drastically reduced in the presence of wormholes.

F. Vishal Kumar et al (2018), had primarily Vehicle networks may be used for a wide range of purposes and have a wide range of features and implementations. VANETs may be used in a variety of ways, including: The first is for safety, while the second is for business. Applications that are primarily focused on making life easier and more productive.

G. E Abinaya and R Sekar (2017), had Vehicle networks may be used for a variety of different reasons, and they have a variety of different features and implementations. There are several applications for VANETs, including the following: The first is for the sake of safety, while the second is for commercial purposes. Applications that are mainly concerned with making people's lives simpler and more productive.

H. Mathew Ann Bittu, Joseph Sumy (2014), had stressed the need of heterogeneous networks in cellular networks in order to keep up with the increasing demand for mobile data Some nodes are under significant stress, yet their neighbors are not experiencing the same level of stress. It is due to this imbalance in node load that the network is unable to use its maximum capacity and deliver better services to its users and customers. As a consequence, a load balancing mechanism is required on the network. According to the findings of this research, load balancing systems have been devised in which heavy nodes are moved to other nodes by determining the shortest path to them. This might result in more efficient utilization of nodes, and nodes may be better able to allocate their resources more efficiently as a result.

İ. Jaswal Kamini et al (2020) had the selection of a network simulator has been examined in order to evaluate the results of the investigation. Instead of saying this, previous tests have shown that the network simulation tool OPNET outperforms its rivals in terms of dependability and usability. The major objective of this research was to evaluate the performance of Wimax over the OPNET network. It is used in OPNET to implement distinct event systems, which means that the system's behavior may be replicated by modeling the system events in accordance with user-defined scenarios, as opposed to traditional event systems. In order to arrange the networks, a hierarchical framework is used.

J. Anwer M. Shahid and Guy Chris (2014), had IEEE802.11p and IEEE1609 vehicle wireless access technology standards were investigated for their potential to serve as a basis for both safety and non-safety applications in the area of wireless connection in vehicles. Wireless standards were also evaluated and compared based on a variety of criteria, including bandwidth, ease of use, upfront cost, maintenance and accessibility to signal coverage, signal interference, and security. Finally, some of the difficulties associated with the interoperability of multiple protocols were discussed in detail.

K. Mohammed Shafeeq Ahmed (2019), had Security solutions, WiMAX flaws, and potential WiMAX attacks were all discussed and shown in detail. The design of IEEE 802.16 has placed a strong emphasis on security, which has been a significant concern throughout the process. The methods of IEEE 802.16 (WiMAXsecurity) remain a source of controversy. WiMAX is a very new technology that has yet to demonstrate any hazards, risks, or vulnerabilities in real-world circumstances to substantiate its promises. – In this article, we look at the security aspects of the IEEE 802.16 standard, which was developed to address the vulnerabilities of the WiMAX physical and MAC layers. The two layers of WiMAX are both subject to the same kind of assaults. Jamming is a severe issue at the Physical Layer (PHY). At the MAC layer, eavesdropping on management messages, masquerade, management message manipulation, and denial of service (DoS) attacks are all serious threats.

L. Pooja Rani et al (2018), had Models for both outdoor and indoor propagation were examined and contrasted, and conclusions were drawn. The signal strength in wireless communication is reduced as a result of a number of obstacles that exist between the transmitter and the

receiver. In order to calculate the loss between the transmitter and receiver, several route loss models, such as okumara, hata, and cost 231, must first be determined. These route loss models may provide a wide range of results in a variety of settings, including urban, suburban, and rural areas. The height of the mobile station antenna, the distance between the mobile station and the base station, and the elevation of the base station antenna are all parameters that impact these models.

M. T.Karthikeyan and B. Subramani (2017), had Agent routing strategies in MANET, WSN, and VANET were investigated for their QoS-based approaches, which were shown to be effective. QoS in ad-hoc networks is affected by a number of issues, including bandwidth and latency constraints as well as fluctuations in the channel state and power limitations. There are several aspects that influence the quality of service, including node mobility, dynamic topology, and packet delivery ratio, to name a few. When there is a growing need for real-time applications in the Wireless Sensor Network (WSN), there is also a growing expectation that the network infrastructure would be able to supply data effectively depending on the quality of service (QoS). The creation of a QoS-based agent routing protocol was a challenging task to solve in order to ensure the reliability and latency of critical events while also ensuring energy economy.

N. H. Vishalakshi Prabhu, G.S.Nagaraja (2017), had Researchers and professionals from across the world were asked about their views on the prospective 4th generation (4G) features and how they may be implemented. Many different methods to Quality of Service (QoS) have been suggested for 4G networks. Based on the amount of work done in each protocol layer and the Cross Layer Design (CLD) technique, the classification was determined. Survey findings were summarized in this report, including noteworthy findings and limits, as well as a concept for future study on increasing 4G network QoS.

O. Anuradha Singh and Mintu Singh (2015), have In-depth discussion was held on VANET, which is an important kind of mobile ad-hoc network (MANET) that permits intelligent communication among automobiles as well as between automobiles and roadside infrastructure. Using this method, the Intelligent Transportation System (ITS) might gain advantages (ITS). There are a number of concerns that must be addressed while using VANET technology. Because of VANET's dynamic design and limited mobility, traditional

MANET protocols are not suitable for usage in this network. The purpose of this review article was to offer an overview of vehicular ad hoc networks, including their standards, applications, security problems, and the current VANET routing protocols, as well as their history.

P. Kshirsagar Suresh Nikhil and Dr. U. S. Sutar (2017), have showed how ambulances, police vehicles, and other vehicles may be better protected from traffic accidents and traffic signals. For this problem, two models have been developed: a highway model that directs vehicle movement and a junction model that displays the genuine communication between cars and the infrastructure (V2V) (V2I). In open access environments, security is one of the most important issues for VANET technology. VANET has attracted a lot of attention in recent years as a potential technology for enhancing both active and preventative safety on the road.

Q. Sadek M. Noha et al (2018), have had a lengthy talk about the rising worldwide interest in intelligent transportation systems (ITS). ITS can provide considerable gains in transportation efficiency, safety, convenience, and environmental sustainability, among other things. In order to address the diverse demands of vehicular applications, this study proposes a mix of IEEE 802.11-based VANETs and LTE cellular networks that make use of mobile vehicular gateways to bridge the gap between them. V2I communications are carried out using LTE, whilst V2V communications are carried out using IEEE 802.11 g. Burst communication is utilized to guarantee that critical uplink ITS traffic does not suffer from packet loss during transmission. In order to determine the feasibility of the proposed system in an urban traffic environment, a performance simulation-based study was carried out in this context. The system's performance was evaluated in terms of data loss, data rate, latency, and jitter to determine how well it performed. It has been discovered that the Multi-RAT system that has been proposed gives acceptable performance that meets the requirements of the numerous vehicle applications.

R. Chib Randeep Singh et al (2021), have It has been argued that radio wave propagation models are particularly significant in radio network planning, design, and interference planning, as well as other applications. Any wireless network that relies on radio propagation must be designed, deployed, and managed in accordance with acceptable design, deployment, and management techniques in order to function properly. Depending on the

topography, frequency of operation, velocity of mobile terminal, interface sources, and other dynamic factors, it might vary dramatically from one location to another. When estimating signal coverage, feasible data rates, bit error rate (BER), and antenna gain, it is critical to have an accurate characterization of the radio channel using essential characteristics and a mathematical model. Analyzed and contrasted with their parameters were path loss models for macro cells such as the Okumura and Hata models, as well as the COST 231 model.

3. MATERIALS AND METHODS

This chapter describes the necessary and essential concepts in the development of this work, in order to make a classification of the existing routing in VANET for a better understanding of the different AdHoc networks behaviors.

3.1 VANET NETWORK

Vehicular Ad-hoc Networks [3, 4] are a particular class of Mobile Ad-hoc Networks (MANETs). They make it possible to establish communications within a group of intelligent vehicles (nodes). These communications are between the vehicles (V2V), and between the latter and the fixed sites (infrastructures) located at the edges of the roads (V2I); see Figure 3.1. This communication is achieved by exploiting wireless technologies; usually those belonging to the 802.11 family. VANETs are considered as Intelligent Transport Systems (ITS) whose main objective is to reduce traffic congestion and improve safety and traffic. road efficiency, by providing conducive information to drivers.

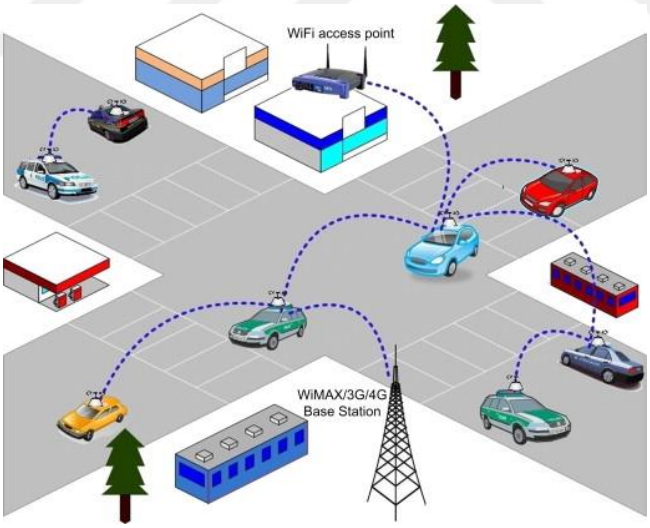

Figure 3.1: Basic infrastructure of VANET

A VANET network consists mainly of three communicating entities (Trusted Authority) This is the trusted authority [5] which may be a transaction or storage server. He is responsible for the management or registration of all network entities (OBU and RSU). It also manages the issuance and allocation of digital certificates and vehicle communication pseudonyms.

RSU (Road Side Unit) The Road Side Units [5] are the subordinates of the TA. They are installed at the edge of the road. The main objective of these infrastructures is to broadcast messages to the vehicles that are in its radio zones. These messages contain information on the weather conditions, as well as on the state of the road (maximum speed, authorization to overtake, etc.). The On-Board Unit (OBU) [5] is a unit embedded in intelligent vehicles, composed of the following units:

A. A data collector (EDR: Event Data Recorder): used to record important parameters such as speed, acceleration or an important event such as crashes. By the way, the collected data can be used for event reconstruction.
B. A front and rear radar: allows obstacles to be detected.
C. A positioning system (GPS): to locate and determine the position of the vehicle.
D. A processing platform: to process data from the various components used.
E. A man-machine interface (HMI).

In VANET networks, three modes of communication can be distinguished: Vehicle-to-Vehicle (V2V) communications, Vehicle-to-Infrastructure (V2I) communications and hybrid-type communications. Before detailing the different modes of communication, we will first present below the different types of messages [6] that can be exchanged between the communicating units. at. Control message: each vehicle regularly sends (every unit of time) a control message (beacon) which contains the position, the speed, the direction and the route. These messages are displayed to other vehicles and thus give a local view of neighboring vehicles (of each vehicle), in order to predict congestion or accident situations. b. Alert message: the alert or safety message is created when an event is detected (accident, obstacle or the receipt of another message from alert). This type of message contains the coordinates of the accident site and the parameters of the retransmission zone. It is transferred urgently thanks to its very small size. vs. Other messages: This message type contains all messages that are not warning or control messages. In other words, it can be for example a financial transaction message or the sending of electronic mail. In general, these messages are not generated on a regular basis.

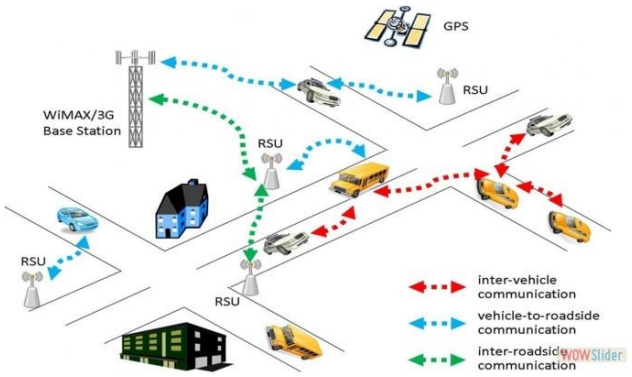

Figure 3.2: VANET communication elements

3.2 VANET COMMUNICATION

In the inter-vehicle communication architecture [3, 6] no infrastructure is needed on the roads It is a purely ad hoc communication between one-hop and multi-hop vehicles. Moreover, even if certain RSUs equipment becomes unavailable (down or out of range), the network continues to operate. To do this, each OBU communicates directly with another if it is located in its radio zone. Otherwise, the communication is done through a multi-hop protocol using neighboring nodes that separate them as relays. V2V communication is not expensive and offers a high transmission rate, but it does not guarantee permanent connectivity between vehicles. However, it is an architecture widely used in the event of alerts (emergency braking, collision, slowing down, etc.) or for collaborative driving. It is a purely centralized communication [7] used for vehicle-to-infrastructure communications only at one hop. This approach is based on the client/-server model in which the vehicles are the clients, and the RSUs installed along the road are the servers. The latter are interconnected through a wired or wireless interface. Better utilization of shared resources and services is provided by this mode of communication. Moreover, the access points are located in certain critical sections of the road, such as traffic lights, intersections, or stops. This is to improve the driving experience and make it safer. However, the major drawback of this approach lies in the installation of the stations along the roads, which is an expensive and time-consuming task. Not to mention the costs relating to the maintenance of these stations. This mode of communication is an approach allowing a vehicle to communicate with another vehicle and/or with a one-hop or multi-hop infrastructure, thus including V2V and V2I

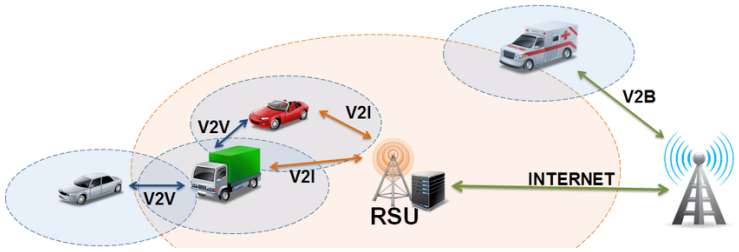

Figure 3.3: VANET RSU unit

This mode has a great economic interest because it makes it possible to reduce the costs of deploying units along the routes. It should be noted that there is another vehicular communication hybridization approach in the literature [8, 9, 10], called Vehicle to Everything or Vehicle to Object (V2X)

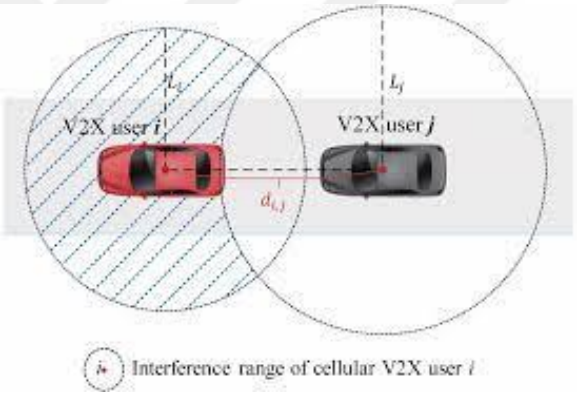

Figure 3.4: Vehicle to Object in VANET

The latter includes the V2V (Vehicle to Vehicle), V2I (Vehicle to Infrastructure) modes already presented above as well as V2N (Vehicle to Network) and V2P (Vehicle to Pedestrian). By the way, the V2N mode of communication consists in connecting the vehicles to the cellular infrastructure and to the Cloud so that the drivers can take advantage of the on-board services; such as the integrated navigation functions (Google Maps, Waze). While the V2P mode encompasses a wide range of road (pedestrian) users, including passengers, cyclists, etc. Currently, vehicular networks can use many transmission technologies. For example, those of the 3rd generation (3G) and 4th generation (4G) of mobile telephony, Wifi, WiMax, and DSRC/WAVE [11]

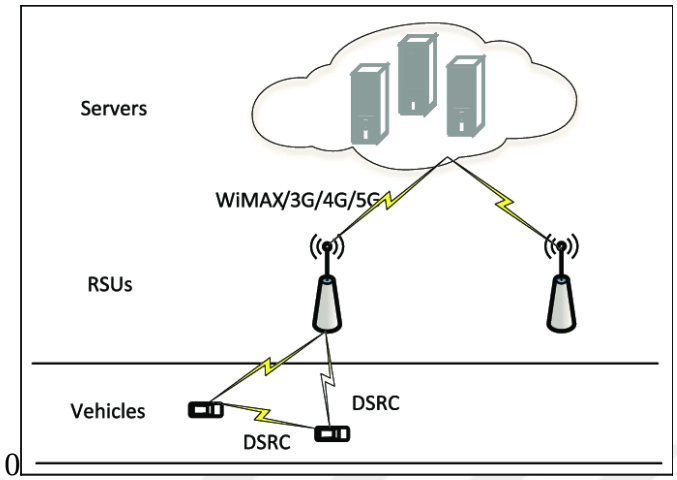

Figure 3.5: Communication structure of VANET

In what follows, we will describe the principle of some technologies. The cellular network [12] uses radio waves to transmit data over long distances. It is used to provide mobile services, and has been since the 1970s. It uses a technique of frequency reuse to increase the coverage area and also to provide multiple transmissions simultaneously. By the way, the intelligent cellular wireless network includes technologies: (3G, Universal Mobile Telecommunications System; UMTS) and (4G, Long Term Evolution; LTE). Current 3G technology reaches a speed of 384 Kbps for moving vehicles at speeds of 3 km/h to 100 km/h and can go up to 2 Mbps for fixed nodes or infrastructures. These 3G systems thus offer fluid transfers. On the other hand, 4G technology was designed to provide high, high speed and cheaper mobile services over the internet. In addition, the 4G system can provide a high transfer rate of 129 Mbps for a frequency that varies between 1700 MHz and 2100 MHz. However, these transmission technologies are poorly suited because their theoretical speeds are highly dependent on the mobility of users. However, each element of the VANET network must have a subscription (a package via a SIM card) with a mobile telephone operator. Wi-Fi (Wireless Fidelity) [13] is a set of wireless communication protocols known by the 802.11 standard. It allows several vehicles and RSUs to be linked by radio waves in order to transmit data between them. This standard also makes it possible to create high-speed links with a range of up to tens of meters (more precisely between twenty and fifty m). Thus, to meet the requirements of vehicular applications, many standards have been developed such as DSRC (Dedicated Short Range Communication) technology and

the WAVE (Wireless Access in the Vehicular Environment) standard. The Wi-Fi 802.11p (WAVE) standard was established especially for VANETs based on their characteristics (vehicle speed, up to 160 km/h, low latency, less than 50 ms, etc.). Among other things, a new technology is being developed called DSRC to transmit information at short distance with a theoretical rate of up to 6 Mbps. It is used for certain automobile-related applications such as electronic payment of tolls without stopping. For its part, the metropolitan wireless network WiMax (Worldwide Interoperability for Microwave Access) [11], which is based on the IEEE 802.16 standard, allows point-to-point transmission over an area g geographic extent. It therefore remains interesting as a means of communication between vehicles and infrastructures, because it allows Internet access to the Ad-hoc network formed by the vehicles. However, it is suitable for moderate speed vehicles but is not more ideal in high mobility situations. This is why we can use it just for I2I communications.

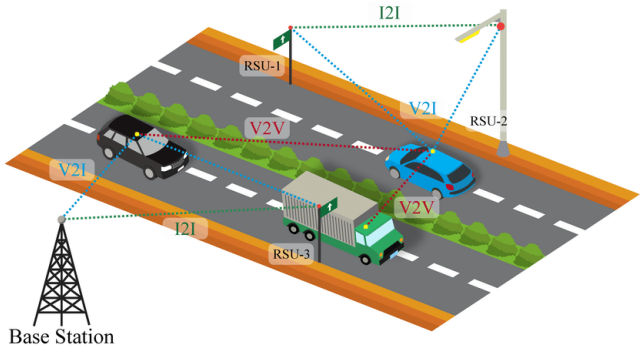

Figure 3.6: I2I in VANET

3.3 CHARACTERISTICS OF VANETS

Vehicular networks have specific characteristics [13, 14, 36] which distinguish them from other types of traditional wireless networks (ad hoc networks, sensor networks). Among the most important characteristics we cite:

A. High mobility VANETs are characterized by high mobility, linked to the speed of the vehicles. This speed allows vehicles to join or leave the network quickly, which makes the topology frequently modifiable and changeable (highly dynamic topology). However, since vehicle mobility can be predicted and modelled, traffic on a road or highway is easily predictable. Thus, knowing the current position of the vehicle and its speed, it is possible to predict the direction, on the condition of knowing the road map.

B. Intermittent connectivity High vehicle mobility and environmental obstacles cause frequent disconnections in the network. The connection links between two vehicles can be interrupted because of the mobility which distances the two communicating entities; obstacles that prevent signal propagation.

C. Variation of environments Vehicular networks require the consideration of a great environmental diversity. This environment can be a road, a highway or an urban city. For example, in an urban environment a traffic jam can lead to network congestion.

D. Energy capacity The energy constraint represents a limiting factor for traditional wireless networks (Ad-hoc or sensors), unlike VANET networks whose entities communicating rooms have a largely sufficient energy capacity. This is possible because the OBUs use the batteries of the vehicles and the RSUs (traffic lights, public lighting) are powered by an unlimited source of energy.

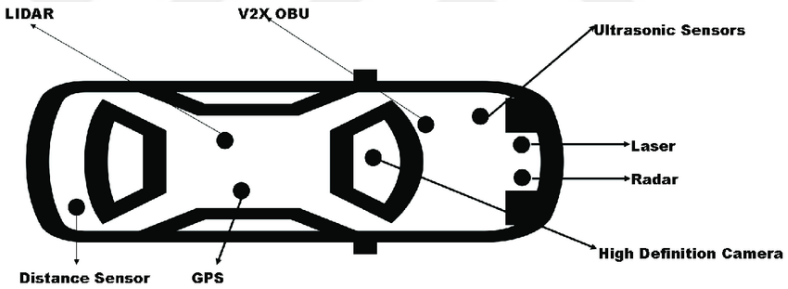

Figure 3.7: Sensors in a VANET vehicle

3.4 APPLICATIONS OF VANET

A. In vehicular networks, three main types of application [6, 36] can be distinguished, namely: road safety applications, traffic management and comfort applications.

B. Road safety applications Road safety applications aim to improve the safety of users on the roads, by informing vehicles of any potential danger. These applications are generally based on the detection of the environment using sensors (radar, camera), as well as the dissemination of periodic informative messages. These messages allow drivers to have knowledge of the state of the road (works, weather), and neighboring vehicles (warning in the event of an accident).

C. Traffic management applications Traffic management applications improve traffic conditions in order to reduce the number of accidents and traffic jams. They consist in

providing drivers with traffic information. These applications aim to balance the flow of vehicles on the roads in order to efficiently use the capacity of these roads and junctions. Therefore, reducing human losses and travel times

D. Comfort-related applications VANET networks provide comfort to drivers during their journeys. As comfort and convenience services, we can cite services including announcement panels:

i. Local services such as restaurant offers, the presence of nearby service stations.

ii. Cultural services such as tourist information relating to the location of the vehicle.

iii. Telematics services such as remote toll collection on motorways automatic payment at service stations (which can make life easier for disabled people).

E. In addition, new entertainment-oriented services are also offered to users. An onboard internet connection with video on demand or games, are a perfect example. In addition to all these applications, there is also remote control of vehicles electronically (verification of driving license, technical control, license plate) for the competent services (police, customs, police).

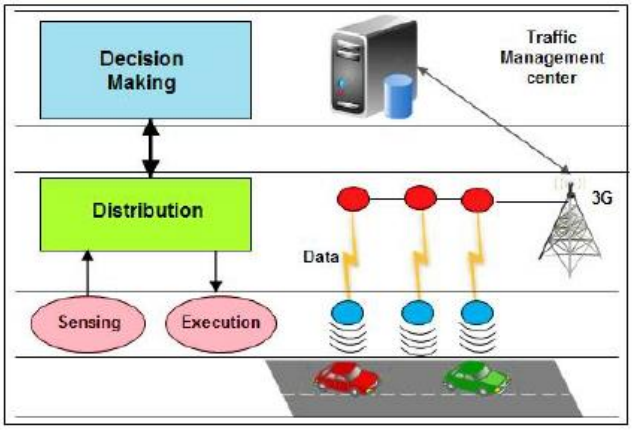

Figure 3.8: VANET distribution in traffic

3.5 CHALLENGES IN VANET

Despite the rapid development of VANETs, several shortcomings and constraints need to be identified and studied.

A. Quality of service the quality of service in a VANET network [17] represents a major issue, which is measured according to the supported application. Thus, various strict constraints are linked to VANETs such as latency and transmission delay (messages must reach their destination in short delays), transmission reliability, bandwidth, jitter and congestion.

B. Channel access the role of radio channel management mechanisms is to provide reliable and robust transmissions and an equitable sharing of the communication medium [18]. To achieve this objective in the case of vehicular networks, it is necessary to define protocols to manage priorities by solving radio interference problems, electromagnetic irregularities, distributed resource allocation in a dynamic topology, etc.

C. Security [15, 16] is a major challenge having a great impact on the future deployment of vehicular networks, since it affects the life people. By the way, the information exchanged in the network cannot be altered or deleted by an attacker. However, security requirements must be taken into account both in the architectural design of the network and in the design of the communication protocols. They differ depending on the applications and mainly include confidentiality, authentication, consistency and data integrity. For example, the communications exchanged between the vehicles of the network, or the information on these vehicles and their drivers must be guaranteed and protected in order to ensure the proper functioning of the system.

D. Routing in order for vehicles to communicate with each other correctly and quickly, an efficient routing protocol is needed. Thus, if the vehicles are not within direct radio transmission range, routing is required to establish communication between these nodes; a transmission of data packets so that the multi-hop messages sent in a path between the source and the destination according to a routing protocol. More precisely, the routing protocols [19] are responsible for determining the way to relay the packet to its destination, to calculate the route and also to adjust the trajectory in case of failure. This is while ensuring a reduced delivery time, high reliability and better use of resources. However, many problems that routing protocols must address. For example, the very dynamic topology of VANET networks which makes already established routes obsolete, as well as the partitioning of the network which prevents the propagation of packets. In what follows we will give an overview of the state of the art of the routing protocols proposed or readapted to vehicle networks.

3.6 ROUTE CHOICE METRICS IN VANETS

Routing packets from a source to a destination can be done in two distinct ways; directly with a single hop if source and destination are directly connected with each other. Otherwise, in stages with several hops (multi-hop). In this case, the communication is done via intermediate nodes positioned between the source and the destination. During multi-hop communication, the path is chosen based on various factors [48] such as:

A. The packet delivery rate (Packet Delivery Ratio, PDR): this is the ratio between the total number of data packets received by the destination nodes and the total number of data packets transmitted by source nodes.
B. The cost of normalized routing (Normalized Routing Load, NRL): it is the ratio between the total number of all the routing control packets sent by all the nodes on the number of data packets sent by ¸source to destination nodes.
C. Latency: this is the time elapsed between the moment a data packet is sent and the moment it is received by the corresponding recipient.
D. Bandwidth: this is the volume of data packets that can be transferred from a sending node to another receiver. Usually, it is expressed as a bit rate measured in bits per second (bps).
E. Jitter: this is the difference in the delay of two successively received packets. routing in VANETs has been the subject of several works in the literature [45, 46, 47]. In the rest of this section we present a classification of protocols proposed for VANET networks taken from [45], while examining the main characteristics of each class. However, routing protocols can be categorized into three main families:

i. According to the routing strategy (proactive, reactive, hybrid).
ii. Depending on the type of routing (Unicast, multicast (geocast), broadcast).
iii. Depending on the network structure (position-based protocols, clustering-based protocols).

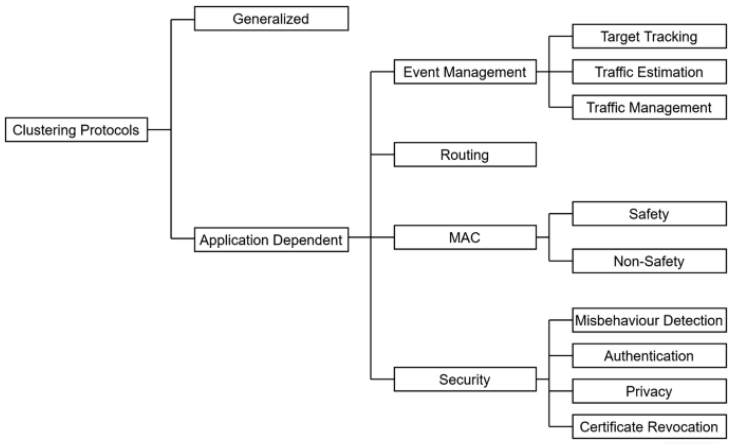

Figure 3.9: Clustering protocols in VANET

According to the routing strategy the routing protocols of this family use the information on the links which exist between the nodes for the routing of the packets. This family of protocols can be divided into three classes: proactive, reactive and hybrid.

3.7 PROACTIVE ROUTING PROTOCOLS

Proactive protocols [21] are similar to the protocols used in wired networks, which use the two main methods (link state and distance vector). Each node keeps a global picture of the whole network topology in a form of tables. These contain information about all recipients. A node periodically exchanges control messages with other nodes to keep these routing tables up to date. Based on these tables it determines the best path or route to route the data. In this type of protocol, the immediate availability of a route when needed saves time; each node has at all times a path to any other node in the network. However, the bandwidth decreases due to the traffic generated by the exchange of control packets. Among the protocols based on this principle: OLSR, FSR and GSRP [24]. We will describe in the following one of the most quoted protocols of this class:

A. The OLSR protocol (Optimized Link State Routing) OLSR [23] is a proactive link state routing protocol. It offers optimal routes in terms of the number of hops in the network. In a link-state protocol each node declares its direct links with its neighbors to the whole network. However, in the OLSR protocol, the nodes declare only a subpart of their neighborhood. The set of neighbors is called the Multi Point Relaying (MPRs) set. Routes

are built based on these relays which are used to minimize the traffic due to the broadcasting of control messages in the network. By the way, the OLSR protocol performs two main actions: ˆ Send the HELLO message and determine the MPRs for neighborhood detection.

B. The intervention of messages TC (disseminate topology information), MID (to publish the list of interfaces of each node) and HNA (to declare the subnets and hosts reachable by a node playing the role of gateway) for topology management. Reactive routing protocols (on-demand driven) In reactive protocols, the path is only calculated on demand. The routing operation in this protocol has two main phases:

i. Route discovery for routing data to a destination; this step is performed by broadcasting a route search message.

ii. Maintenance of existing routes in the event of a change in network topology. Reactive routing minimizes the exchange of control messages which frees up bandwidth. Like proactive protocols, the route discovery latency is high in this type of routing. Among the best known protocols, we can cite: DSR, AODV and TORA [28]. In the rest of this section, we will describe the AODV and DSR protocols.

C. The AODV protocol (Ad-hoc On-Demand Distance Vector Routing) The AODV protocol [27] is one of the most famous reactive routing protocols. Paths are discovered and maintained on demand. When a sender node wishes to send data to a destination node, the first step is to broadcast to all nodes of the network a route discovery message RREQ (Route Request). Consequently, when receiving an RREQ message, each node acts according to the following scenarios: If it is not the recipient, then the node retransmits the RREQ message by adding its own address in the routing path.

D. If it is not the recipient and if the RREQ message already contains its own address in the routing path, then the node discards the message without transmitting it.

E. If it is the recipient, then the node sends back an RREP message (route reply) following the routing path contained in the RREQ message.

F. By the way, the RREP message is the message confirming the establishment of a connection between sender and receiver. As soon as the sender receives this message, communication can begin.

G. Receives no response in a given time period, it will assume that the path is not available.

H. The DSR protocol (Dynamic Source Routing) The DSR protocol [26] uses the principle of the DSDV protocol. This protocol builds the routing tables in a reactive way based on the state of the links. Indeed, the modification of the table is done only when the state of the links varies. Moreover, it copies the IDs (identities) of the traversed nodes into the message header to allow the message to find its way back to the source. As a result, the DSR protocol can thus choose alternative routes if it considers them to be better. It thus has a faster reactivity than that of the AODV protocol in the event of loss of connection with a node. However, DSR does not work well if the mobility is very high, and increasing the nodes to traverse will cause the packet size to increase.

3.8 HYBRID ROUTING PROTOCOLS

This is a combination of proactive and reactive protocols [26] such as ZRP, HARP [30] and HLAR [31]. This family of protocols uses the mechanism of proactive protocols to keep knowledge of the topology for a predefined number of hops. Beyond this predefined zone, routes to more distant nodes are obtained by reactive protocol techniques, i.e. sending broadcast requests. These protocols adapt well to more or less dense networks. Nevertheless, protocols of this class combine the drawbacks inherited from two approaches, namely periodic control packets and the route discovery delay. We will describe in what follows the ZRP protocol, one of the most important protocols of this class.

A. The ZRP protocol (Zone Routing Protocol) The ZRP routing protocol [29] is a hybrid protocol which combines both proactive and reactive approaches at the same time. This protocol divides the network into several zones. For each node, it defines a routing zone expressed in maximum number of hops. Thus, the routing area of a node includes all nodes that do not exceed this maximum hop distance. Nodes that are exactly this far apart are called edge nodes. Routing within an area is done proactively, while routing to nodes outside the area is done reactively. In addition, the ZRP uses a BRP protocol (Border cast Routing Protocol), whose purpose is to build the list of peripheral nodes of an area and the routes to reach them. However, the path search procedure is carried out as follows: If the destination node is in the area of the source node, the path is assumed to be already known.

B. Otherwise, an RREQ route setup request is initiated to all edge nodes. The latter check if the destination exists in their zones. In this case the source will receive an RREP packet (route reply) containing the path leading to the destination. Otherwise, the edge nodes broadcast the request to their own edge nodes which, in turn, perform the same processing.

4. PROPOSED METHOD

4.1 CHAPTER OVERVIEW

Clustering-based routing is considered one of the most important solutions to maintain links between communicating nodes, and thus make the network more stable. In the previous chapter, we studied a set of routing protocols based on clustering, including the AODV protocol [41] which was briefly exposed. Since, we have analyzed some disadvantages in the working of the latter, therefore, we have proposed two improvements to it called PSO-MOADV. This chapter will be broadly organized into three main parts. The first will be devoted to the presentation of the preliminaries composing the tool used in the implementation of our improvement. However, the second part of the chapter will be dedicated to the detailed description of the operation of the CBR protocol. Also, to the improvements made to the latter; using a weighted function for CH selection, and introducing a maintenance phase in the first version, as well as a reinforcement learning method in the second. The last part of the chapter will be devoted to its performance evaluation, by comparing it as well as its two improvements, with the two protocols DSDV and GPSR. Finally, we end this chapter with an analysis of the results obtained and a conclusion...

4.2 OPTIMIZATION PROBLEM

The term "optimize" refers to determining the most efficient method of performing a task. A function is most useful when its inputs produce the lowest or highest possible results, respectively. When a mathematical function models an operation, it is useful to optimize it. In this case, the activity may be referred to as a cost-effective, conducive to efficiency, or proficient. Thus, the premises are classified as either a design or a statement. solving the problem of making something less efficient in terms of something that is more efficient.:

$$\min_{x \in \mathbb{R}^n} f_i(\mathbf{x}), i = 1,2, \dots, M$$
$$\text{sujeto a } \phi_j(\mathbf{x}) = 0, j = 1,2, \dots, J$$
$$\psi_k(\mathbf{x}) \leq 0, k = 1,2, \dots, K$$

A mixed factor of real and discrete variables is known as decision variables. Objective functions are labeled, in the case that M = one. In the case of M 1, the challenge is to find as many goals as possible. The value obtained after evaluating a design vector is known as fitness. The solution

space provided by the objective functions is known as the search space. non-linear or linear functions Constraints of equality are referred to as equalities, and constants of inequality are called inverses. Differences can be shown to be zero, but it is still possible to express the goal in the form of a maximization problem. As long as the value of max(x) is less than or equal to the value of x. And any inequality of Max(x) < 0 is equivalent to Min(x) if negative x is greater than 0. Adding the new constraints increases the decisional variable by an amount that is less than or equal to the new desired constraint. These constraints are called specifications. More effectively, decision variables are only given, but the effects are observed. Instead of performing a series of fixed operations, the operators progressively and quantitatively adjust the device inputs before they find a final solution. The decision-variable modification method is generally falls under the respective algorithm mechanisms.

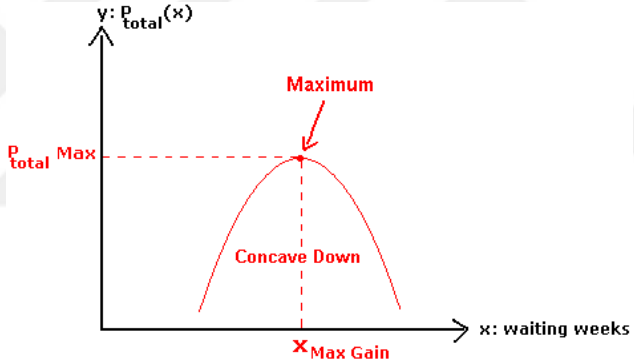

Figure 4.1: Simple optimization problem

The solution space could be monotonic or polytonic depending on the relationships between the inputs and outputs. There are no local solutions in a unimodal space (hills or valleys). In the multi-modal realm, one answer is to choose only one, which works best for you. Everyday real-world problems and search spaces are subject to constant change. Global optimization needs a complex adjustment. It is possible for different solutions to have equal fitness values, as well. Isolated regions and optimal results should be a desirable feature of an optimization algorithm. For each search space, a set of limits can be assigned which serves as an upper and lower limit for parameters. a solution optimizer must be able to handle local minima that are located beyond the allowable area of the search space.

4.3 EVOLUTIONARY ALGORITHMS OPTIMIZATION

Metaheuristic metaheuristic approaches, particularly evolutionary algorithms (i.e.generally, evolutionary algorithms have the same structure First, they generate a random solution set of potential solutions to a problem. Once a solution is found, the function or functions associated with the problem are executed in an evolving manner to reduce or enhance the goal function, and the results are saved as an optimization solution (s). While this framework is clear, dealing with complex problems in the real world requires consideration of many factors, the most important of which is computational cost, it must be noted that it takes into account the existence of local optima, function complexity, and uncertainty. A local optimum occurs frequently when optimizing real problems, particularly if there are numerous suboptimal solutions lurking in the unknown space. Here, the algorithm gets locked into a specific answer, and comes to believe that it's the whole answer. Since the local evasive behavior of stochasticizers is preferred to deterministic behavior, suboptimal results do not occur in deterministic optimization approaches. Many paradigm-based interventions attempt to be highly relevant to the target population. This suggests that they iteratively go through several iterations of the population, which is generally referred to as a swarm. While improving the local optimums helps, there are also a large number of objective assessments required with EAs, so it is not possible to use this approach for every issue. For the example shown above, to illustrate the point, mechanisms must be implemented to decrease the number of accesses to the target. There are two types of problems: actual and unconstrained. Selection criteria and processes must be balanced so that no viable options are ignored and appropriate search algorithms must be applied to non-feasible regions to find the global optimum. Managing constraints has been a common among researchers in the last decade or so.

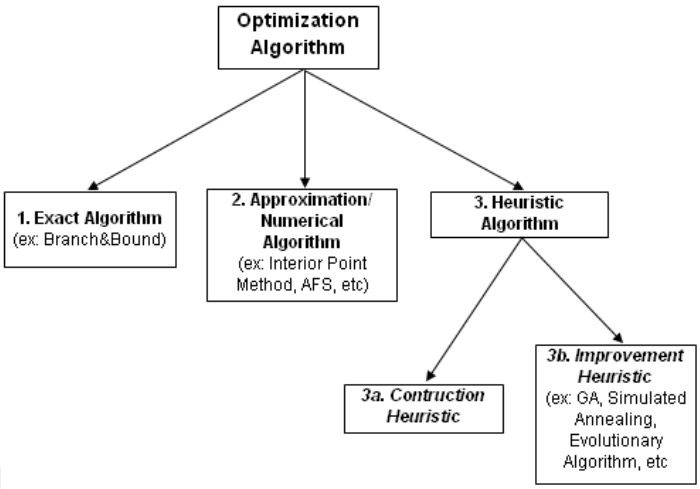

Figure 4.2: Classification of optimization problems

It is commonly thought that there is no algorithm that can completely solve all problems in the field of optimization. This suggests that the best algorithm in test functions or other real-world problems is not always the best solution to a specific problem. To solve a problem, an algorithm can need to be modified, improved, or adapted. As a result, the research sector is very involved. As a result, there is no rigorous and agreed classification of optimization methods as such, and there is considerable controversy in the literature; however, certain principles associated with optimization problems can be classified using the following criteria:

A. The number of goals. This classification is divided into two categories: single-objective problems (M = 1) and multi-objective problems (M > 1).
B. The total number of constraints J + K. It is called unrestricted if there are no limits (J = K = 0). In every other case, it is referred to as limited.
C. Error surface is a term used to describe the surface of an error. If a problem has only one valley or peak with a global optimum, it is said to be unimodal; if the surface has more than one mode, it is said to be multimodal. • The function's shape. If the constraints j and k are all linear, the problem is transformed into a linearly constrained one. When both the constraints and the objective functions are linear, the problem is transformed into a linear optimization problem.

   Because of the type of value of design variables, a discrete or combinational optimization problem It's an optimization if they are real numbers or integers; on the other hand, it's a challenge

When the design parameters and the values are exact, they are defined as deterministic problems. If any uncertainties and random variables exist in the design and objective functions, the solution becomes a random search problem.

4.4 PSO OPTIMIZATION

The PSO randomly generate a population of N particles throughout the search space. Each element of the population is evaluated to determine if it is dominated by other particles. Un-mastered items are stored in an external memory called a file. The following operators are the same as those used by PSO. The position and velocity of each particle in the population are calculated in each generation considering a variable acceleration weight in time. In PSO the best global solution is a particle taken from the file. If a solution is determined to be unviable, the particle takes on a limiting value. The best local position is updated only if the current position dominates the previous best local. In the case of two solutions that do not dominate each other, one of the two is randomly selected. At the end of each generation, the file is updated to store the current non-mastered solutions.

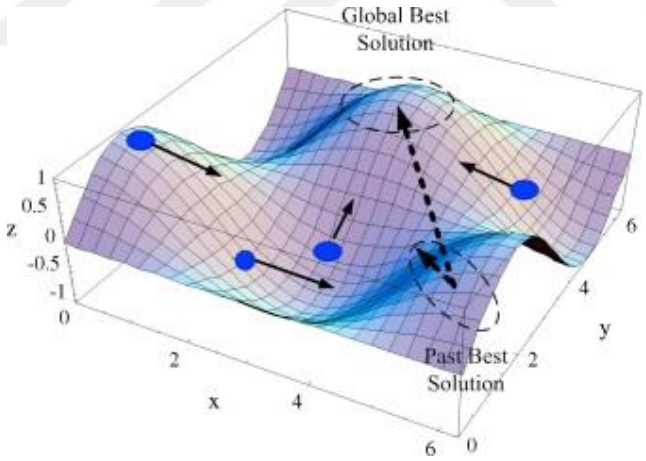

Figure 4.3: PSO search for global best solution

4.5 AODV PROTOCOL

The AODV protocol [27] is one of the most famous reactive routing protocols. Paths are discovered and maintained on demand. When a sender node wishes to send data to a destination node, the first step is to broadcast to all nodes of the network a route discovery message RREQ (Route REQuest) . Consequently, when receiving an RREQ message, each node acts according

to the following scenarios: If it is not the recipient, then the node retransmits the RREQ message by adding its own address in the routing path.

A. If it is not the recipient and if the RREQ message already contains its own address in the routing path, then the node discards the message without transmitting it.
B. If it is the recipient, then the node sends back an RREP message (route reply) following the routing path contained in the RREQ message.
C. By the way, the RREP message is the message confirming the establishment of a connection between sender and receiver. As soon as the sender receives this message, communication can begin.
D. Receives no response in a given time period, it will assume that the path is not available.
E. to improve the QoS of the AODV protocol, the authors tried to find the best two-step parameter configuration.

i. Step 1: apply the ACO to refine the network layer of the AODV protocol.
ii. Step 2: use city maps to have real simulations Similarly, in [82], the new routing strategy proposed makes it possible to seek the most optimal route possible between two nodes. This idea combines graph theory with ant colony optimization. This model responds quickly to frequent changes in network topology and avoids congestion. Three major components characterize the model.

A. Forward-ants: collect information about network quality during a trip.
B. Forward-ant: recognizes the validity of the path which is stored in the "forward-ant".
C. Routing table: this table must be maintained and updated by the node itself. Somewhat similar to the previous work, uses ACO to find routes considering the best compromise between the shortest path and the lowest probability of disconnection.

Furthermore, to overcome the problem of obstacles that negatively affect communication between vehicles, Silva et al. improved the AntSensor algorithm to find alternative routes. This algorithm contains two basic steps.

i. Step 1: find all the neighbors of each vehicle in the network.

ii. Step 2: select the best route according to its pheromone level, its number of hops and the Euclidean distance between the vehicles. Another improvement where Rana et al. developed a hybrid routing model based on the ants algorithm.

ACO is used to find multiple routes between two nodes to overcome link failures. At the beginning, the network is divided into different zones, where each vehicle must belong to a maximum of two zones. Then the proactive approach is used to find routes within an area and the reactive approach to find routes between areas. ant algorithm optimization to improve the performance of the reactive DYMO protocol. The proposed model (ACO-DYMO) contains two phases:

A. Phase 1: integrating additional information (position and speed) in the "Hello" message of the DYMO protocol. This task allows each vehicle to predict the position of its neighbors at a given time t. The "Hello" message will not be sent regularly, but only when needed.
B. Phase 2: select the best path from the routing table according to its pheromone level, this is measured by the application of the two ACO mechanisms pheromone deposition and pheromone evaporation a clustering model based on the concept of trust and on ant algorithms. To do this, three steps are designed to create clusters and elect cluster heads.
C. Stage 1: group formation: to join a given group, a vehicle must have the same direction as all the others belonging to this group, and its speed must be equal to or less than the value of a given threshold.
D. Step 2: selection of the cluster head: if the cluster contains a roadside unit, then the cluster head is this unit, otherwise the elected node must:
E. Be a normal node.
F. Be the slowest in the cluster.
G. Have the highest trust value.
H. Step 3: to avoid false paths, malicious vehicles must be detected and their transmitted messages must be removed from the network. In the same context, combine two metaheuristics (artificial immune system (AIS) and ant algorithm optimization (ACO)) to obtain clustering algorithms suitable for the dynamic environment of VANETs. Indeed, five processes are triggered after the initialization and the creation of the clusters.

Process 1: Divide clusters into subclusters.

Process 2: Assign vehicles and objects to appropriate subgroups based on pheromone consistency.

Process 3: Merge clusters with high similarity.

Process 4: Remove nodes that cause large dissimilarity within subclusters.

Process 5: the vehicle with a minimum distance of Dmean (Tm) is selected as the group leader. (Dmean is the average distance between all objects of an ant m and the center of its cluster).

4.6 ACO-PSO PROTOCOL

The ACO-PSO routing protocol [43] is a hybridization of the two protocols ACO (Ant Colony Optimization) and PSO (particle Swarm Optimization). The ACO ant colony optimization protocol is an intelligence inspired by the behavior of the ant. It includes cooperation and adaptation to produce an optimal solution. In contrast, the PSO particle swarm optimization protocol is population-based. It depends on the movement and intelligence of the swarm. Thus, the combination of these two optimal solutions provides the best path that can be used by the vehicles, so that they can reach the destination as quickly as possible. In addition, a pheromone value is used in the hybrid protocol (ACO-PSO) for decision purposes. However, the path that has a maximum pheromone level will be indicated as the best one for the ants to follow. Moreover, this protocol uses two elements: Gbest (Global best solution) and Pbest (Personal best solution) to find the optimal solution. As the first step of ACO-PSO, each particle is initialized by a random position. Subsequently, the values of Gbest and Pbest of the particles are initialized. By the way, the partial solution will be obtained while continuing to update the pheromone level. These steps are performed by all nodes in the network. To reinforce the result obtained, the techniques of optimization of the swarm of particles are applied. Find the physical form of the particles. If the result obtained is Gbest, then this is the final result. Otherwise, keep searching until you find the correct particle.

A. Advantages

Combine a hybrid protocol to have an optimal solution to a multicast network and thus, it helps in clustering.

Updating the velocity of the particles allows to find the appropriate position.

Reduce time complexity.

B. Disadvantages

There is a probability of change in each iteration.

Convergence time is uncertain.

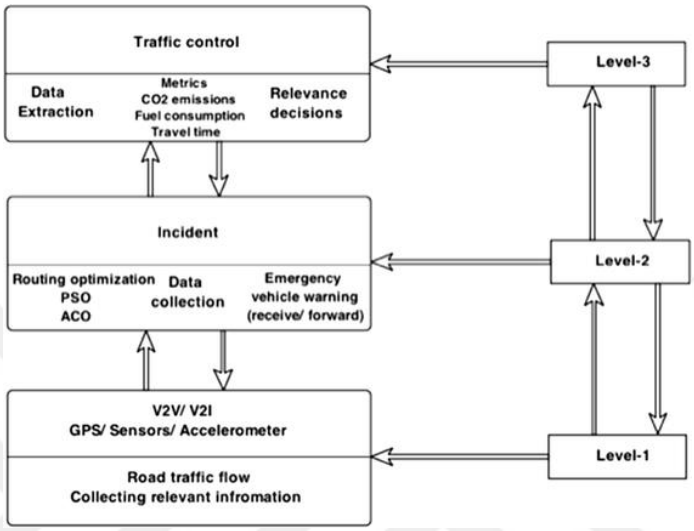

Figure 4.4: Sensor data from the vehicle

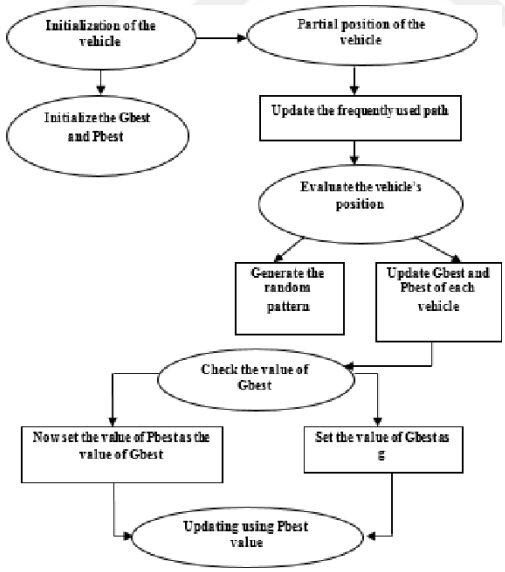

Figure 4.5: ACO-PSO routing diagram

The formation of the clusters and the election of the CHs a) The formation of the clusters In this sub-phase a dynamic partitioning of the network into square virtual cells (grids) of size rxr is carried out; (see Figure 4.4). Cells represent clusters. Each node u can know which cluster it belongs to by using an identity assignment (id Grid) to each cluster. The latter is calculated by

the following mathematical formula: id Grid = √ NCx yr + xr + 1. Where NC represents the number of clusters, so (x,y) are the coordinates Cartesians of the node u and r is the lateral length of a grid. The CBR protocol [40, 41] aims to eliminate the route discovery process by dividing the network into clusters. The latter is executed in two main phases. The first concerns the formation of clusters and the election of cluster-heads (CHs). The second phase is devoted to data routing. The detail of each phase will be given in the rest of this section.

4.7 SIMULATION AND RESULTS

The main objective of clustering [3] is to increase the performance of the intelligent agent based on the experiences already seen. This increase concerns the ability to extract information from one's experiences. There are three types of learning depending on the nature of the information available and the purpose sought: supervised learning, unsupervised learning and reinforcement learning. However, done from samples of a knowledge base called examples, so that the agent builds a general knowledge. The sample database is composed of the desired input/output pairs. The goal of the algorithm of this type of learning is to generalize for unknown inputs what it has been able to learn thanks to the data already processed in the database. examples. In unsupervised learning [45], only input information is provided to the agent. The latter must determine its outputs according to the similarities detected between the different inputs. However, in reinforcement learning [45], it is a matter of finding, through a process of trial and error, the optimal action to perform for each of the situations that the agent will encounter in order to maximize its rewards. It is a goal-oriented learning approach that leads to optimal control for the specified task through rewards.

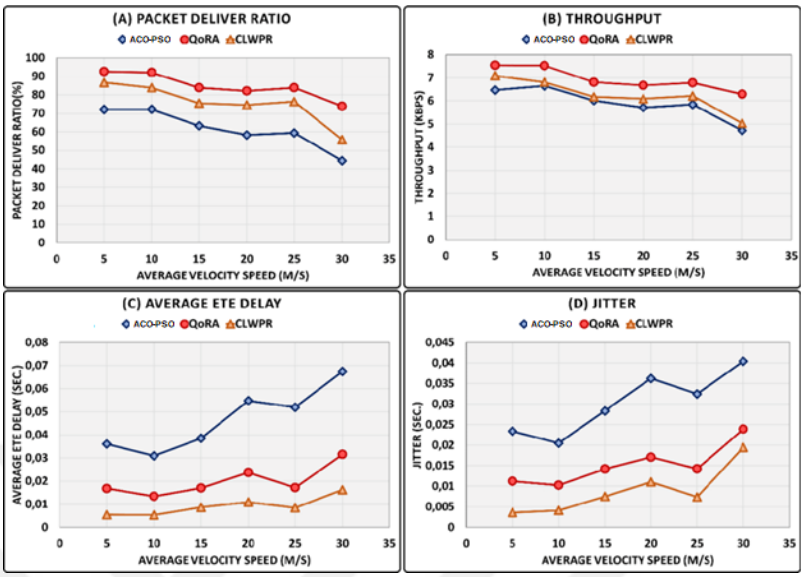

Figure 4.6: Communication parameters compared different VANET protocols after using ACO-PSO routing

If the destination node is not located in the same cluster as the source node, the latter starts the routing request procedure. He sends the Data packet to the CH of his cluster. Hence the selection of the optimal CH which is done according to the minimum angle criterion in order to efficiently transfer the packets from the source to the destination. According to the example shown in Figure 4.5, network parameters are affected by the average velocity.

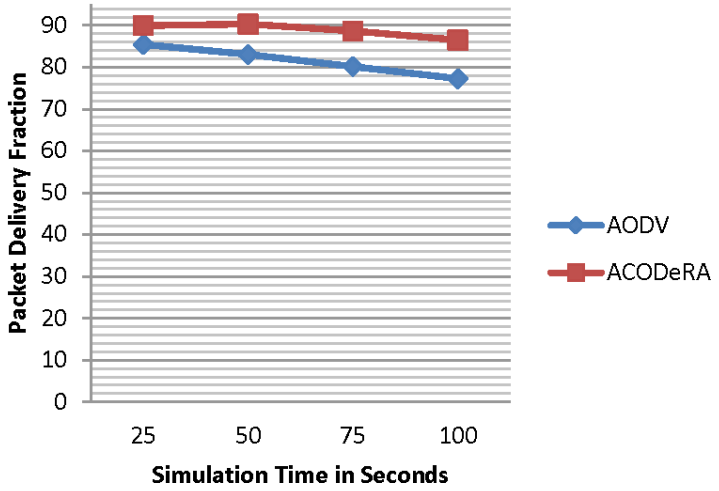

Figure 4.7: Packets successfully sent over time

However, in order to select the optimal neighbor CH, the location of the destination node is analyzed from the source node by measuring the angles surrounded by two rays towards the destination and the neighboring clusters of the source CH. Thus, an optimal CH is then chosen under the minimum angle criterion to transfer the packet. In the example, CH A finds that CH1, CH2, CH3, CH4 and CH5 are the CHs of neighboring clusters. Among the angles formed between the ray AD and the rays A-CH1, A-CH2, A-CH3, A-CH4 and A-CH5 respectively, the CH A determines the optimal routing path to CH2 under the crit minimum angle era. This CH, in turn, applies the above procedure to select the optimal neighbor CH. The procedure is executed repeatedly until the forwarded packets reach the destination.

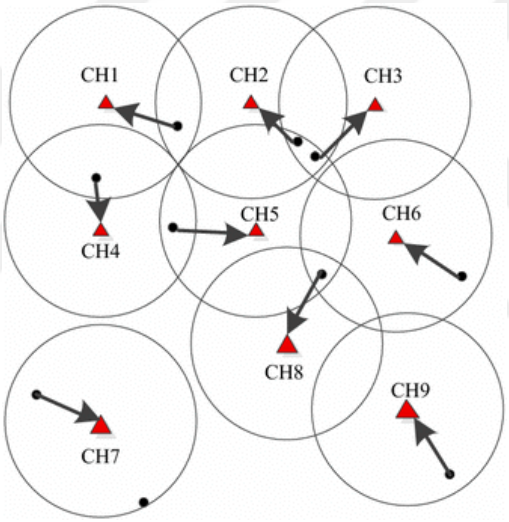

Figure 4.8: Final clustering output using ACO-PSO

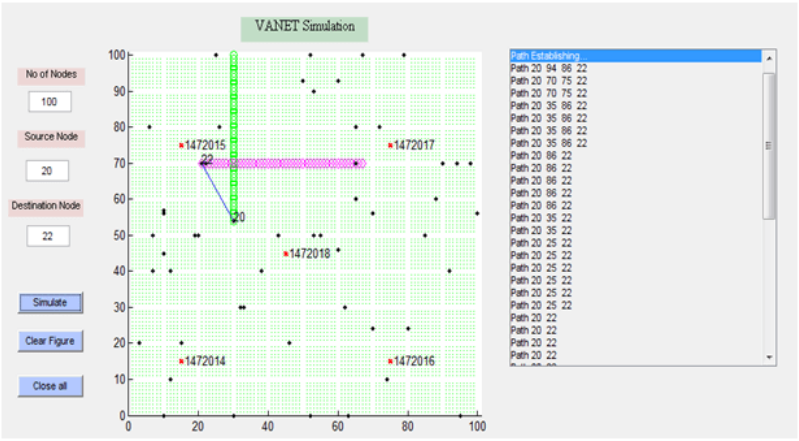

Figure 4.9: Simulation GUI in MATLABr2018a

5. CONCLUSION

Vehicular ad hoc networks (VANETs) form a new type of networks derived from mobile ad hoc networks (MANETs). They are composed of a large number of vehicles circulating on the roads, and able to communicate with each other without a fixed infrastructure. The fact that the network topology is very dynamic makes it difficult to maintain and communicate information in the network. As a result, data routing stands out as an important challenge to address in order to efficiently route information to the destination. In VANETs, there are several routing approaches. We tried through this memory to make the turn on the approach of clustering. To do this, we started by introducing the generalities surrounding the routing paradigm in these networks. Thereafter, we exposed the technique of clustering, its principle as well as its various characteristics. Our study then focused on the main clustering-based routing protocols proposed in the literature. We brought them a new classification, and this in relation to their mode of operation and according to the parameters of decision-making. Also, we have presented the different characteristics of these protocols and their operating principles. The critical study of the protocols of this approach allowed us to draw the guideline of our objective, which is the implementation of the hierarchical CBR protocol in a first step, then its improvement in a second. The two enhancements to the CBR protocol have been named WeCBR and Q-WeCBR respectively. In order to show the efficiency of the clustering approach compared to other conventional approaches, we studied the performance of the CBR protocol compared to the GPSR and DSDV protocols, in terms of loss of packets transmitted and the throughput offered. Among other things, a second series of simulations was carried out to validate the improvements made by us to the two WeCBR and Q-WeCBR proposals in terms of the same criteria in front of the CBR protocols., GPSR and DSDV too. By way of perspective, we are considering:

A. Study the application of other techniques from artificial intelligence and machine learning in the routing process, such as neural networks, Deeplearning, PSO, ACO, AG, etc.
B. Since the selection mechanism of CHs has been modified, choose more/other metrics in the selection criteria, and also study other selection strategies election.

C. The addition of data aggregation and caching mechanisms run by/within each CH to eliminate redundancies and improve quality of service, minimizing the time of routing of packets.
D. The integration of security mechanisms in our proposed improvements, more specifically in their operation in order to protect communications and counter system vulnerabilities the ˆ It would also be interesting to test and implement the different protocols under the new variants of network communication technologies, namely quantum communications and 5G, 6G, etc.
E. New energy harvesting techniques, green energy, and their use in the routing process in intelligent and electric vehicles are emerging as an interesting line of research.

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