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ALTINBAS UNIVERSITY

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Electrical and Computer Engineering

**EFFICIENT ROUTING N VANET NETWORKS  
USING EPSO OPTIMIZATION AND MAODV  
PROTOCOL**

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OPTIMIZATION AND MAODV PROTOCOL**

by

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Mustafa Abdulsattar Kareem

Al-Esawi

## **DEDICATION**

I would like to thank Allah Almighty for the power of mind, health, strength, guidance, knowledge and skills to complete this study.

This thesis is wholeheartedly dedicated to my parents. There are no words to describe what you mean to me; there is nothing that I can repay for what you have done to me. I will continue to do my best to achieve your expectations.

Lastly, I dedicated this to my brother and sisters, relatives, and friends who have been encouraging me during this study

## **ACKNOWLEDGEMENTS**

I hereby acknowledge that this work was not funded in anyway and I want to extend my gratitude to my thesis supervisor professor Sefer KURNAZ for his continuous support.



## ABSTRACT

# EFFICIENT ROUTING IN VANET NETWORKS USING EPSO OPTIMIZATION AND MAODV PROTOCOL

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Supervisor: Asst. Prof. Dr. Sefer Kurnaz

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Smart grids are electric grids that are composed of multiple power sources and devices connected to each other to provide better reliability in power generation and power management, modern developments of the smart grid aim at either improving the control of power sources and loads connected to the smart grid by developing a specialized software/hardware, or by improving the communication within the parts of the smart grid and the central control. In this paper we aim at improving both sides of the smart grid system (communication and control), we propose a fuzzy logic based controller for renewable energy and fossil fuel sources in a grid and an internet of things based monitoring system which oversees the state of the smart grid, faults that occur in the grid, and how the fuzzy controller overcomes those faults, all in which provide an extra layer of support to the smart grid.

**Keywords:** Photovoltaic, Solar energy, Fuzzy logic, Smart grid, Internet of things IOT, Matlab Simulink.

## ÖZET

# EFFICIENT ROUTING IN VANET NETWORKS USING EPSO OPTIMIZATION AND MAODV PROTOCOL

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Akıllı şebekeler, güç üretimi ve güç yönetiminde daha iyi güvenilirlik sağlamak için birbirine bağlı birden fazla güç kaynağı ve cihazdan oluşan elektrik şebekeleridir; akıllı şebekenin modern gelişmeleri, güç kaynaklarının kontrolünü ve akıllıya bağlı yükleri kontrol etmeyi amaçlamaktadır. özel bir yazılım / donanım geliştirerek veya akıllı şebekenin bileşenleri ile merkezi kontrol arasındaki iletişimi geliştirerek. Bu makalede akıllı şebeke sisteminin (iletişim ve kontrol) her iki tarafını da geliştirmeyi hedefliyoruz, akıllı bir şebekede yenilenebilir enerji ve fosil yakıt kaynakları ve devleti denetleyen şeylere dayalı bir izleme sistemi için bulanık mantık tabanlı bir kontrolör öneriyoruz akıllı şebekeye, akıllı şebekede meydana gelen arızalara ve bulanık denetleyicinin bu hataların üstesinden nasıl geldiği, bunların hepsi de akıllı şebekeye ekstra destek katmanı sağlar.

**Anahtar Kelimeler:** fotovoltaik, Güneş enerjisi, Bulanık mantık, Akıllı ızgar, Nesnelerin İnterneti, Matlab Simulink.

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# INTRODUCTION

## 1.1 BACKGROUND

From a traditional perspective, a communications network can be conceived as a set of devices that offer communication services to external users. In this way, the set of parameters that must be treated for its design, operation and achievement of the required quality levels is restricted to the internal sphere of the same, limiting the role of users to mere access to the network under certain conditions imposed. However, nowadays the end user does not resign himself to playing only a secondary role in communication, in his communication. At first, it demanded mobility, later diversity of media and content and finally freedom to establish its own networks that meet specific needs in time and space. This requirement requires new schemes in which the network is made up solely of terminal devices, which therefore act as nodes without external and fixed infrastructure, and whose deployment is simple and low-cost. All this requires a technological response that shifts the control of said communications towards the most peripheral ends of the networks. In contrast to conventional wired networks, each part or node acts as a station and as a router concurrently in an ad hoc wireless network. In order to interact with each node, knowledge about which network it belongs must be kept and a packet transmission and receipt algorithm has to be developed. The collection forming the routing and network requirements algorithm is named routing protocol (routing protocol). Ad hoc network routing protocols can respond to regular and abrupt variations in network topology fast and accurately, with the minimal memory, drive and bandwidth available. [2]:

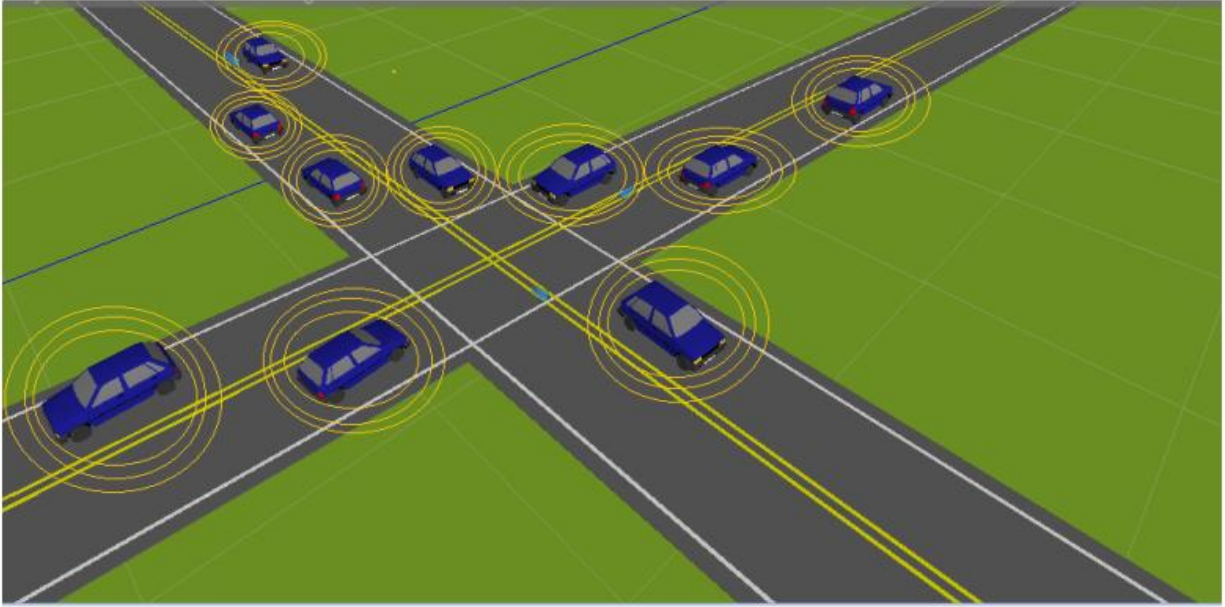
## 1.2 MOTIVATION

In essence, the method of the routing of information from a source or origin to a destination is known as the act of transmitting information end to end. The routing mechanism is assimilated by choosing paths from a network source to a goal. An ad hoc network routing protocol enables the network to fully organize its own organization and its key purpose is to create proper and reliable routes between nodes such that messages are sent efficiently and on time. Route structure can take place with low overhead and minimum bandwidth usage on packet headers. The concept and analysis of new routing protocols must also take account of:

- Simplicity and ease of implementation.
- Fast convergence of routes, free of loops and optimal. It may even be possible to establish different routes between the same pair of source and destination nodes, to increase robustness.
- Distributed and lightweight nature, in such a way that, in the face of changes in the topology and traffic patterns, the reaction of the protocol implies a minimum overhead of headers.
- Efficiency in terms of bandwidth, transmission power and computation, with minimal headend overhead.
- Scalability, in such a way that if the network increases significantly in the number of nodes, performance is not degraded.
- Security at the level of confidentiality, access control and denial of service attacks produced by malicious nodes.
- Ability to support quality of service requirements. Quality of service assurance is essential for on-time delivery of multimedia traffic.

### **1.3 PROBLEM STATEMENT**

In recent years, many methods and protocols focused on the research field of VANET networks have been proposed. In the near future, it is expected that vehicles will be equipped with smart sensors and actuators, which will have integrated wireless communication interfaces to share information among themselves [14]. "Vehicular Ad hoc Network" (VANET) is part of "Mobile Ad Hoc Networks" (MANET), this means that each node can move freely within the network and remain connected; they can also communicate with other nodes via single-hop or multi-hop, and any node could be an RSU. The term VANET was originally adopted to reflect the nature of highly dynamic ad-hoc networks [15]. Within VANET each vehicle can freely establish communication with another vehicle, or with the system infrastructure, [12]:



**Figure 1.1:** Basic VANET network

#### **1.4 CONTRIBUTION**

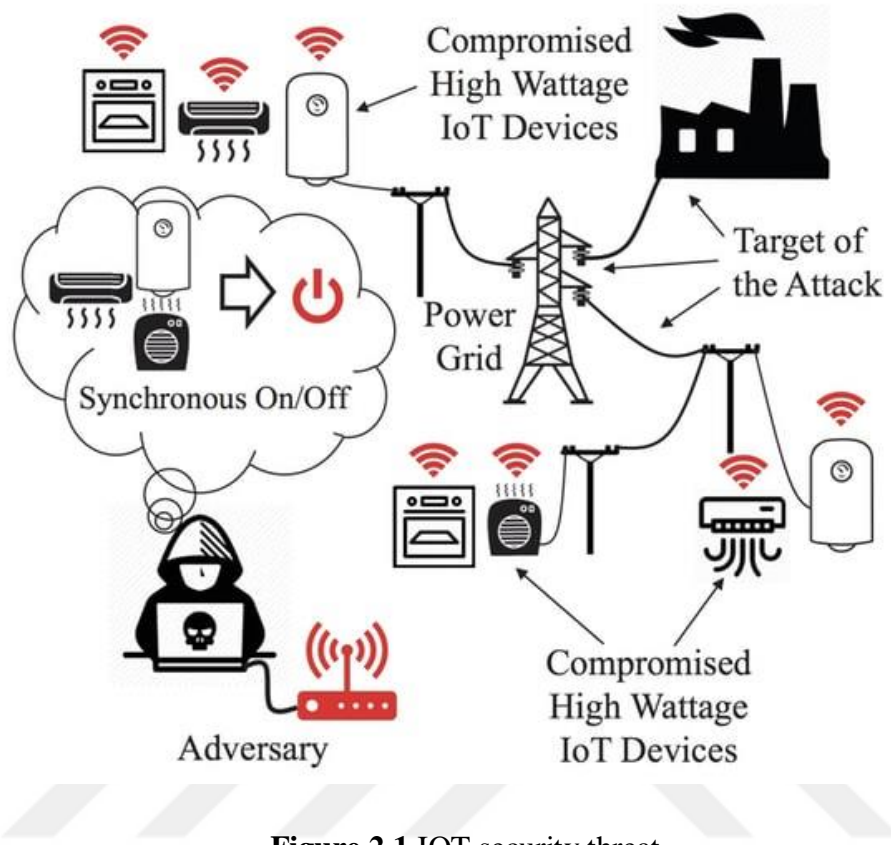
The main study of this project focuses on the planning methodology for the expansion of the primary and secondary Design a V2V and V2I communication model based on the IEEE 802.11p AODV and several other protocols, using "machine learning optimization", in order to optimize the transmission and reliability of shared messages in a VANET network. It is intended to compare this proposal against the normal behavior of a VANET network and against other optimization mechanisms.

#### **1.5 THESIS ORGANIZATION**

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

## 2. LITERATURE REVIEW

In the analyzed literature, The goal of planning will be to meet demand. That is why the first step of the planning study is the forecast of demand, which will be a fundamental stage in the process and a determining factor for the conclusion of adequate results. Therefore, it will be essential for good planning to have an adequate demand forecast for the study area. Even so, planning and forecasting demand are always associated with uncertainty. Projections of demand face problems including vast volumes of data, a growing array of demand profile drivers, insecurities in distributed and renewable generation profiles and a shortage of historical data. A structure of hierarchical demand forecasting can integrate new technology, consumer behaviour, and environmental factors. The proposal for the distribution network aims to determine an optimum range of network solutions in a geographical region to provide electrically spatially dispersed demands. Rapid growth and rollout of dispersed production and smart grid devices (e.g. control, connectivity, structures, etc.) now necessitate accelerated upgrades in distribution grid preparation, so that businesses can modernize their networks proactively. Current methods of delivery. Converting the electricity infrastructure into an intelligent grid is a crucial goal in engineering. Information networks are a key feature of smart grid technologies where there is a broader and more central interaction between information technology and electrical energy delivery systems. Conventional or conventional network delivery planning, which continues to neglect this relationship, cannot meet the needs of smart grid growth. A joint planning process is suggested in this study for the distribution of electric power systems. Detailed teamwork would be examined between the preparation of the power delivery network, the connectivity system planning and the distribution system automation scheme planning. This chapter examines existing strategies and patterns for intelligent planning in this field. Any smart planning issues are described and addressed briefly.



**Figure 2.1** IOT security threat

Distribution network preparation is historically regarded as a method of 'prompting and supply' and is carried out by distributors of energy. With expected growth in load, efficiency requirements (e.g. voltage, stability and protection), regional details, and other restrictions, the network designers are following design processes and are seeking suitable strategies to address the electricity spatially dispersed needs in a particular field. In general, engineering tasks include power measurement, topology design, substations placement, selection of components, etc. Network planners have been pressured over the last few years to respond to the accelerated implementation of the distributed energy resource (DER) and to focus on grid safety in relation to other issues. A significant disadvantage to such planning practices is that developers should not change their planning methodology for developing suitable network options for new scenarios. Now, due to various convergent factors[13] –[14], including: the increased participation in several distributed energy resources technologies (DER), a greater focus on the development of smart grid technologies, particularly related to distribution grid operations, demand administration (DSM) and information and communication, the electrical power distribution industry is expected to

evolve. A potential, independent of fossil fuels, which use vast volumes of wind power in transportation and heating, is explicitly presented in the Smart Grid study series[15] -[16] and the Smart Grid claims to embody the most successful plan for developing a power infrastructure that meets these criteria in the future. The series also highlights the significance of distributors strengthening their methodologies of conventional forecasting since this immediate intervention allows them to best use new technology and to minimize associated risks early on. The main goal of traditional network distribution design is to optimize the physical configuration and placement and size of the transformers in distribution networks. Rarely are influences on physical device efficiency and system stability taken into consideration by the delivery automation system, the Coordination System and the Management System. The distribution network planning, distribution automation and distribution communication processes are carried out on their own, and few theoretical tools are available for integrated planning between these structures. State Grid Corporation of China (SGCC) has evolved special methods for the deployment planning of automated systems and for the operation of communications networks in recent years[17]. In turn, the advancement of academic studies on this subject [18] shows that the electrical power system is interconnected[19] with the corresponding communication method. All these activities establish the foundation for more research on physical and electric power delivery system joint preparation. Indicate that part of the analysis discussed in the book entitled: Analyzes on the Deployment of smart grids in Ecuador (ISBN 978-84-608-5432-6) of the work of the co-author and organizer of this study is written.

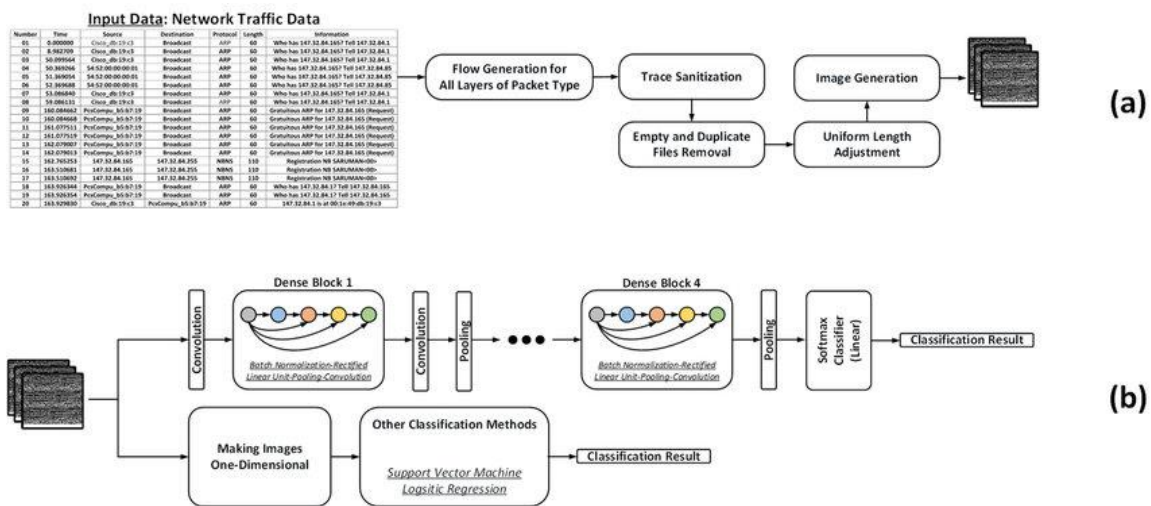


Figure 2.2 DER communication

### 3. MATERIALS AND METHODS

In this chapter we review some of the essential components that we used to implement our model; we give a brief introduction to the component.

#### 3.1 VANET NETWORK

VANETs are a particular case of ad-hoc networks (Mobile Adhoc Network (MANET)) focused on vehicular environments. It is a set of nodes that communicate with each other through wireless links without the need for a fixed network infrastructure. Each node acts as a router and has routing capabilities to redirect packets to their destination. [24].

##### 3.1.1 VANET Characteristics

Let's see below the set of characteristics that define these networks: □ Autonomy. Each node is an autonomous node with the capacity to process the information that is exchanged on the network. The control of the network does not depend on an external infrastructure but is distributed in all the nodes of the network, thus being more tolerant to failures.

- Distributed routing. In the same way that they are autonomous, the nodes must be able to route information, they must have router capabilities. Therefore, it is necessary to define new routing protocols capable of supporting this characteristic.

- Variable network topology. In a MANET the nodes can be moved arbitrarily. This characteristic must be qualified in the case of VANETs since vehicles tend to follow a certain pattern of movement, for example following the curves of a street circuit. Still, the vehicles move faster than a terminal in a classic mobile network. Due to this position variability, significant packet losses can occur. Mechanisms that detect these circumstances and minimize their effects will be necessary.

- Variable capacity of the links. This characteristic has a place in all wireless communications, as it is intrinsic to the transmission medium but its effects are more aggravated in VANETs. This is because each node acts as a router and the information traverses multiple wireless links.

- Limited terminals. In most cases the nodes of this type of network will be light terminals on board vehicles with limited processing, communication and power capabilities, so it is essential that the algorithms used optimize these three resources.

### **3.1.2 Challenges**

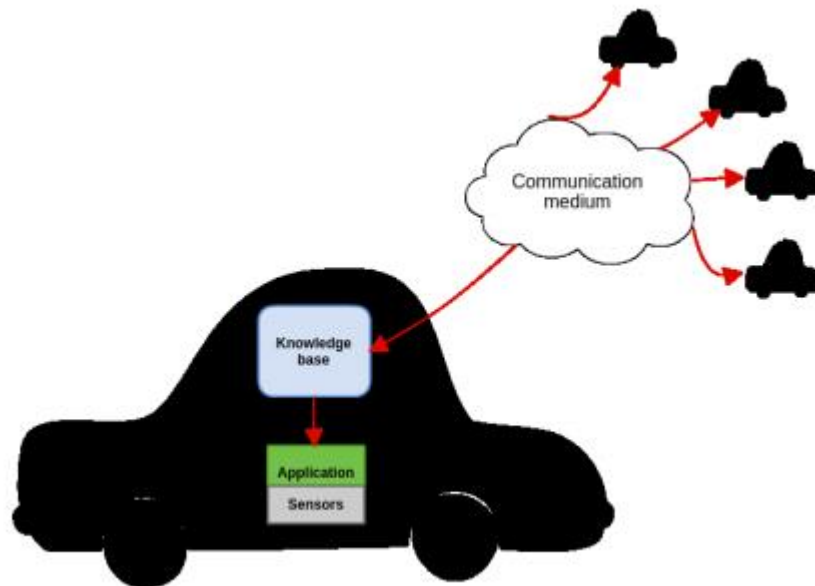
Although a VANET network has many characteristics that distinguish it from other networks, VANET imposes many challenges to function properly. Some of them are mentioned below: Network administration: Due to the high mobility, the network topology and the communication channel conditions change rapidly. Consequently, known structures, such as the tree structure, cannot be used because these topologies do not withstand multiple changes in a short period of time. Congestion and Collision Control: The unlimited size of the network creates a great challenge. Traffic density can become too high at peak times and in rural areas. Consequently, the network can collapse at peak hours, and therefore there will be no control over road accidents and congestion on the road. MAC implementation: VANET generally uses a shared medium to communicate, hence the MAC design is key to network operation. Security: Due to the multiple applications that VANET offers, data integrity is vulnerable to attack, therefore it is a challenge to consider. Aside from the technical challenges of implementing a VANET network, there are also social and economic challenges. It is difficult to convince manufacturers to invest in a system that can have consequences due to its high vulnerability. If this type of network were to have a major attack this could have consequences for confidential data [4]

### **3.1.3 Wireless technologies used in VANETs networks**

## **3.2 VANET ROUTING PROTOCOLS**

Traditionally, a vehicle is a locomotion system that operates on the commands of a driver. Recent advances in communication and control systems have changed this model, to make vehicles behave in an autonomous and intelligent way, thus leading to an intelligent vehicle network. VANET behaves like a wireless network (WLAN), but instead of connecting mobile devices and computers it connects vehicles, presenting a stage for the next generation of wireless communications. Before the propagation of information, the vehicles need to process some data (that is, the measurements of one or more local parameters). Broadcast protocols and applications based to a great extent depend on this mechanism to consolidate their design. This scheme is shown

in Figure below. Some works, like the one mentioned in [5], change this scheme, since the vehicles perform more data processing by having a Learning Automata (LA) mechanism. On the other hand, the advantages it will bring to VANET applications opens up a new scheme. If vehicles can communicate directly with each other, and with an infrastructure, a completely new paradigm for highway and highway safety applications can be created. For example, if an accident occurs on the road and it is monitored by vehicles close to the event, they can spread the information further through other nearby vehicles; and they will recalculate their route looking for other alternatives. This will provide a great decrease in congestion resulting in an efficient and optimal transportation system. Figure below illustrates this scheme in which vehicles cooperate with each other, reporting a traffic alert message.



**Figure 3.1** Car communication system

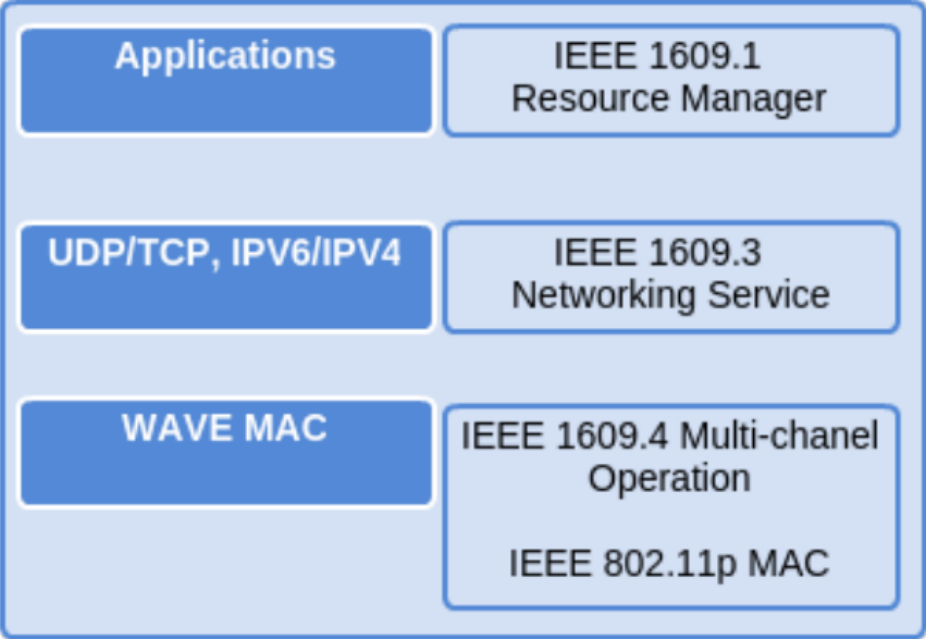
Although there are many applications that a VANET network brings, network connectivity plays a very important role. It is common in MANET networks to propagate the information using flooding. In this type of network, each node relays the information to its neighbors. To avoid infinite duplication of packets, at most each node transmits only once. In addition, TTL (from English: time of live), is used to limit the area where the packet propagates. The general procedure is that if a vehicle detects an incident or situation on the road, it must be communicated to other vehicles. The idea is to introduce rules within the network connectivity, about whether a particular

node or vehicle should forward a packet adapting the retransmissions used according to the traffic present in the network. In a MANET network, the mobile nodes must cooperate with each other, providing a distributed routing between the vehicles. Since VANET networks have a lack of centralized control; The main characteristic of this type of network, routing becomes a central issue and an important challenge due to the random change of the network topology [19]. In context, for the correct operation in a VANET network, the approach is not limited to the retransmission of messages in the network, it is necessary to design optimization algorithms that adapt to the demands of the network. In these cases, a vehicle will explicitly request to obtain specific information, by means of the transmission of a request message. The recipient can know the information of the request, for example, if the user requests the gasoline prices of the stations near where he is, or requests information of the nearby parking places, etc. The transmission of this type of messages can be transmitted in different ways, according to the cooperation implemented in the vehicles. For example, the efficiency of information transmission from vehicles driving in the opposite direction has often been observed [30]

### **3.2.1 IEEE 802.11p**

The most common protocols for controlling access to the medium are: TDMA (from the English: Time Division Multiple Access, Multiple Access by Time Division), FDMA (from the English: Frequency Division Multiple Access, Multiple access by frequency division) and CDMA (from the English: Code-Division Multiple Access, Multiple access by code division). For any of these protocols, managing communication through time-slots with different channels and coding is complicated in vehicle networks, due to the fact that synchronization is required, this is difficult to achieve since in this medium there is high mobility, characteristic of VANET networks. For communication between vehicles it is necessary to use a standard that defines the communication rules. In vehicle networks the most widely used protocol is currently the IEEE 802.11p. Basically, this protocol uses CSMA / CA (from English: Carrier Sense Multiple Access with Collision Avoidance, multiple access with carrier listening and collision avoidance), which allows obtaining a slot in real time; in a communications channel, using an algorithm to access the channel randomly. IEEE 802.11p adapts to the specific characteristics that have to be respected in a vehicle-to-X communication; This is an adaptation of the IEEE 802.11 family of standards, which defines the technologies and rules widely used in wireless local area networks (WLANs). Most of

the IEEE 802.11 protocols are They are designed on a network that contains a centralized controller where nodes can access it through the use of APs (from English: Access point). In a VANET network the use of APs is limited, due to the lack of infrastructure, characteristic of a Vehicular network [4]. Instead of this, it is common to use a P2P communication where the nodes act as infrastructure. On the other hand, a VANET network broadcasts a message through the use of broadcast.



**Figure 3.2** IEEE protocols as registered

**3.2.2 Bluetooth**

Also known as 802.15.1. It is the most widespread technology in terms of personal wireless communications (wPAN). There are several classes depending on their range and power consumption, reaching rates of 2Mbps and ranges up to 100m. It operates in free band and its security mechanisms are sufficiently robust

**3.2.3 UWB**

Ultra Wide Band is an 802.15.3-based standard that works by emitting at very low power over a huge spectrum. Its range is very limited <10m but it provides very high transfer rates reaching 480 Mbps. Its power consumption is very low

### 3.2.4 ZigBee

Ultra Wide Band is a standard based on 802.15.3 that works by emitting at very low power over a huge spectrum. Its range is very limited (10m) but it provides very high transfer rates reaching 480 Mbps. Its power consumption is very low.

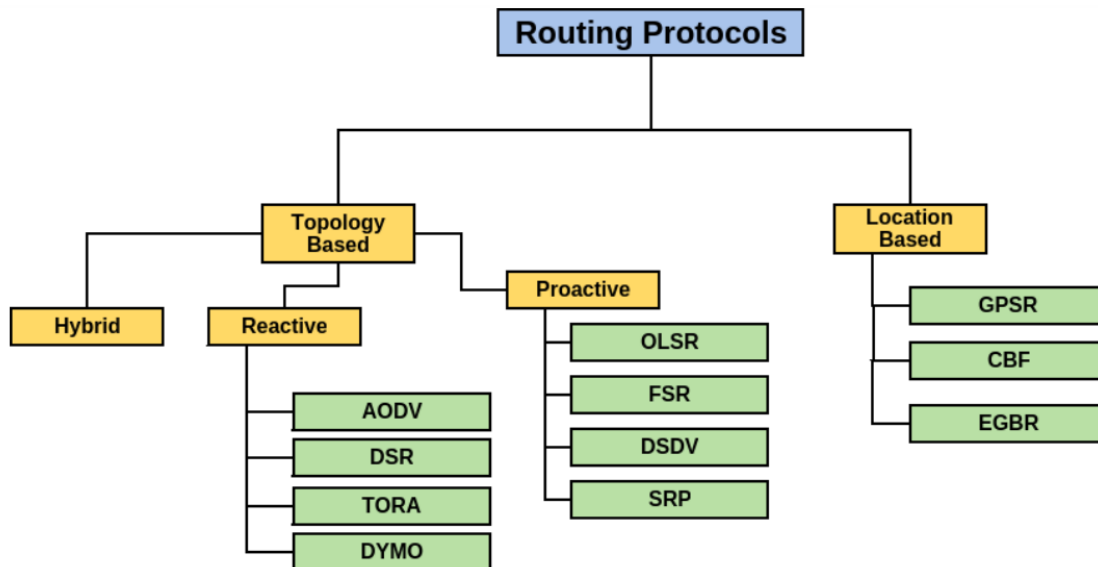
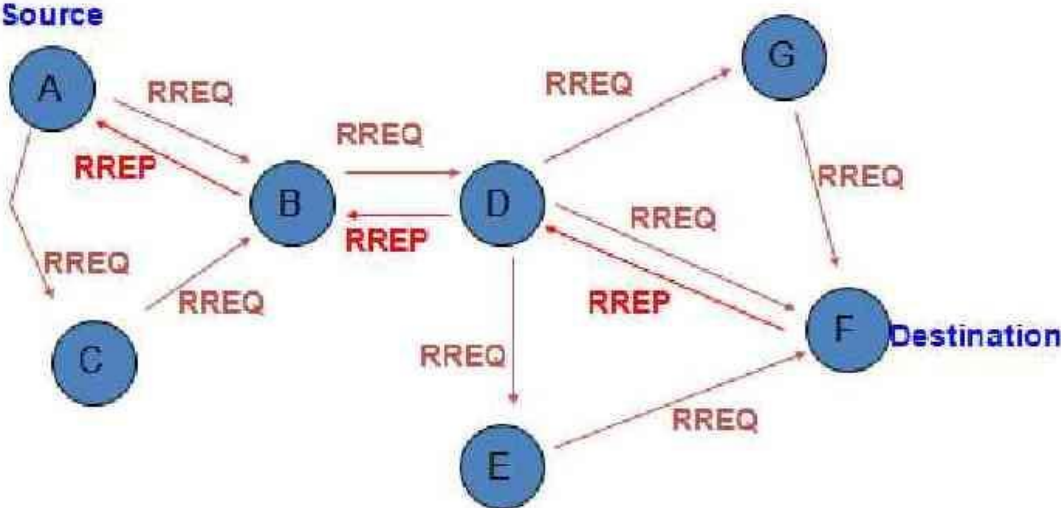


Figure 3.3 Routing protocols

### 3.2.5 AODV protocols

Also, routing protocols designed for wireless ad-hoc networks make use of routing tables. Each node maintains a routing table to store the routes that have to be used to transmit packets to a given destination. The main difference between proactive and reactive protocols is in the way the routing tables are calculated and updated. Proactive protocols such as OLSR (Optimized Link State Routing) are based on a continuous exchange of control messages that helps nodes to achieve an up-to-date understanding of the network topology. A node periodically checks the status of the connectivity of the links towards its direct neighbors. In regular periods, or when the connectivity detection changes; This informs the rest of the nodes about the status of their links. Generally, this is done by flooding the network with control messages or HELLO messages [33]. Another protocol designed for mobile ad-hoc networks is AODV (Ad hoc On-Demand Distance-Vector), where nodes can communicate with direct neighbors. A node keeps track of its neighbors by listening to a hello message that each node broadcasts, at set time intervals. When a node needs to send a

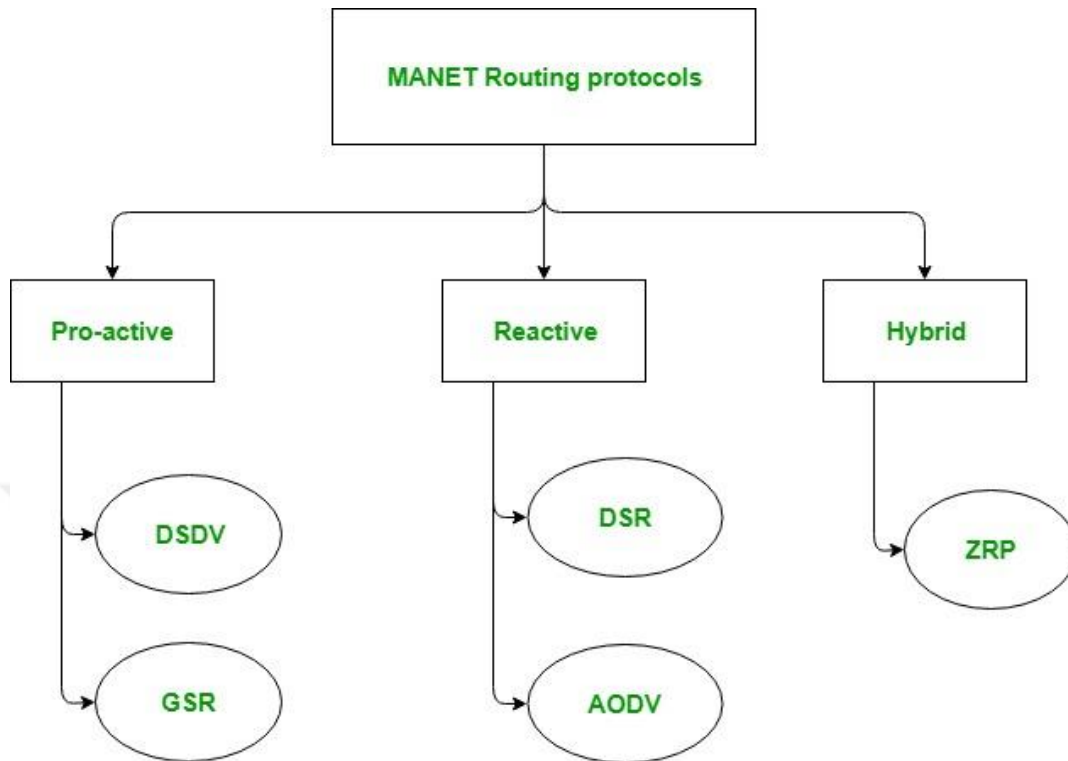
message to another node that is not its neighbor, an RREQ message is broadcast (from the English: Route Request, or route request message). The RREQ message contains several bits of key information: the source, the destination, the lifetime of a message, and a sequence number that serves as a unique identifier [18]. The successor of AODV is DYMO (from the English: Dynamic Manet on Demand, MANET dynamic on demand). DYMO works in a similar way to AODV;



**Figure 3.4** AODV protocol

It is a purely reactive protocol in which routes are calculated on demand, that is, only when necessary. Unlike AODV, DYMO does not broadcast unnecessary HELLO messages and its operation is purely based on the sequence numbers assigned to all packets. This protocol uses sequence numbers to ensure successful packet delivery. Dymo allows on demand, the use of multi-hop using the unicast type of routing between the nodes in an ad-hoc mobile network, the discovery of a route from a source node to a destination node is performed only when not it has information about this route in the routing table, and the updating of the routes is performed every so often, to eliminate the non-existent routes from the routing table and also to reduce the probability of packet loss [ 22]. In order to analyze the messages shared between vehicles, each node can calculate and update the local topology of the network. In turn, this topology is used to calculate the detour routes and update the routing tables. Following this approach, the centralized control design needs

to be in charge of updating the routing tables, for this reason, the adoption of dynamic routing protocols is only done when the data packets of source are frequently transmitted over the network. On the other hand, the efficiency of the channel of proactive protocols decreases highly in the case of mobile networks ad-hoc or MANET. In MANETs, the mobility of the nodes is determined by frequent changes in the topology, which have to be notified with control messages. When source data traffic is not generated continuously and has to be transmitted in mobile settings, the adoption of reactive protocols is preferable. On the other hand, protocols based on position, also called GeoRouting; they take an approach making use of message forwarding. In this case, the nodes that will forward the information are selected, based on their ability to progressively carry transmitted data packets closer to the destination. Basic examples of protocols based on position, using this scheme are: GPSR (from English: Greedy Perimeter Stateless Routing, Greedy routing by perimeter) and CBF (from English, Contention-Based Forwarding) Both are commonly used for packet distribution in traditional Ad-hoc or MANET mobile networks. In GPSR, the destination node checks its location table to find the neighbor with the shortest distance. Once this neighbor is detected, the data packet is re-transmitted unicastly. In contrast, in CBF, the data packet is forwarded using broadcast transmissions. Along with the position of the destination, the packet also carries the position information of the source node [35] [36]. For the analysis of this information, each receiver can calculate the geographical position of their destination. Upon receiving a packet, each receiver activates a timer whose expiration triggers the transmission of packets. Since the duration of this timer is inversely proportional to the progress provided, the receiver closest to the destination retransmits the packet first.



**Figure 3.5** MANET routing protocols

However, there are protocols that are a combination of routing, based on position, path, and network topology [37]. The main idea of this type of protocol is to use the information of the medium in a specific domain context to help the routing decision. The source node uses the information in a global context to calculate the forwarding path and thus efficiently avoid topology drawbacks. Intermediate nodes use local context information to quickly forward packets along the path, around favoring unicast packet forwarding, the method that uses routing and forwarding. they can also be extended to support many other important network functions, such as broadcasting, multicasting, multipath, new route discovery, and resilience. Just as the protocols work in order to improve performance on the network, there are special properties of road traffic used to predict the location of a vehicle. The traffic flow can be generalized to a line with a bidirectional traffic flow and the speed of a car is not random, since each car travels along a set of fixed roads; following some traffic patterns. Therefore, cars traveling in the opposite direction are connected only briefly, while cars traveling in the same direction are connected for long periods of time. As shown in Figures 5-4 and 5-5, the probability of a link going down is much lower if the links provided by vehicles traveling on the other side of the road are used. By choosing pairs

in the same direction instead of the opposite direction, changes in the topology are considerably reduced. This policy of pair selection has a greater potential for reducing the rate of changes in the topology, reducing the frequency of route changes, and increasing routing efficiency [33]

### 3.3 OPTIMIZATION ALGORITHMS

Optimizing the Particle Swarm (PSO) is an optimizing approach for non-linear operation in continuous and discrete areas created by Kennedy and Eberhart (1995) centered on the simulation of the social paradigm of the move of schools and livestock ( Kennedy and Eberhart, 1997). The quest is conducted using a community of particles corresponding to the people in a PSO scheme, each one of which is a candidate solution. By "moving" through search space, the particles shift their state before they find a sufficiently stable state. A framework for PSO combines a 'social only' paradigm that proposes that individuals disregard their own perspective and modify their information in line with the active views of individuals in the neighborhood. The location of a particle changes through these two model (Ozca and Mohan, 1999). Inside the PSO, the  $i$  – th particle shall have a dimension within the  $N$  domain of  $X_i = x_{i1}, x_{i2}, \dots, x_{iN}$ .  $P_i = p_{i1}, p_{i2}(), \dots, p_{iN}$  is the best spot previously identified by the particle that is the one where the best value was obtained in the cost function. The symbol  $g$  represents the optimal location found by the total population. The velocity rate for the particle  $i$  is seen as  $v_i = v_{i1}, v_{i2}, \dots, v_{iN}$ . Equations for particles (1 and 2, with both  $c_1$  and  $c_2$  having two positive constants,  $R_1$  and  $R_2$  having two random numbers  $[\ ] 01$ , and  $w$  with inertial weight, are manipulated. Equation (1 is applied in calculating the new velocity and distances of the particle from its current location in its best position and best position within the group, based on its previous velocity. Then, according to Equation 2, the particle shifts to a new location. Weight of inertia, A systematic expression of the topic of multi-objective evolutionary optimisation: Find the vector

$$X = [x_1 x_2, \dots \dots x_n]$$

That satisfies the  $m$  inequality constraints

$$g_i(x) \leq 0 \quad i = 1, 2, 3, \dots \dots m$$

And optimize the vector function

$$F(X) = [f_1(x), f_2(x), \dots, f_k]^T$$

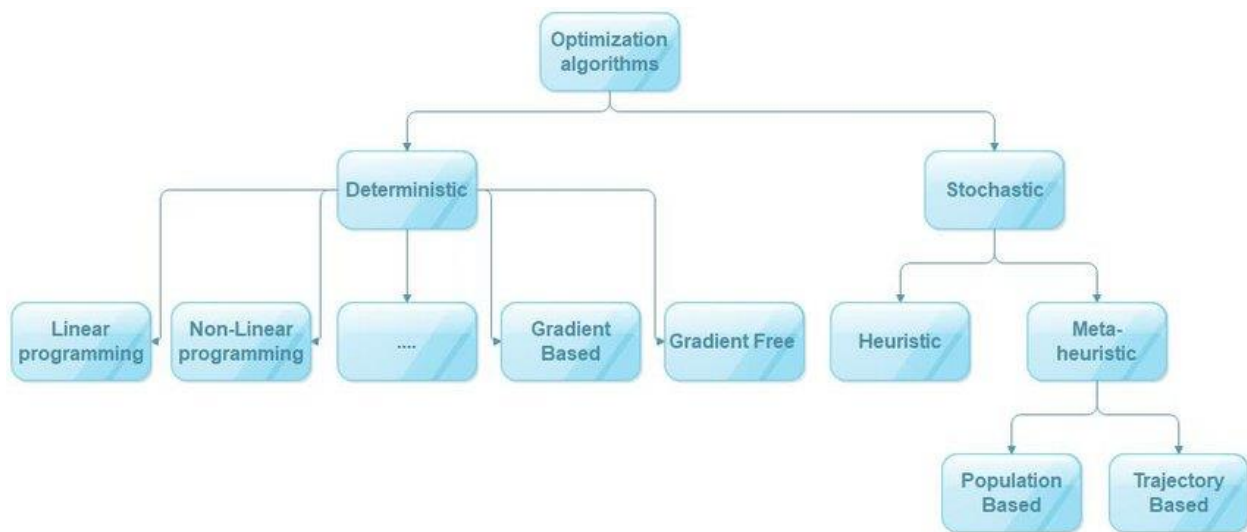
It is important if a specific approach has certain parameters to test it in order to decide how "healthy" is. These parameters are defined as calculable functions of the judgment variables known as objective features. In the case of multi-objective issues, there are three categories of situations:

- Minimize all target functions by defining maximizing all target functions by reducing certain functions and maximizing others. In order to be straightforward, all functions are usually translated into a maximization or minimization problem. You may use the following identity to transform all functions such that they are a minimum challenge.:

$$\max f_i(x) = \min(-f_i(x))$$

The Shi & Eberhart formulation (1998) is used to monitor current velocity impacts of earlier speeds, which affect the changes in particle exploration capabilities between world (wide) or local (shorts). Increase inertial weight enables worldwide scanning for new regions, although reduced inertial weight makes local scanning easier to fine-tune the existing search environment. A proper collection of inertial weights will match the local and global search capabilities, so less iterations are required for optimum search. Conceptually the PSO algorithm is very basic, but there are different approaches to find ways to increase the efficiency of the algorithm. The first modification was made by Eberhart and Kennedy (1995) by changing the neighborhood concept, selecting instead of the best global position  $pg$ , the best position of the  $m$  closest particles  $pl$ . Clerc (1999), makes use of a constriction factor  $K$  that helps the convergence of the PSO algorithm by preventing the particles from stopping their movement. Løvbjerg and Kink in their works (2001, 2002) combined the concepts of PSO with the reproduction found in Genetic Algorithms, subpopulations and critical self-organization (Self-Organized Criticality - SOC), with the aim of increasing the diversity of the population. Miranda and Fonseca in their works (2002a, 2002b) present EPSO, which mutates by means of a Gaussian distribution the inertia ( $w$ ), individual ( $c1$ ) and social ( $c2$ ) parameters in order to self-adapt them during the execution. Zhang and Xie (2003) include a differential evolution operator, which provides a Gaussian-type mutation on the  $pin$ , giving rise to the DEPSO variation. Monson and Seppi (2004) developed the KSwarm, which uses a Kalman filter to update the positions of the particles. Poli et al., (2005) explore the possibility of evolving

the optimal force generating equations to control the particles by means of genetic programming. Grosan et al., (2005) present the variation with independent neighborhoods (INPSO), where independent sub-swarms are established, unlike the previous definition of neighborhood. Tillett et al., (2005) introduce the concepts of natural selection in the DPSO variation, where independent sub-swarms are used, which are reproduced or eliminated depending on their overall performance. present the variations with turbulence (TPSO) and with diffusely adapted turbulence (FATPSO), in which the turbulence prevents rapid convergence by penalizing the drastic reduction in particle velocity. include the concept of worst point repellency. present the variations with distribution vector (DVPSO), with crossing ability (COPSO) and adaptable to the environment (LAPSO). Other fields of research on the PSO algorithm correspond to mathematical or statistical analysis to better understand the behavior of the system New applications of the algorithm are also being sought where better results are sought than with other optimization methods. Some examples are the training of neural networks replacing the backpropagation training algorithm in multilayer perceptron-type networks identification of dynamic models the identification of groups or clustering for the classification of images and other optimization problems such as the control of reactive power and voltage

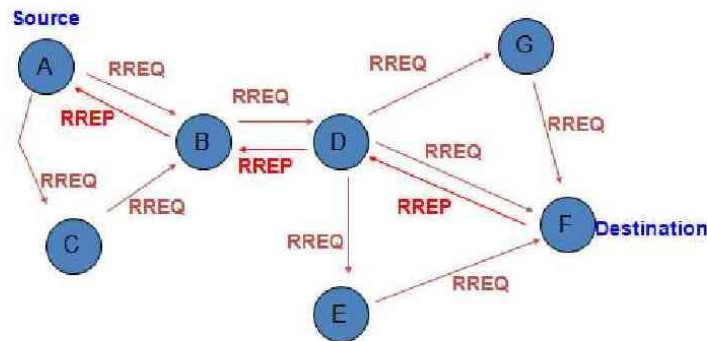


**Figure 3.6** Optimization algorithms

## 4. PROPOSED METHOD

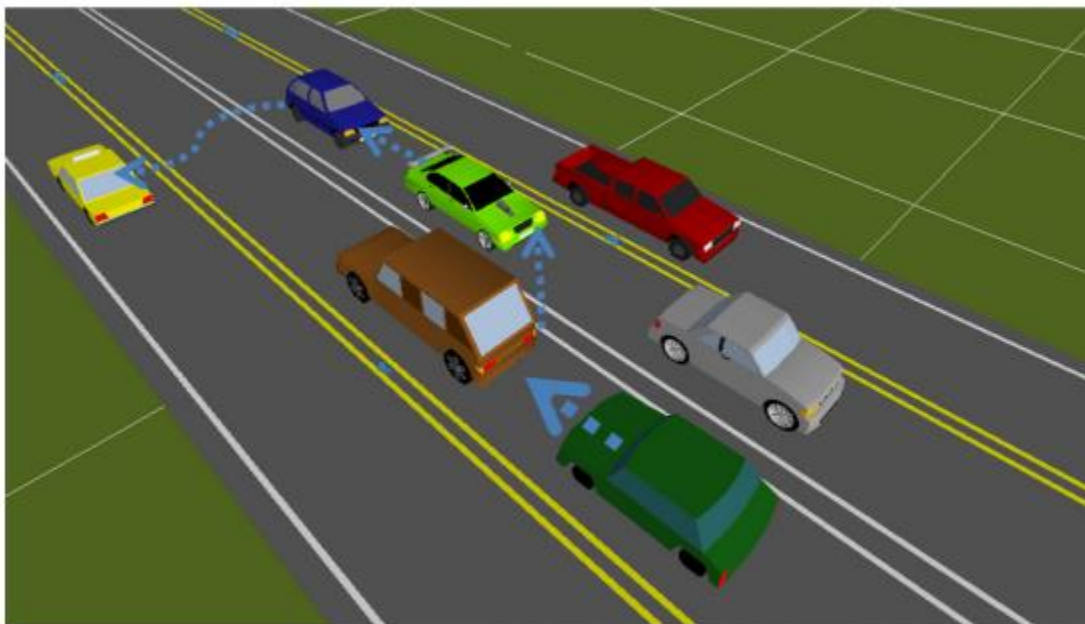
### 4.1 MAODV

MAODV is an expansion of AODV Multicast sometimes known as AODV. What you want to create are two-way cross-country trees connecting many outlets and destinations for each multi-country community. This trees are held until the community members are linked to part of the forest. Each multicast community has a leading node which keeps the sequence number value. The multicast community still uses modified routes thanks to this sequence number. The base of the tree is the leading node. MAODV shares several AODV unicast protocol similitudes, including packages such as Route Request (RREQ), Route Reply (RREP) and routing chart. Multicast activations (MACT) and Group Hello are also available (GRPH) messages are used. The spread range of the RREQs is indicated by the TTL field in the header. Group leader nodes flood the network periodically announcing their address and group leader status as well as the sequence number of the group. When a node wants to send messages to said multicast group for which it does not know the leader, it first tries to become the leader of the group. If he does not receive an answer, he himself becomes the leader and begins to broadcast. If he already knew the identity of the leader by having previously received an announcement message, he sent the data messages directly to the group leader for him to distribute them over the multicast tree. When a node wants to join a group as a receiver, it sends a request flooding the network. These requests can be answered by any member of the multicast group. The responses are sent to the origin so that the nodes through which it passes become new members of the multicast tree.

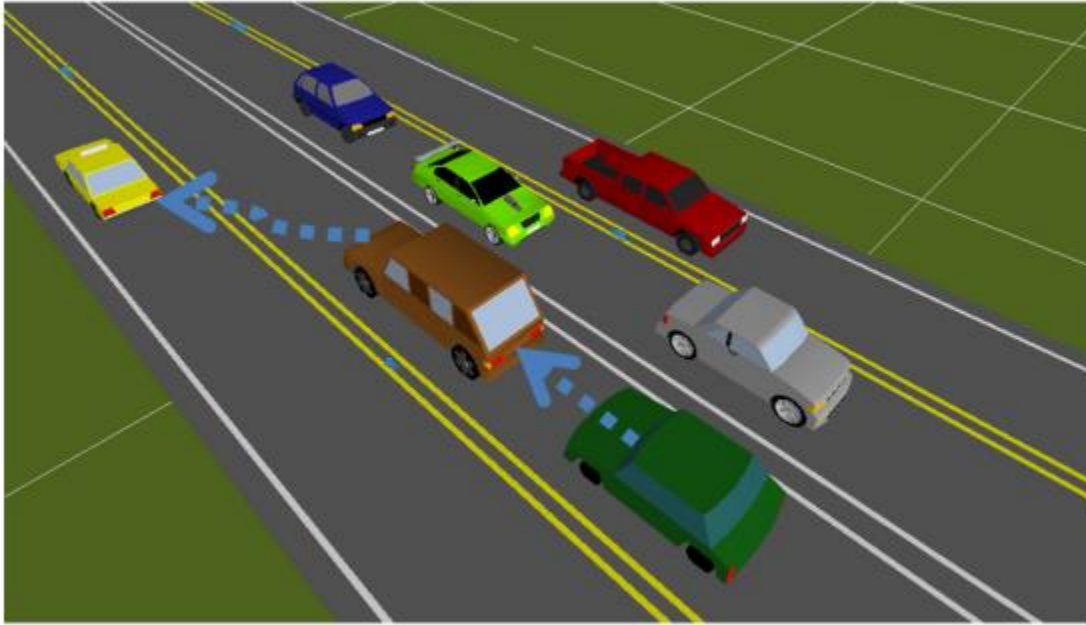


**Figure 4.1** Source to destination AODV routing

As in traditional networks, VANETs need a mechanism that controls access to both the network and the services it provides. The consequences of an attack in which an intruder would have access to network services can be catastrophic, since in the VANETs the nodes assume management and routing tasks by not having a centralization unit. An intruder could divert traffic during routing or gain access to identification keys. At the network layer, it is necessary to ensure that no unauthorized node joins the network either to receive information or to route it. Likewise, at the application level, it is also essential to ensure that unauthorized elements do not access services, for example the key management service. Access control generally consists of the authentication of network users. In other words, to access the network and its services, a user must uniquely identify himself and the network authenticates him as authorized for access. In certain ad hoc networks the services are centralized while in others they are distributed, this fact makes it necessary to use different access control mechanisms. If we choose a distributed access control mechanism for the network, an access control based on digital certificates and certification authorities will be necessary. In other schemes with centralized services, authentication based on user and password is required. It is very useful to do a preliminary study of the security needs of the network to be deployed, in this way, the network access control mechanisms can be adapted.



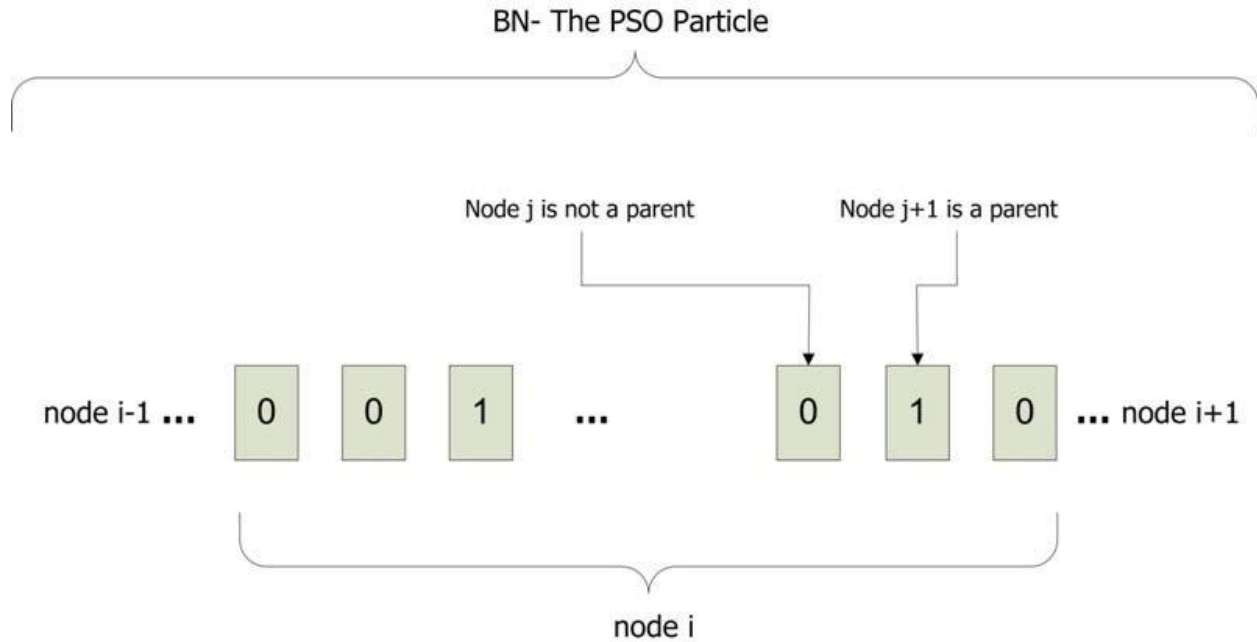
**Figure 4.2** Car communication between each other



**Figure 4.3** Ca routing using routing protocol

#### **4.2 MOADV PSO workflow**

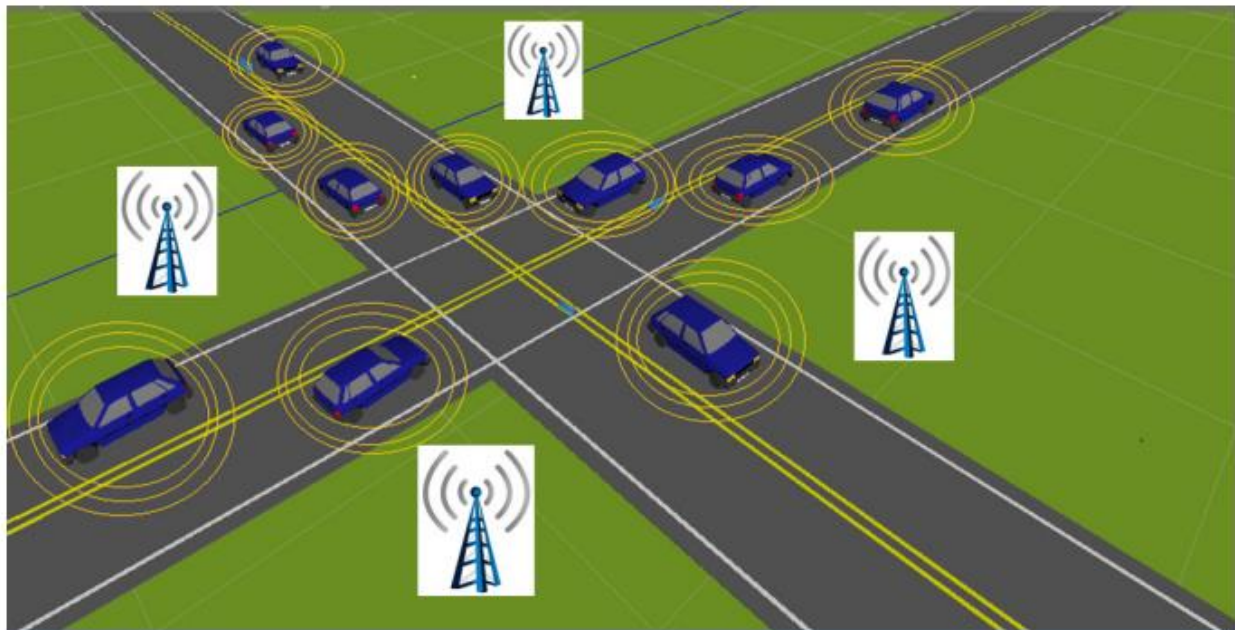
Stigmergy is called agents which locally change the environment and respond to those changes[23]. This approach suggests a mode of contact between each particle to direct each particle effectively to achieve the ideal solution. Circuit flipping is possible for communications networks. Each data packet will in theory pursue a different route in packet-switched networks, which often call data networks, where fixed virtual circuits are formed. In this scenario, local computing networks and the Internet are common cases. We might say that ensuring the dissemination of knowledge between its users is the key feature of a data network. The use of an appropriate network control device will do this. Various ParticleNet research also introduced PSO-based algorithms to solve the telecommunications network routing challenge. Network routing refers to the activities needed to guide information from source to destination nodes. It is a critical and complex issue to resolve because its global impact on network efficiency is high and may change over time. Besides the physical propagation of the problem to a real network, PSO algorithms are a highly promising tool for solving this problem.



**Figure 4.4** MAOD-PSO scheduling

In reality, the PSO processing model is a reasonable approach for distributed mechanisms, with a high degree of redundancy and fault tolerance and flexibility for numerous goals and constraints. While ParticleNet has established several algorithms for routing problems, it is the only algorithm that has achieved good output in at least experimental and simulations[27]. In principle, PSO is a technology that aims to optimize, speed up the heuristic method. Particle Colony Optimization routing algorithms comprise a group of algorithms that generally agree on the best routes for routing. The core concept of this approach is to use the concepts of self-organization of the particles that make it possible for normal particles to conduct themselves in a highly organized way to organize artificial agent communities that work together to solve compute problems. In the past few years, computer scientists have been able to optimize and monitor useful algorithms by converting collective particle knowledge models [27] [39]. [40]. PSO was used for various combinational optimization issues, including the problem of passenger and the problem of quadratic assignment[23]. The tests show that particulate colonies have an adaptive optimization capability based on local knowledge based on probabilistic principles that can locate their environment on the shortest path between two points[29]. The efficiency of algorithms that use PSO under an academic understanding, with hundreds of areas of use, is meta-heuristic and has increased substantially, there are many areas where preliminary investigations have been carried

out so far and where there are many contributors. One of these fields of research is expanding PSO algorithms to more difficult problems of optimisation, including dynamics in which the input, function objective values, parameters Decision making may dynamically shift or restrictions can change; Stochastic issues with probabilistic knowledge only concerning the importance of the objective function, judgment values or boundary limits, as a result of complexity, noise, approximation or other factors; and other objective issues where an objective function evaluates response quality parameters [29]



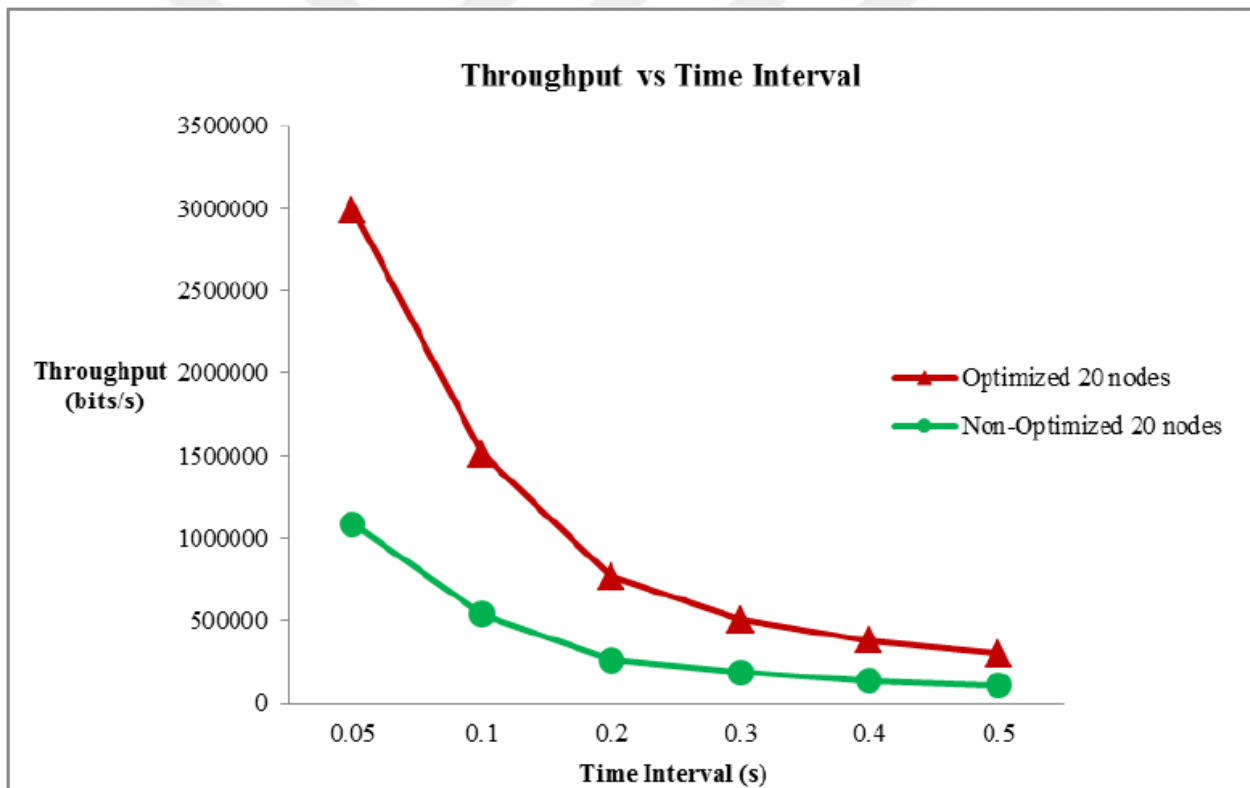
**Figure 4.5** Handshake between load balancing base stations

This segment introduces the Ant Colony Optimization model designed to optimize communications between V2V and V2I in the vehicle network in an IoV setting, where users can access different device resources from anywhere. Figure 7-2 illustrates the interaction of different vehicles in the IOV environment to different tools. The aim is for vehicles to reach various services, which is typical of VANET networks, from all over the world with reduced time. In order to utilize the intermedia nodes as repetitives, the mechanism must run in partnership, that is, in order to share resources with the other vehicles in the Network, each vehicle must be able to cooperate with its neighbours. A cooperative model that can be built between the nodes that operate as a P2P structure is required for the execution of various vehicular tasks in an IOV context[11]. Furthermore, the closest RSUs may be used along the highway to exchange services such as bandwidth, processing

and storage. In order to minimize access time and to enhance flexibility in comparison with centralized networks, RSUs offer services to traveling cars, from which access to facilities is delayed if traffic data is large. In combination with the IEEE 802.11 families of protocols described below, cars can use various short-service and long-range networking technologies such as Zigbee, Bluetooth and WiFi. The versatility of the nodes in an IOV environment is large, allowing vehicles to share their energy simultaneously with other vehicles; that an access channel is used simultaneously, a protocol must be introduced. In a decentralized model for programming and shifting the same nodes function as an infrastructure There are a number of simultaneous providers. The sharing of resources can be either built from the location of P2P or through the global RSUs (centralized server). In both instances, the duration of access to services from somewhere is compatible with the overhead created. For the swapping of packets, vehicles sharing resources globally or locally need an optimum infrastructure in order to delegate separate resources to a resources when requested. During the collection of the details, in a time-space,

## 5. SIMULATION AND RESULTS

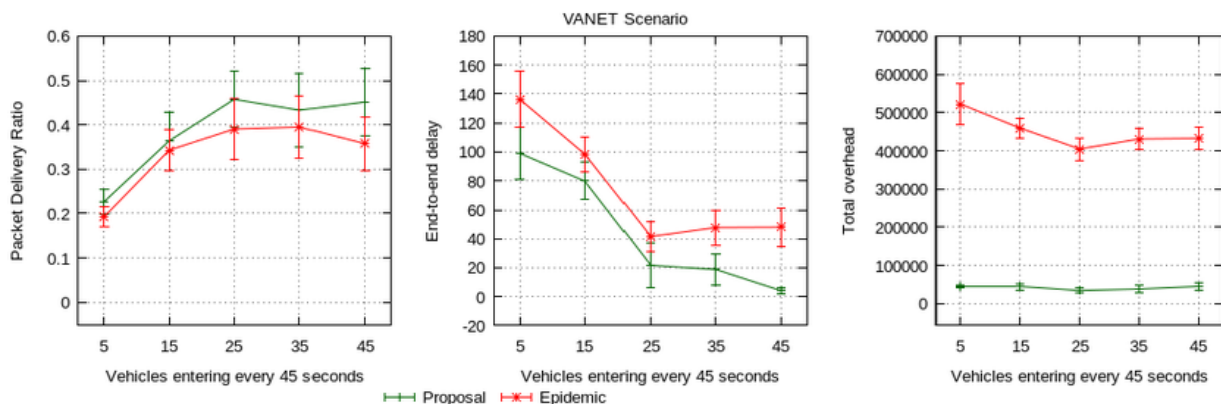
In these simulations the first two scenarios come into play: pure VANET communications and VANET communications through intermediate nodes. In this study, different ad-hoc unicast protocols will be simulated: - MAODV - DSDV - DSR - FSR - OLSR The characteristics of each protocol are described in chapter 2 of the state of the art, but it is worth remembering at this point to which group does each of them belong? MAODV and DSR are reactive protocols while the others are proactive. For each topology, two nodes are chosen from among all the nodes present and a connection will be created between them, first UDP and then TCP.



**Figure 5.1** Throughput in MAODV-PSO

A UDP CBR (Constant Bit Rate) application has been chosen as it is very close to UDP applications that send traffic at a constant speed and without worrying about whether the packets have been delivered or not. To simulate a TCP connection, an FTP application has been chosen. The characteristics of the connections to be defined in the tcl file are the following: For FTP over

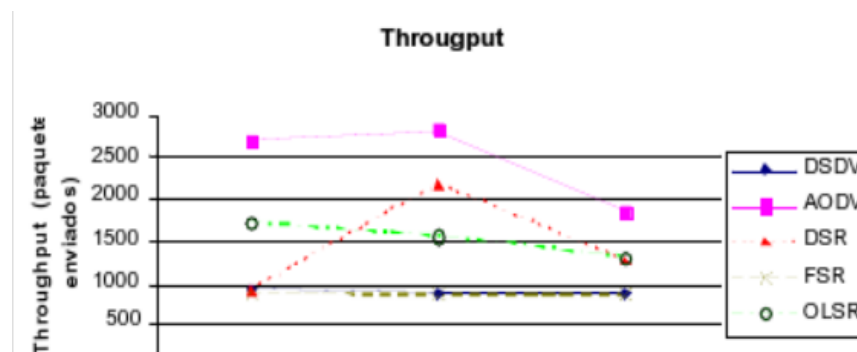
TCP: 1000-byte packets are sent. The congestion control algorithm is the TCP TAHOE with a 20 packet window. For CBR over UDP: 210-byte packets are sent at a speed of 448 kbps at an interval of 3.75 ms. A maximum of 2684353456 packages can be sent. The simulations of these connections are carried out with all the protocols, comparing the performance of each one of them in terms of percentages of deliveries (pdfr), end-to-end delays and communication overhead introduced by the protocol. Three-dimensional graphs of the results obtained will be presented for a visual approximation of the performance of each protocol. More comparisons could be made, for example, by varying the speed of the vehicles or by introducing a greater number of connections in the VANET successively, but we consider that these scenarios are sufficiently representative for our case study. It is important to study the setting carefully before carrying out the work. Indeed, we must ensure that the two nodes we choose have the same relative positions in the different scenarios with different traffic flows and different protocols. This condition is essential for the results of the simulation to be viable. If we chose the nodes at random, the result would also be random: for example, it may be that the vehicles are so far away that they cannot be seen and no packet can reach or that the nodes are vice versa. they are so close that the connection is always direct and that the pdfr is 100%. Pre-simulation tests are performed to determine the nodes to consider. Thanks to the animator nam we can observe the mobility schemes. It is observed that nodes 0 and 1 are the first to arrive in each lane and that by maintaining the same speed scheme in all the scanners, they maintain their constant relative positions, the number of vehicles between them being the only variation.



**Figure 5.2** VANET scenarios

## 5.1 Comparison Between Protocols

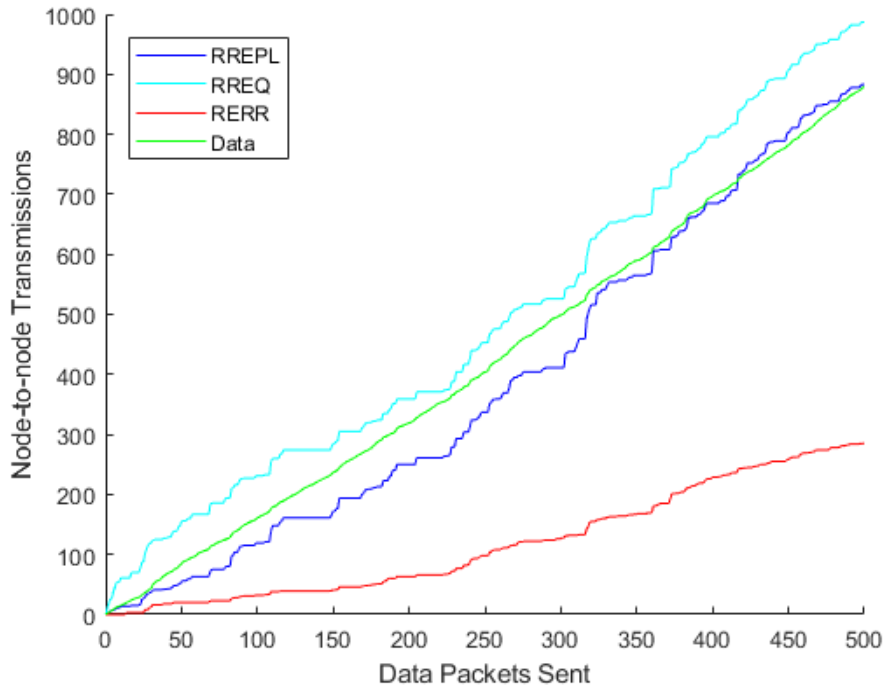
It can be seen that for the scenario considered, an optimal behavior is obtained in the mean profile. We see, in effect, that it is within this scenario that the delivery percentage is higher for all protocols. It is also observed that reactive protocols have a higher percentage of success, lower delay and overhead. These results coincide with expectations, since in VANETs, where topology changes are very frequent, proactive protocols quickly become obsolete. Let's take a closer look at the conclusions of each graph: - Success percentage: There is a very clear difference between reactive protocols (DSR closely followed by MAODV) and proactive protocols. Reactive protocols have better packet delivery rates. We can notice that for the FSR protocol the delivery rates are almost constant, they do not increase with increasing car density. This means that FSR does not react well to topology changes and is not able to optimize the routes with the new nodes that appear between the sender and the receiver. On the other hand, in low traffic situations the pdfr decreases. This is so because as there are fewer nodes between sender and receiver, there is no communication when the nodes are too far apart. - Comparison of the delays: The first observation that can be made is that with low traffic profiles, the delays decrease significantly for all protocols.



**Figure 5.3** Comparing throughput in multiple schemes

If it is true that fewer packets arrive at the destination, those that do have fewer delays since they pass through fewer intermediate nodes before reaching the destination. The reactive protocols, although they present better pdfr, introduce greater delays. This is explained by the fact that they get updated and fresher routes, but that the route discovery mechanism that is carried out every time a packet has to be sent introduces transmission delays. Within reactive protocols, MAODV has lower delays than DSR except in the high traffic profile. - Overhead: In the overhead graph,

the OLSR behavior draws attention, which presents an overhead far above the other protocols. Therefore we can conclude that its use is not recommended in those environments. Reactive protocols load less the network.



**Figure 5.4** Data packet delivery in our method vs other methods

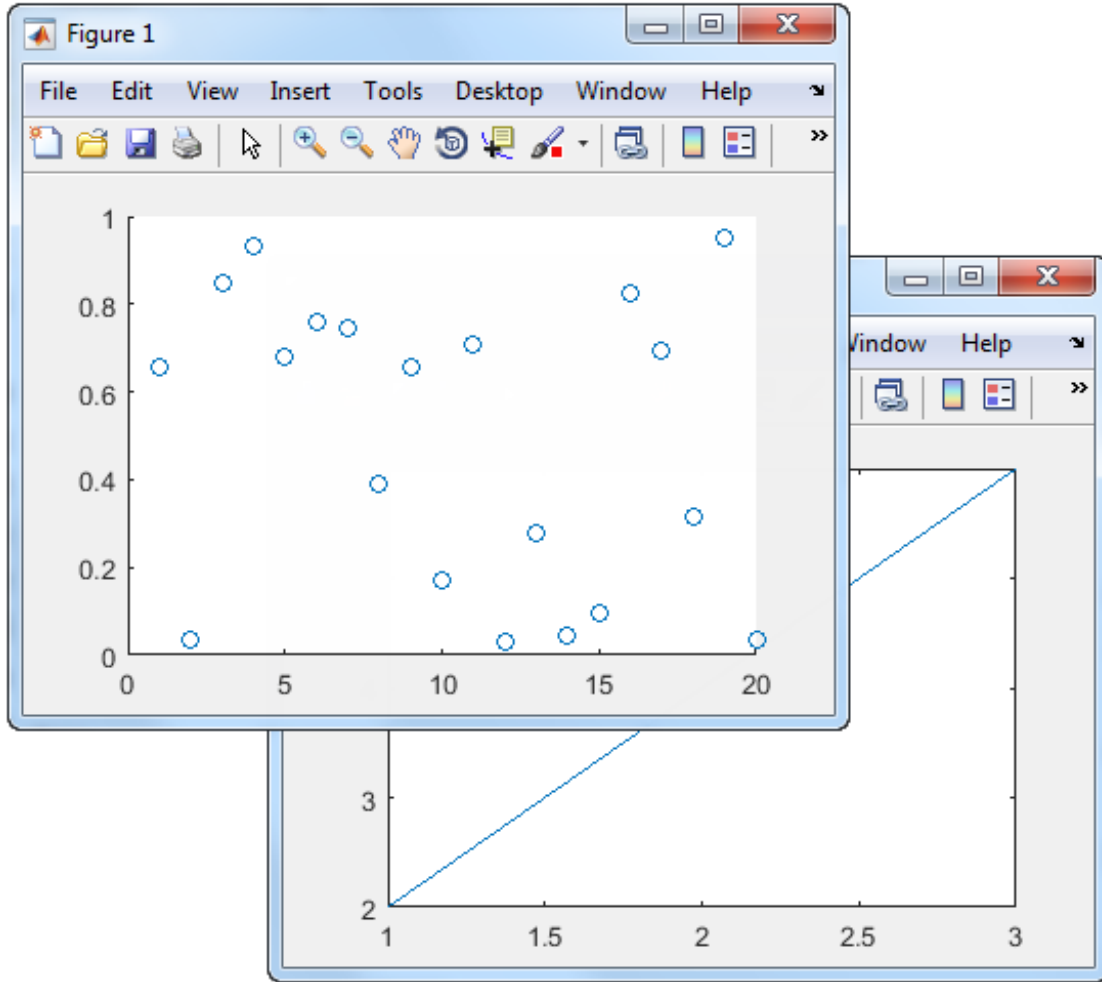


Figure 5.5 MATLAB view of our method

AODV Sim - Table View														
SeqNum: 7 Node a					SeqNum: 3 Node b					SeqNum: 1 Node c				
dest	nextHop	hopCnt	seqNum	lifeTime	dest	nextHop	hopCnt	seqNum	lifeTime	dest	nextHop	hopCnt	seqNum	lifeTime
1	d	d	1	1	1	d	c	2	1	1	d	d	1	1
2	g	e	2	1	2	c	c	1	1	2	g	e	2	1
3	c	c	1	1										
SeqNum: 1 Node d					SeqNum: 3 Node e					SeqNum: 5 Node f				
dest	nextHop	hopCnt	seqNum	lifeTime	dest	nextHop	hopCnt	seqNum	lifeTime	dest	nextHop	hopCnt	seqNum	lifeTime
1	g	a	3	1	1	d	a	2	1	1	d	d	1	1
2	c	c	1	1	2	g	g	1	1	2	c	c	1	1
					3	c	c	1	1					
SeqNum: 3 Node g					SeqNum: 1 Node h					SeqNum: 5 Node i				
dest	nextHop	hopCnt	seqNum	lifeTime	dest	nextHop	hopCnt	seqNum	lifeTime	dest	nextHop	hopCnt	seqNum	lifeTime
1	d	e	3	1	1	d	e	3	1	1	d	d	1	1

Figure 5.6 MATLAB simulation of our method

## 6. CONCLUSION

IOV is a new emerging area, in which several vehicles are considered as interconnected objects through the Internet that collaborate with each other, for the exchange of data and updates. In this work a study has been carried out on the state of the art in the development and implementation of VANET networks. Consequently, the main restrictions and characteristics of this type of wireless communication networks have been presented, showing the importance that their applications will bring in a future where IoT dominates. Nodes in an IOV environment have the potential to provide safety, and entertainment for passengers on board, but due to continuous topological changes and the variable density of vehicles on the road, the diffusion of information on to the final destination requires a specialized approach specifically in the IOV environment. In this work, we have introduced a procedure to improve performance in the 802.11p standard based on Optimization. This method uses the information available in this type of network, such as: the position of the vehicles, the speed and the information available on the link between two vehicles, thus adapting it, to a framework for making predictions about the mobility and connection of neighbor vehicles. The model implemented in this work adopts the routing schemes: topology-based and location-based, forming a hybrid scheme, since the position of a vehicle and the information of a link between two vehicles are used. The heuristic was defined based on choosing the best path, according to the link parameters and the propagation probability. Using the strategy of artificial ants for the selection of the best route, based on the Optimization theory, it is intended to improve the reliability in relation to the distribution and transmission of data, it was defined or an algorithm for updating routes in order to maintain load balancing. The purpose is to keep the paths efficient to reach a destination, using hello messages, the nodes know the state of their immediate neighbors and have the pheromone information about them in their routing tables. When initiating a communication from a source node to a destination node, the method chooses the best path based on the level of pheromone deposited in the link. The proposed method demonstrates the best performance in terms of packet loss, and successful packets received, in scenarios with different characteristics, and with different vehicular densities.

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## APPENEDX OF ALL THE CODES USED

```
function [] = calcConnections(distance,draw)

    % Sanity check
    if nargin <=0
        return
    end

    % Bring globals into scope
    global nodes graphFig
    set(0, 'CurrentFigure', graphFig);

    % Erase current lines
    lines = findobj('type','line');
    delete(lines);

    % For each node, calculate new connected nodes
    % Also draw lines, if requested
    for i = 1:numel(nodes)
        before = strcat(num2str(nodes(i).connectedNodes));
        nodes(i).connectedNodes = [];
        for j = 1:numel(nodes)
            if i == j
                continue
            end
            if sqrt((nodes(i).x-nodes(j).x)^2+(nodes(i).y-
nodes(j).y)^2) <= distance
                if draw == true

plot([nodes(i).x,nodes(j).x],[nodes(i).y,nodes(j).y],'Color','b
lack');

                end
                nodes(i).connectedNodes =
[nodes(i).connectedNodes,j];
            end
        end
        after = strcat(num2str(nodes(i).connectedNodes));
        if(~strcmp(before,after))
            nodes(i).seqNum = nodes(i).seqNum + 1;
        end
    end

    % Build a table to node connections to display
    % output = table;
    % for i = 1:numel(nodes)
    %     name = nodes(i).name;
    %     if numel(nodes(i).connectedNodes) > 0
    %         connectedNodes =
num2str(nodes(i).connectedNodes);
```

```

%         else
%             connectedNodes = "";
%         end
%         output = [output;{name,connectedNodes}];
%     end
%     output.Properties.VariableNames = {'Node',
'Connected_Nodes'};

end
function [myTable] = sendPacket(src,dest,quickMode)

% Check args
if(nargin <= 2)
    quickMode = false;
end
if(nargin > 3 || src == dest)
    return
end

% Bring globals into scope
global nodes colors routeLifetime;

% Persistent variables
requestDepth = 0;
depth = 0;

% Get sequence number
idx = find(nodes(src).routeTable.dest==dest)';
if isempty(idx)
    seqNum = 0;
else
    seqNum = nodes(src).routeTable.seqNum(idx);
end

% Initialize our table and add the start node to it
myTable = table(0,0,src,src,colors.Src);
myTable.Properties.VariableNames =
{'Depth','HopCnt','Node','From','Color'};

% If this node has a route entry for our dest, try
sending normally
tryAgain = false;
if(any(idx))
    if(~send(src,dest,colors.Data))
        tryAgain = true;
        flood(src,dest);
    end
else
    tryAgain = true;
    flood(src,dest)
end
end

```

```

        % Delete any routes marked by RERR
        for route = find(myTable.Color == colors.RERR)
            idx =
find(nodes(myTable(route,:).Node).routeTable.dest == dest);
            nodes(myTable(route,:).Node).routeTable(idx,:) =
[];
        end

        if(quickMode)
            quickUpdate();
        else

            % Make a timer to iteratively light up paths
            colorTimer = timer('Name','colorTimer',...
'ExecutionMode','fixedDelay',...
                                'Period',0.5,...
                                'TimerFcn',@setColor);

            depth = 0;
            start(colorTimer)
        end

        % Remove route with expired lifetimes
        for i=1:numel(nodes)
            for j = 1:size(nodes(i).routeTable,1)
                expired = find(nodes(i).routeTable.lifeTime >
routeLifetime);
                nodes(i).routeTable(expired,:) = [];
            end
        end

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        % Send function
        % Sends a packet normally assuming the
        % routeTable has an entry for it
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        function [success] = send(sendSrc,sendDest,color)
            success = false;

            % Check if we already have a route entry for this
            currentNode = sendSrc;
            visitedNodes = [];
            while true
                depth = depth + 1;

                % Look in currentNode's routeTable for the
nextHop node
                nextNode =
find(nodes(currentNode).routeTable.dest==sendDest);

```

```

        % Exit if no node was found
        if(~any(nextNode))
            % If we were expecting to have a valid
path, send a RERR
            if(color == colors.Data)
                replyTable =
floodReply(sendSrc,currentNode,colors.Data,colors.RERR);
                myTable = [myTable;replyTable];
                success = true;
                tryAgain = true;
                return
            end
            break;
        end

        % Update lifetime field now that we've used
this route
nodes(currentNode).routeTable(nextNode,:).lifeTime = ...
nodes(currentNode).routeTable(nextNode,:).lifeTime + 1;

        % Convert from index in routeTable to actual
node index
        nextNode = nextNode(1);
        nextNode =
nodes(currentNode).routeTable(nextNode,:).nextHop;

        % Exit if this nextNode is unreachable
        % Send a RERR back to source

if(~any(find(nodes(currentNode).connectedNodes==nextNode)))
    %
    myTable =
[myTable;{depth,depth,currentNode,currentNode,colors.RERR}];
    %
    send(currentNode,sendSrc,colors.RERR);
    %
    myTable =
[myTable;{depth,depth,sendSrc,sendSrc,colors.RERR}];
    if(currentNode == sendSrc)
        myTable =
[myTable;{depth,depth,sendSrc,sendSrc,colors.RERR}];
    else
        replyTable =
floodReply(sendSrc,currentNode,colors.Data,colors.RERR);
        myTable = [myTable;replyTable];
    end
    tryAgain = true;
    success = true;
    return
end

        % Exit if we're in a loop

```

```

        if (any (find (visitedNodes==currentNode)))
            replyTable =
floodReply (sendSrc, currentNode, colors.Data, colors.RERR);
            myTable = [myTable; replyTable];
            tryAgain = true;
            success = true;
            return
        end
        visitedNodes = [visitedNodes, currentNode];

        % Update our path table
        myTable =
[myTable; {depth, depth, nextNode, currentNode, color}];
        currentNode = nextNode;

        % Exit when we've reached the destination
        % Set success to true
        if (currentNode == sendDest)
            success = true;
            break
        end
    end
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Flood function
% Performs network flooding for route discovery
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [] = flood(floodSrc, floodDest)

    % Walk down table rows and add connected nodes
breadth-first
    i = 0;
    success = false;
    replyNodes = [];
    while true
        i = i + 1;

        % Get connected nodes here
        currentNode = myTable.Node(i);
        connectedNodes =
nodes (currentNode).connectedNodes;
        depth = myTable.Depth(i)+1;

        % Remove duplicates when we've finished at
this depth
        if (depth > myTable.Depth(end))
            % For each duplicated value in
myTable.Node

```

```

        for j =
find(hist(myTable.Node,unique(myTable.Node))>1)
        % Find the distance between Node and
From for all
        % occurrences of this duplicated node
        dist = [];
        duplicates = find(myTable.Node==j &
myTable.Color == colors.RREQ)';
        for k = duplicates
            dist =
[dist,sqrt((nodes(myTable.Node(k)).x -
nodes(myTable.From(k)).x)^2 ...
            +
(nodes(myTable.Node(k)).y - nodes(myTable.From(k)).y)^2)];
        end
        % Remove occurrences but the one with
the min distance
        [~,idx] = min(dist);
        duplicates(idx) = [];
        myTable(duplicates,:) = [];
        i = i - numel(find(duplicates<=i));
        end
    end
    % If this node happens to have a valid entry
on the route
    % table, go ahead and send normally from here
out
    if(any(find(nodes(currentNode).routeTable.dest==floodDest)) ||
currentNode == floodDest)
        replyNodes = [replyNodes;currentNode];
        success = true;
    else
        % Add each of this node's connected nodes
unless its already
        % on the table before this depth
        for connectedNode = connectedNodes
            if(currentNode ~= floodDest)
                if(~any(find(myTable.Node==connectedNode & myTable.Depth <
depth)))
                    myTable =
[myTable;{depth,depth,connectedNode,currentNode,colors.RREQ}];
                end
            else
                success = true;
            end
        end
    end
end
end
end

```

```

        % Check for termination
        if(i >= size(myTable,1))
            if isempty(replyNodes)
                tryAgain = false;
            end
            break
        end
    end
end
requestDepth = depth-1;

if(success)
    tempDepth = depth;
    for reply = replyNodes'
        depth = tempDepth;
        replyTable =
floodReply(floodSrc,reply,colors.RREQ,colors.RREPL);
        myTable = [myTable;replyTable];
    end
end

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Flood Reply function
% Finds the return path based on the current table
% Returns a path in table form
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [replyTable] =
floodReply(floodReplySrc,floodReplyDest,colorLookFor,colorMake)
    % After successful flooding, send reply
    currentNode = floodReplyDest;
    depth = depth + 1;
    route2Dest = nodes(currentNode).routeTable.dest ==
dest;

    if(any(route2Dest))
        hopCnt =
nodes(currentNode).routeTable(route2Dest,:).hopCnt;
        if(iscell(hopCnt))
            hopCnt = cell2mat(hopCnt);
        end
    else
        hopCnt = 0;
    end
    replyTable =
table(depth,depth,floodReplyDest,floodReplyDest,colorMake);
    replyTable.Properties.VariableNames =
{'Depth','HopCnt','Node','From','Color'};
    visitedNodes = currentNode;
    while true

```

```

        depth = depth + 1;
        hopCnt = hopCnt + 1;
        nextNode =
myTable.From(find(myTable.Node==currentNode & myTable.Color ==
colorLookFor));
        if(numel(nextNode) > 1)
            nextNode = chooseClosest(nextNode,
currentNode);
        end
        visitedNodes = [visitedNodes,currentNode];
        replyTable =
[replyTable;{depth,hopCnt,nextNode,currentNode,colorMake}];
        currentNode = nextNode;
        if(any(find(visitedNodes==currentNode)) ||
currentNode == floodReplySrc)
            break
        end
    end
end
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Timer function
% Colors nodes at the global depth
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [] = setColor(obj,event)

% Set color update
% Set highlight path update
% Add new route entry to table
for node = find(myTable.Depth==depth)'
    nodes(myTable.Node(node)).color =
myTable.Color(node);
    nodes(myTable.Node(node)).pathFrom = ...

[nodes(myTable.Node(node)).pathFrom,myTable.From(node)];
    if(depth ~= 0 && myTable.Node(node) ~=
myTable.From(node))
        if(myTable.Color(node) == colors.RREQ)
            nodes(myTable.Node(node)).routeTable =
nodes(myTable.Node(node)).addToRouteTable(...
                src,...
                myTable.From(node),...
                depth,...
                nodes(src).seqNum,...
                1);
            elseif(myTable.Color(node) ==
colors.RREPL)
                nodes(myTable.Node(node)).routeTable =
nodes(myTable.Node(node)).addToRouteTable(...
                    dest,...

```

```

myTable.From(node), ...
myTable.HopCnt(node), ...
myTable.From(node), ...
nodes(dest).seqNum, ...
1);
end
end
end

% Increase depth for next timer iteration
depth = depth + 1;

% Update views to show changes
updateTableData()
updateGraphView()

% If we're beyond the max depth of the table,
% Clean up timer and reset UI
if(depth > max(myTable.Depth)+1)
stop(colorTimer)
delete(colorTimer)
for node = 1:numel(nodes)
nodes(node).color = 'black';
nodes(node).pathFrom = [];
end
updateGraphView()
depth = 0;

% If we need to re-send now that we have a
path, try again
if(tryAgain)
sendPacket(src,dest);
end
end

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Update (non-timer, non-GUI) function
% Performs the iterative updates of the
% color function, but without displaying
% it on the GUI
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [] = quickUpdate()

depth = 0;
while(depth <= max(myTable.Depth))

% Add new route entry to table
for i = find(myTable.Depth==depth) '

```

```

                                if(depth ~= 0 && myTable.Node(i) ~=
myTable.From(i))
                                if(myTable.Color(i) == colors.RREQ)
                                    nodes(myTable.Node(i)).routeTable
= nodes(myTable.Node(i)).addToRouteTable(...
                                                src,...
myTable.From(i),...
                                                depth,...
nodes(src).seqNum,...
                                                1);
                                elseif(myTable.Color(i) ==
colors.RREPL)
                                    nodes(myTable.Node(i)).routeTable
= nodes(myTable.Node(i)).addToRouteTable(...
                                                dest,...
myTable.From(i),...
myTable.HopCnt(i),...
nodes(dest).seqNum,...
                                                1);
                                end
                            end
                        end

                        % Increase depth for next timer iteration
                        depth = depth + 1;
                    end

                    % If we need to re-send now that we have a path,
try again
                    if(tryAgain)
                        nextTable = sendPacket(src,dest,quickMode);
                        myTable = [myTable;nextTable];
                    end
                end
            end

        end
    end
end

```