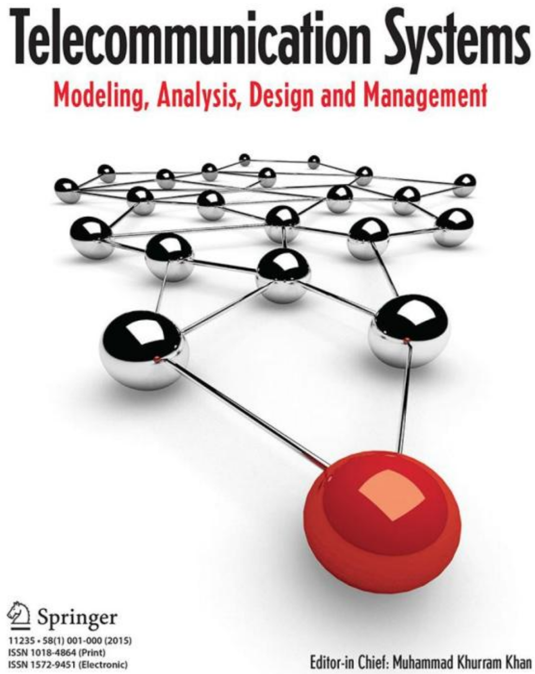

A survey on QoS routing protocols in Vehicular Ad Hoc Network (VANET)

Fatima Belamri[1] · Samra Boulfekhar[1] · Djamil Aissani[1]

Accepted: 27 April 2021

Abstract

Vehicular Ad Hoc Network (VANET) is an emerging new technology and a promising approach for Intelligent Transportation Systems (ITS) domain. Many researchers focused on the creation of reliable, scalable and efficient routing protocols for VANET and improve their Quality of Service (QoS). Communication among vehicular nodes which enable drivers to take appropriate decision needs a high reliability, therefore the design of a routing protocol that ensures a certain level of QoS, represents one of the most important challenges of the vehicular networks, because VANET are characterized by specific features, such as restricted mobility, high node speed and a very dynamic topology. keeping in view of the above, this paper provides a detailed description of various existing QoS routing protocols in literature with an aim to classify them. Based on the optimization methods used to improve routing protocols in VANET, we have surveyed and classified the routing protocols into two classes, QoS routing protocols not based on meta-heuristics and QoS routing protocols based on meta-heuristics.

Keywords Vehicular Ad-Hoc Network · Routing protocols · QoS · Meta-heuristics · Optimization

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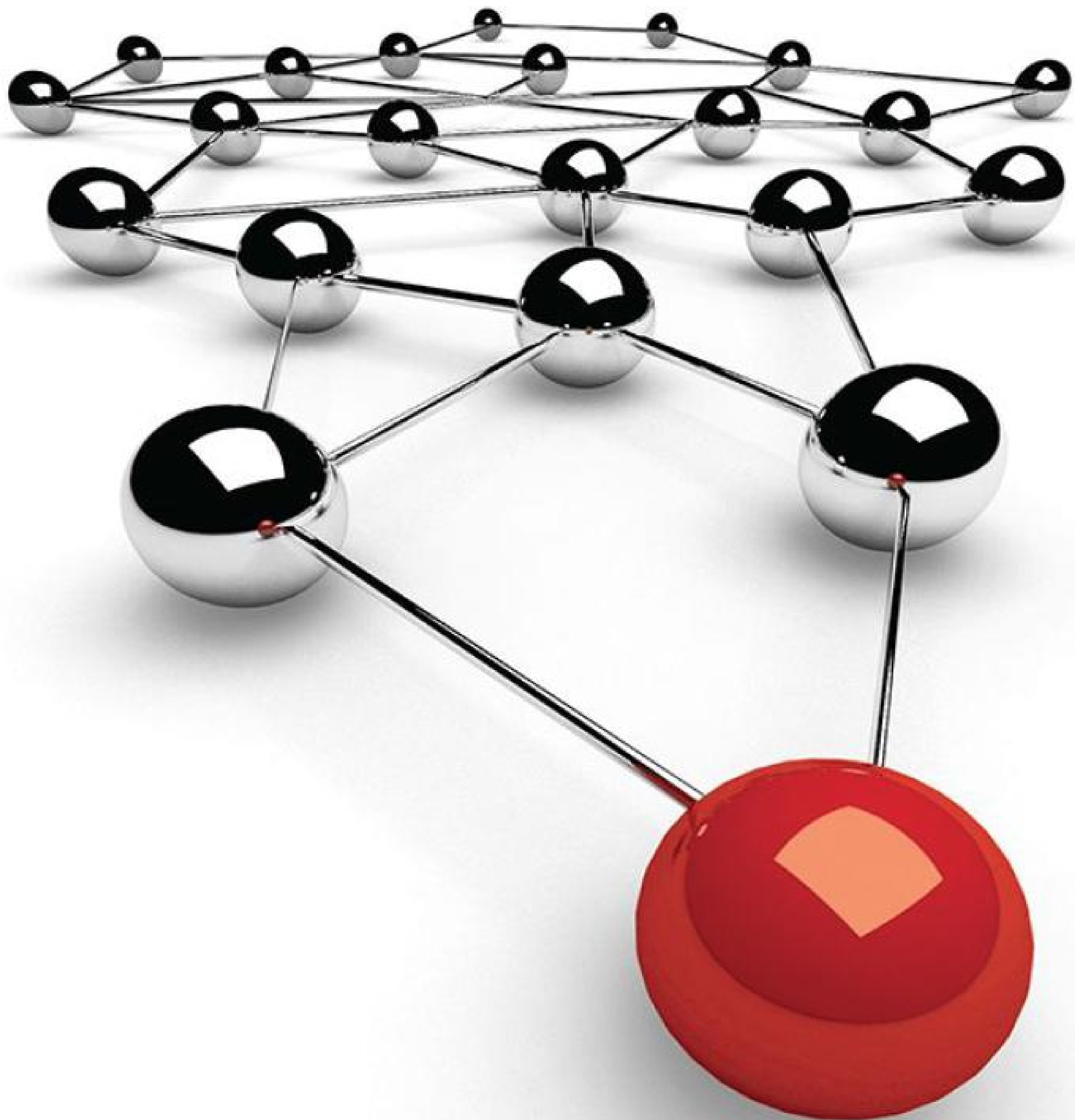

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Keywords Vehicular Ad-Hoc Network · Routing protocols · QoS · Meta-heuristics · Optimization

Abbreviations

A-AODV	Ant Colony Optimization-AODV
ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
ACO-EG	Ant Colony Optimization Routing Algorithm Based on Evolving Graph
ADSR	Ant Colony Based Dynamic Source Routing For VANET
AODV	AD-hoc On-Demand Distance Vector
AQRV	Adaptive QoS based Routing for Vehicle network
ARDt	Average Routing Discovery time
ARRr	Average Routing Replay ratio
B-ants	Backward ants
BSC-GA	Genetic Algorithm-Based Sparse Coverage Over Urban VANETs
BSC	Budgeted Sparse Coverage
CALAR-DD	Cache Agent based Location Aided Routing using Distance and Direction
CB-QoS-VANET	Multiconstrained QoS-Compliant Routing Scheme for Highway-Based Vehicular Networks
CJBR	Connected Junction-Based routing Protocol
COMES	COoperative service-based MEssage Sharing
CP	Connectivity Probability
DE	Differential Evolution
DFS	Depth First Search
DSRC	Dedicated Short Range Communication
DSR	Dynamic Source Routing
DTN	Delay Tolerant Network
DTRP	QoS Support in Delay Tolerant Vehicular AdHoc Networks
E2ED	End-to-End Delay
EDD	Expected Disconnection Degree
EG	Evolving Graph

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EG-RAODV	Evolving Graph-Based Reliable Routing Scheme for VANETs
EIAC-ABCMR	Enhanced and Integrated Ant Colony-Artificial Bee Colony oriented Multicast Routing
Fants	Forward ants
G-NET	Genetic Network Protocol
GA	Genetic Algorithm
GABR	Genetic Algorithm Based QoS Perception
Geo-PSO	Geocast routing based on Particl Swarm optimization
GHR	Generic Geographical Heuristic Routing protocol
GPS	Geographic Position System
HC	Hop Cont
I-OLSR	Intelligent-OLSR
IBR	Intersection Based Routing
ICAIR	Improved Connectivity Aware Intersection based Routing protocol
idle time	Percentage idle time
IGAROT	Improved Genetic Algorithm-based Route Optimization Technique
ITS	Intelligent Transportation Systems
JTAEG	Journeys Traversal Algorithm on Evolving Graph
LF	Link failure
LMQ	Local QoS Models
M-OLSR	Modified Optimized Link State Routing Protocol
MABC	Micro-Artificial Bee Colony based multicast routing in vehicular ad hoc network
MAC	Media Access Control
MANET	Mobil Ad Hoc Network
MAS	Multi Agents System
M-DVRP	Multiobjective Dynamic Vehicle Routing Problem
MPLS	Multi-Protocol Label Switching
MPR	Multi-Point Relay
MQBV	Multicast QoS swarm Bee routing for Vehicular ad hoc networks
MRJ	Most Reliable Journey
MURU	Multi Hop Routing Protocol for Urban Vehicular Ad Hoc Networks
NHV	Next Hop Vehicle
NL	Network Load
NOL	Normalized Overhead Load
NRL	Normalized Routing Load
NSCPs	Number of Sent Control Packets
OFAODV	Optimized Fuzzy AODV
OLSR-SA	Optimization Techniques of Optimized Link State Routing Protocol in VANETs
P-GEDIR	Peripheral node based GEographic DIstance Routing
PDR	Packet Delivery Ratio
PLoss	Packet Loss
PSO-C-MADSDV	Destination-Sequenced Distance Vector Routing protocol(DSDV) based on the Particle Swarm Optimization (PSO) and the Multi-Agent System (MAS)
PSO-DREAM+SIFT	Particle Swarm Optimization based Routing Protocol for VANET
PSO	Particle Swarm Optimization
PSOR	Particle Swarm Optimization based Routing Method for Vehicular Ad hoc Network
QoS	Quality of Service
QoS-ACOMpVS	QoS-aware multi-path video streaming for ur-ban VANETs using ACO algorithm
QoS BeeVANET	QoS Swarm Bee Routing Protocol for VANET
RALAR	Genetic Optimized Location Aided Routing Protocol for VANET Based on Rectangular Estimation of Position
RBF	Radial Basis Function
RBN	Roadside Backbone Network
RPVSANN	Routing Protocol for Vehicular ad hoc networks using Simulated Annealing algorithm and Neural Networks
RREQ	Route Request
RReqr	Routing Request ratio
SA	Simulated Annealing
RSU	Road Side Unit
SAMQ	Situation-Aware QoS Routing Algorithm for Vehicular ad hoc networks
SAw	Situational Awareness
SMT	Steiner Minimum Tree
TCP	Transmission Control Protocol
TLRC	Traffic-light-aware Routing Protocol based on Street Connectivity for urban vehicular ad hoc networks
TS	Tabu Search
TS-PSO	Time Seed Based Solution Using Particle Swarm Optimization
V2I	Vehicle to Infrastructure communication
V2V	Vehicle to Vehicle communication
VANET	Vehicular Ad Hoc Network
VoEG	VANET-oriented Evolving Graph

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1 Introduction

Vehicular Ad Hoc Networks were created and developed in recent years in most of the world's cities. VANET adds information to the road network by including wireless communications between its components [1,2].

A vehicular network is a subclass of Mobile Ad Hoc Network (MANET), which is able to set up in an autonomous way, without the need to any infrastructure prepared in advance [3]. However, VANETs are not purely ad hoc networks, they can opportunistically communicate with infrastructure called Road side Unit (RSU). These latters offer an access to internet or local databases [4]. In VANET, vehicles act as a router to communicate between them, and use a variety of advanced wireless technologies such as Dedicated Short Range (DSRC) [2,5–7]. These DSRC are dedicated to Vehicle to Vehicle communication (V2V), Vehicle to Infrastructure communication (V2I), and Hybrid Communication [8–10] as shown in Figure 1.

Such networks are used in transportation applications, safety applications, comfort or user applications [11,12]. Due to the delay requirements, safety applications demand usually direct vehicle-to-vehicle communication. However, comfort applications which improve passenger comfort require an optimized route to a destination [1,2].

VANET is characterized by high mobility and an extreme dynamic topology. Nodes tend to enter and exit the network frequently. Therefore, frequent path interruptions occur. In a such network as VANET, routing packets from source to destination vehicle is more challenging [13]. The frequent path interference during the routing process cause dysfunction of supported applications and decrease performances of the network. Consequently, routing algorithms should be efficient and should adapt to vehicular network characteristics. Moreover, it is important to design routing protocols which offer the best result to ensure QoS. In this context, QoS means find an optimal route that allows the use of network resources in an optimal way to send data between nodes successfully and with high reliability.

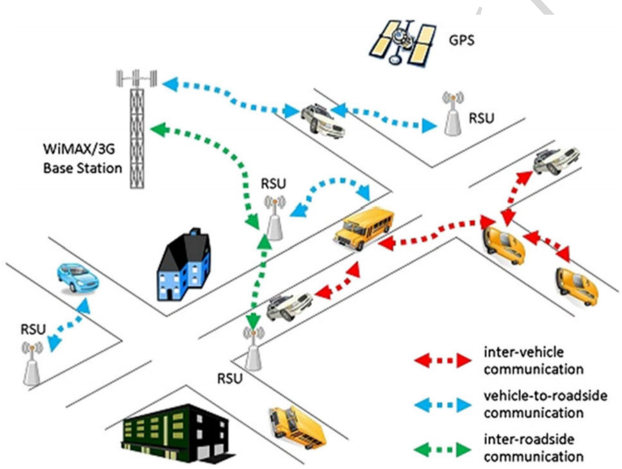

Fig. 1 VANET architecture

QoS [14] is considered as one of the most challenging tasks in VANET. Because of the network topology changing, QoS parameters are difficult to ensure, and the available state information for routing are inaccurate [15]. To achieve QoS, researchers considered different layers of the VANET protocol stack, and mainly focused on dealing with QoS by devoting great efforts in order to develop a robust routing protocols for vehicular networks and optimize QoS in VANET. The main purpose of QoS routing protocol is to offer guarantees about the level of performances provided [16]. However, QoS metrics for VANET should be well-defined [17,18].

For many reasons, such as finding an optimal set of routs or the best route, determining the most cost-efficient route, routing in vehicle networks can be reduced to a problem of optimization and finding the best solution. Optimization is about making a design, or decision as fully perfect, functional or effective as possible. In other words, finding an alternative that offers the most cost effective or highest achievable performances within the given limitations, by increasing the desired factors and reducing undesired ones [19]. Searching for feasible routes subject to multiple QoS constraints is in general an NP-hard problem [20], which cannot be solved in a polynomial time region. Consequently, the need to reach the optimal solution at a reasonable cost leads researchers to use approximate methods called meta heuristics [21].

Meta-heuristics are nature inspired algorithms [22–24]. They are considered to be an algorithmic structure, which are generally applied to a variety of optimization problems with some modifications for adapting to the given problem. They have been applied to almost all areas of optimization, design, scheduling and planning, data mining, machine intelligence, and many others [25]. Meta-heuristics explore the search space to find a solution good enough, they are usually approximate and allow an easy parallel implementation.

Sins QoS routing in VANET is an NP-hard problem [26], meta-heuristic approaches like (Ant Colony Optimisation, Artificial Bee Colony, simulated annealing, etc.) represent one of the appropriate approaches which provide a suitable method to solve it [27].

In this paper we survey some routing protocols which use different algorithms and techniques to optimize and achieve an efficient routing in VANET. Focusing on the different techniques and methods used to improve routing in VANET networks, we classify the detailed QoS routing protocols by highlighting the optimization algorithms and techniques used to improve the routing protocols performances.

The proposed classification contains two classes which are QoS routing protocols not based on meta-heuristics and QoS routing protocols based on meta-heuristics. These latter are able to provide an excellent solution to routing problems.

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The motivation of this work came from the lack of a reference classifying the VANET-related QoS routing within the notion of optimisation method used to improve the QoS routing protocols in VANET. further it allows to have a vision on a set of tools and techniques used to solve optimisation problems related to QoS-routing in VANET.

The remainder of this paper is organized as follows: Sect. 2 introduces QoS in VANET. Section 3 provides some related works. Section 4 presents the QoS routing protocols classification proposed for VANET and Sect. 5 gives a comparison between presented QoS routing protocols. In Sect. 6 we present some challenges and research directions. Finally, Sect. 7 concludes the paper.

2 QoS in VANET networks

QoS at the network level refers to its ability to deliver a guaranteed level of service to applications [28]. QoS is measured according to the supported applications in VANET networks. Several constraints can be distinguished in VANET applications such as: road safety, comfort applications, and traffic monitoring applications [1,29]. The main constraint for road safety and traffic monitoring applications is the real time information validity. However, comfort applications require continuous connectivity. The QoS solution for VANETs requires the cooperation and coordination of various network components such as: a QoS routing protocol, a resource reservation scheme, and a Media Access Control (MAC) layer [30]. The key technology for providing QoS is at network layer, which is achievable through QoS routing protocols [31,32], so optimization of routing protocols is one of the criteria for improving the QoS in VANET. The principal objective of the latter is ensuring that a network has capacity to provide the expected results [33,34].

2.1 QoS routing in VANET

QoS routing in an Ad Hoc network is difficult because the network topology may change constantly, and the available state information for routing is by nature imprecise [35]. QoS routing requires not only to find a route from a source to a destination, but a route that satisfies QoS requirements [36]. To support QoS, a service can be characterized by a set of measurable pre-specified service requirements, such as maximum delay, minimum bandwidth, and maximum packet loss rate. Hence, choosing the best available path is an important decision that directly affects QoS parameters. Due to frequent changes in VANET network topology, traditional routing protocols commonly used in cable networks can pose many problems for VANET such as intermittent connectivity caused by its unique features, like high mobility, poor link quality, and inadequate transporting distance [37]. To overcome these problems, the researchers have taken into account the different challenges of VANET networks, and propose several QoS routing protocols that can support reliability and security requirements in VANET [38–41].

2.2 QoS routing parameters used for optimizing the routing protocol

In this subsection we introduce the basic QoS parameters used in order to optimize routing protocols and improve their performances. The QoS routing parameters are used to choose the best upcoming neighbor node or an optimal path between source and destination node.

- **Delay:** The delay [42] is the most important parameter considered in routing protocols. It refers to the access delay, transmission delay, propagation delay, and processing delay. Access delay called queuing delay, is the average time from the moment a node attempts to send a packet until the time of actual transmission. Transmission delay is the time to send a packet online. The propagation delay is the average transportation time between the sending and receiving a packet. The processing delay is the time that a message has to wait in the destination queue until it is verified by the destination and finally delivered to the destination [37,43].
- **Distance:** It refers to the geographical distance from the next forwarding neighboring node to the current node. Distance is the most widely used basic parameter [44].
- **Link reliability:** Communication links are highly vulnerable to disconnection in high dynamic networks such as VANET. Hence, the routing reliability of these networks needs to be paid special attention. Link reliability refers to the probability that a direct communication link between two nodes will stay continuously available over a specified time period [45,46].
- **Number of hops or Hop Count (HC):** Number of hops or Hop Count represents the number of links over which resources are allocated on the path between source and destination nodes [47].
- **Security:** Secured QoS routing algorithms represent a fundamental part of wireless networks that aim to provide services with QoS and security guarantees. Security attacks [48] pose significant challenges in terms of secure routing [49] and the QoS of the entire network could be degraded by an attack on the routing process, and manipulation of the routing control messages. For this reason, security needs to be considered in routing optimization.
- **Energy:** This parameter represents the energy in a node at the beginning of the network deployment. energy-aware routing protocol purpose is to maximize the network lifetime [50,51].

Neighbor Nodes: A node has a set of one-hop nodes in its transmission range. These one-hop nodes are called neighbor nodes.They update their information, like current location, current time, speed and direction by exchanging the Hello message. In dynamic mobile ad hoc network, a node and its neighbors are moving randomly and changing their positions frequently [52]. Hence, the quality of neighbors is an important parameter to consider to enhance routing protocols performances.

Mobility: The high mobility of nodes in wireless mobile network such as VANETs, generates frequent topology changes and network fragmentation [53]. For these reasons, routing packets through the network is a challenging task. The routing performances can be effectively enhanced by taking into account the mobility [54]. It has been observed that the mobility models utilized in the ad hoc network simulations greatly influence the effectiveness of the routing algorithms [55].

Street connectivity: Street connectivity [56] refers to the directness of links and density of connections (i.e., intersections) in street networks. A neighborhood with a highly connected street network has streets with many short links, numerous intersections, and few dead-ends [57]. Street connectivity is an important parameter to design an efficient routing protocol in vehicular ad hoc network.

2.3 QoS evaluation metrics

In addition to the basic metrics used to evaluate routing protocols, such as End-to-End Delay (E2ED), Packet Delivery Ratio (PDR), Packet Loss (PLoss), etc). In this subsection we present some routing metrics considered to evaluate VANET QoS routing protocols detailed in Sect. 4.

End-to-End Delay (E2ED): refers to the required time it takes a packet to reach destination after being transmitted from a source [58]. Delay increases with network congestion, and it negatively affects the QoS.

Packet Delivery Ratio (PDR): It is expressed as the ratio between the number of data-packets successfully delivered to the destination, and the number of packets transmitted by the source [59].

Packet Loss (PLoss): refers to the failure of one or more transmitted packets to arrive at their destination [28], it is caused by errors in data transmission or network congestion. Packet loss is measured as a percentage of packets lost with respect to packets sent.

Bandwidth: bandwidth quantifies the data rate at which a network link, or a network path can transfer packets [60].

Throughput: refers to the average number of successfully delivered bits per time slot over a communication channel. The factors affecting the throughput are the node mobility, number of hops, and transmission range [61,62].

Jitter: It refers to the difference between maximum end-to-end delay and minimum end-to-end delay (the variance of the delay). It is caused by the difference in consecutive packet queuing delays [28].

Overhead: routing and data packets have to share the same network bandwidth most of the times, and hence, routing packets are considered to be an overhead in the network [63].

Connectivity Probability (CP): The connectivity probability represents the measure that can capture the impact of the node movement on the network connectivity. It can capture the important properties of a network when position of nodes and states of the links changes over time [64].

Network load (NL): It is defined as the percentage of vehicles receiving a duplicate copy of a message and total hello message required for forwarding of a packet [65].

Normalized Routing Load (NRL): It represents the ratio routing packets transmitted per data packet delivered at the destination, each hop is counted separately [53].

Normalized overhead Load (NOL): This parameter represents the ratio between the total numbers of routing packets and the total number of successfully delivered data packets. NOL provides an indication of the extra bandwidth consumed due to routing packets [66].

Average Routing Replay ratio (ARRr): It refers to the average ratio of route reply packets sent from all nodes in the network if they are destinations of route requests over all route requests generated by the all source node [67].

Average Routing Discovery time (ARDt): It represents The average time between sending a route request to a specific destination and receiving a route reply from the destination [67].

Routing Request ratio (RReq): It expresses the ratio of the total transmitted routing requests to the total successfully received routing packets at the destination vehicle [45].

Link Failure (LF): It refers to the average number of link failures during the routing process. this metric shows the efficiency of the routing protocol in avoiding link failures [45].

Percentage idle time (idle time): It refers to the average of the idle time sensed by a node measured in 1s. A node senses the channel as idle when it is not transmitting nor receiving a packet [68].

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3 Related works

There exist few surveys papers that discuss QoS based routing protocols in VANET. In this section, we discuss some of these survey papers published over the last 10 years.

The surveys presented by Bernsen and Manivannan [69, 70] present and provide a performance evaluation of few protocols for vehicular network which try to support QoS. Authors classified and characterized the existing QoS routing protocols. This classification and characterization gives a clear picture of the strengths and weaknesses of existing protocols. In [70], authors provided an extension of the survey [69], and treats only unicast routing protocols which are not current.

Bitam et al. [39] presented a taxonomy of bio-inspired routing algorithms dedicated for VANETs. They identified three bio-inspired categories for routing in VANETs: Evolutionary algorithms, Swarm intelligence algorithms, and other biologically inspired algorithms. For each category, they classified, evaluated and compared some existing routing protocols in VANET. They also identify the key features, strengths, and weaknesses of these protocols. Moreover, they propose a unified formal model of the bio-inspired multi-modular approaches applied to VANET routing.

Kaur et al. [40] reviewed nine QoS routing protocols and classified them. This classification has been done on the basis of various parameters, such as reliability, link lifetime, connectivity probability and stability. They proposed four classes. Also authors, provided a comparison table of all surveyed protocols. Unfortunately, this paper provides brief description of the various presented protocols and they did not presented any QoS offered by these protocols. Moreover, referring to the definition of classes, we notice that each class can be included in other one.

Mchergui et al. [71] Proposed a survey of broadcasting in vehicular networks and discussion of different performance and QoS related to broadcasting issues. Authors provides a comparative study of QoS aware broadcasting protocols and classified them according to different taxonomies. This survey specified QoS requirements and performance metrics of VANET services. Furthermore, this survey discusses QoS aware broadcasting as a challenging problem regrading VANET characteristics.

Zeeshan et al. [41] made a comparison of some QoS routing protocol in VANET and defined their applications. In their survey, authors highlighted the usage of establishing both V2V and V2I communication in the real world and the applicability of each protocol in different scenarios. They also discussed the various approaches used to ensure QoS in VANETs. Moreover, two comparison tables are provided in this paper. Finally, authors discussed the open research issues that need to be addressed for improving the performance of routing protocols for VANETs. Regrettably, authors did not give any classification to the presented protocols in this survey.

Oche et al. [72] have detailed twenty QoS routing protocols. Authors examined the protocols based on their ability to support ITS infotainment services. They also compared different solutions, providing a taxonomy of the surveyed QoS-aware routing protocols based on their multi constraint (i.e., additive, concave and multiplicative) path choice metrics. Then, authors highlighted open research issues in VANETs QoS at the network layer, paving the way to new research direction on QoS-aware routing. This survey provides a very useful comparison table of QoS routing protocols reviewed.

Hotkar and Biradar [73] reviewed the existing QoS routing protocols based on the two important parameters: link efficiency and link stability. They also presented modeling and prediction techniques for Realistic Routing and concluded that most of the conventional QoS routing approaches in VANET focus on either link efficiency or stability. However, authors didn't provide any comparison of surveyed protocols.

Tripp-Barba et al. [74] reviewed unicast routing protocols designed for VANETs using different metrics to improve vehicular communications. They presented the most frequently used metrics in the different proposals and their application scenarios and provided a description of these multimetric routing protocols. This survey aims to know how important metric selection is in routing protocols for VANETs, and how multimetric uses improves path selection. They concluded that link stability, position, density, and speed are the more promising metrics in routing protocols for VANETs because of geographical constraints.

Senouci et al. [75] provided a review of clustering algorithms in VANETs. They presented background material regarding the clustering process and proposed a new taxonomy that categorizes clustering algorithms in VANETs based on different design aspects. In this survey an analysis and comparison of the algorithms in each category is provided according to various comparison metrics. Also, authors highlighted the main challenges for each category and discuss some open research issues.

Gawas and Govekar [76] presented a review of the classification of existing QoS routing protocols, cross-layer design approach and classification, and various performances parameters used in QoS routing protocols in Vehicular network. Moreover, they discussed and presented a state of art of challenges and issues of QoS routing in VANETs.

Burušić et al. [77] presented an overview of bio-inspired routing protocols and methods that are handling issues of VANET efficiently by applying several approaches such as clustering, using hybrid or MANET protocols or merging two bio-inspired routing protocols. Moreover, they classified the routing protocols according to this approaches.

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Table 1 Summary of previous surveys on QoS routing in VANET

Year	Authors	Literature	Contribution
2008	Bernsen et al.	1-Routing protocols for vehicular ad hoc networks that ensure quality of service	Qualitative Comparison of QoS VANET Routing Protocols
2009		2-Uicast Routing Protocols for Vehicular Ad Hoc Networks: A Critical Comparison and Classification	Qualitative performance evaluation of routing in VANET protocol
2014	Bitam et al.	Bio-Inspired Routing Algorithms Survey for Vehicular Ad Hoc Networks.	Taxonomy of bio-inspired routing algorithms dedicated for VANETs Comparison of Bio-inspired algorithms
2017	Kaur et al.	Qos Aware Routing in Vehicular Ad hoc Networks: A Survey	Classification of QoS routing protocols with respect of various parameters Comparison of all surveyed protocols
2017	Mchergui et al.	A survey and comparative study of QoS aware broadcasting techniques in VANET	Classification according to different taxonomies Deep discussion of different performance and QoS related to broadcasting issues
2018	Zeeshan et al.	QoS in Vehicular Ad Hoc Networks: A Survey	Comparison of QoS routing protocol in VANET and definition of their applications Discussion of the challenging factors in VANET
2018	Oche et al.	VANETs QoS-based routing protocols based on multi-constrained ability to support ITS infotainment services	A new taxonomy for QoS routing in VANETs Discussion of open research issues in VANETs
2019	Hotkar and Biradar	A review on existing QoS routing protocols in VANET based on link efficiency and link stability	Presentation of modeling and prediction techniques for Realistic Routing
2019	Tripp-Badbra et al.	Survey on routing protocols for vehicular ad hoc networks based on multimetric	Classification of routing protocols based on metrics used to improve path selection
2020	Senouci et al.	Survey on vehicular ad hoc networks clustering algorithms: Overview, taxonomy, challenges, and open research issues	New taxonomy for clustering algorithms Analysis and comparison based on various metrics Discussion of challenges, and open
2020	Gawas and Govekar	State-of-Art and Open Issues of Cross-Layer Design and QoS Routing in Internet of Vehicles	Provides a review of the classification of existing QoS routing protocols Comparison discussion, issues, and challenges routing protocols for VANET
2020	Burušić et al	Review and Analysis of Bio-Inspired Routing Protocols in VANETs	New taxonomy for Bio-Inspired routing algorithms
2021	Kherzi and Zeinali	A Review on Highway Routing Protocols in Vehicular Ad Hoc Network	New taxonomy for Highway routing algorithms

Khezri and Zeinali [78] proposed a review on highway routing protocols in VANET. In this survey, authors classified the routing protocols into highway routing and urban routing protocols. Then, they evaluated and studied all highway routing protocols. None of the above surveys has highlighted the concept of optimization algorithms and methods, like meta-heuristics, game theory, graph theory and many other techniques used to optimize QoS routing protocols for VANET. These algorithms and techniques are a powerful tool which allows to design efficient routing protocols and enhance their performances. This motivated us to survey and classify forty one existing QoS routing protocols in VANET.

Table 1 summarize the previous survey papers, and highlights their main contributions.

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4 QoS routing protocols classification proposed for VANET

The main purpose of our paper is to give a classification to the QoS routing protocols by highlighting the optimization algorithms and techniques used to improve the routing protocols performances and offer a better QoS.

We present below QoS routing protocols classification proposed for VANET.

Figure 2, presents QoS routing protocols classification proposed for VANETs. As shown in this figure, the routing protocols fall within two categories:

– QoS routing protocols not based on meta-heuristics.
– QoS routing protocols based on meta-heuristics.

Here is the classification detailed as following:

4.1 QoS routing protocols not based on meta-heuristics

In this section, we present a number of QoS routing protocols that are not based on meta-heuristics, but use a different techniques to improve the performances of these protocols, such as graph theory,game theory, traffic light, etc.

– *Multi-Hop Routing Protocol for Urban Vehicular Ad Hoc Networks (MURU)*
Mo et al. proposed Multi-Hop Routing Protocol for Urban Vehicular Ad Hoc Networks (MURU) [79]. It is considered among the first QoS routing protocols proposed for VANET. Authors, used a novel metric called Expected Disconnection Degree (EDD) to estimate the quality of path between source and destination. This metric is based on factors of the road, such as: position, velocity and trajectory of the vehicles. The main purpose of MURU is to minimize the risk of broken links, i.e., it aims to minimize path failure probability. MURU protocol is an on-demand protocol designed and developed based on the Ad-hoc On-Demand Distanc Vector (AODV) protocol. Source node sends a Route REQuest (RREQ) message, each RREQ records the cumulative value of EDD. Then each node calculates a link quality estimation and updates the current path value. Finally, path which recordes the lowest EDD value will be chosen as the optimal one. In summary, MURU protocol operates in four steps: trajectory-constrained rout request, path evaluation, calculating EDD. In order to control the overhead, MURU protocol uses a self pruning mechanism.
MURU is distributed protocol which doesn't need infrastructure. It improves QoS by providing a robust paths which reduce the end to end delay, overhead, and also it offers better packet delivery ratio. The proposed protocol is more suitable for safety application. However, MURU takes into account only the local information during routing decision making. So, MURU may suffer from the local optimum.

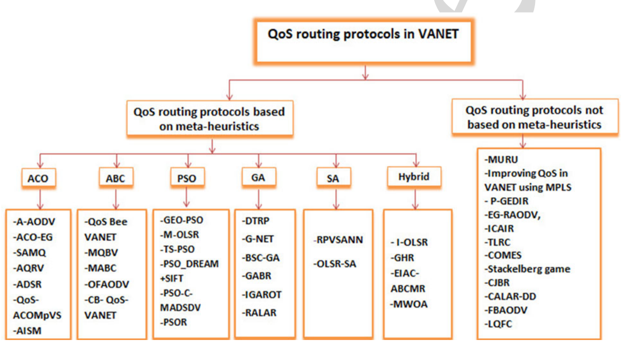

Fig. 2 Classification of QoS Routing Protocols in VANET

– *Multi-Protocol Label Switching (MPLS)* Fathy et al. proposed the use of Multi-Protocol Label Switching (MPLS) in a road network in order to improve the QoS of VANET network. [80].
Because of the unreliability of using MPLS in wireless Vehicles to Vehicle (V2V) communication, authors assumed that each vehicle is covered by a base station. Every base station has its own domain of service. these base stations are connected with wired network called Roadside Backbone Network (RBN). The MPLS domain is created by a set of RBN in a wired domain. According to the proposed protocol, the vehicles send data to the nearest base station. Then, data are routed by the MPLS. Due to the AODV features, such as: reducing the network load and requiring less space to store routing information and also consuming less bandwidth, authors chose it to be the wireless routing protocol to communicate among vehicle neighbors.
The strength of the proposed protocol combines the use of MPLS domain and sending data through the wired infrastructure. This allows to gain a higher QoS than V2V ad hoc communication and it improves QoS in terms of packet loss, end-to end delay, and throughput in urban area. Unfortunately, the proposed method requires communication via infrastructures which is a very expensive method.

– *Peripheral node based GEographic DIstance Routing (P-GEDIR)*
Raw and Das proposed Peripheral node based GEographic DIstance Routing (P-GEDIR) [52]. It is a position-based protocol and it aims to improve next hop selection. Authors designed a mathematical model for

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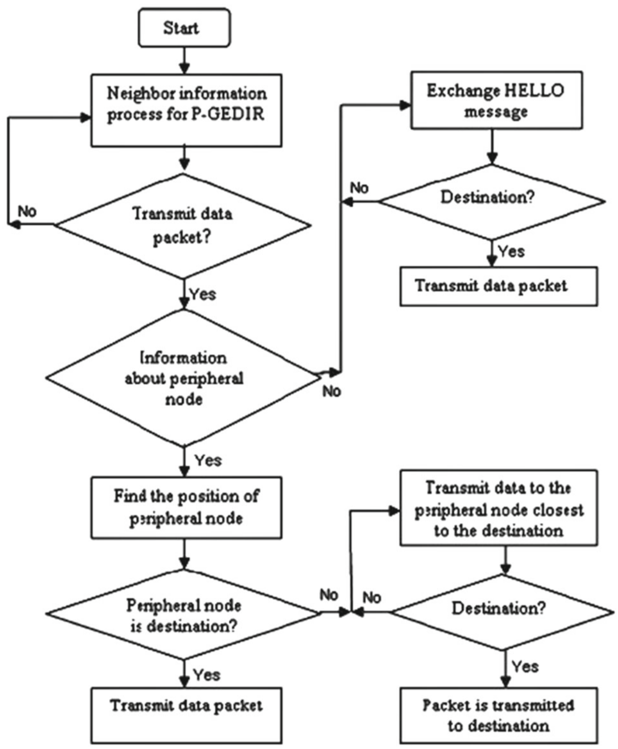

Fig. 3 Flow diagram of P-GEDIR protocol

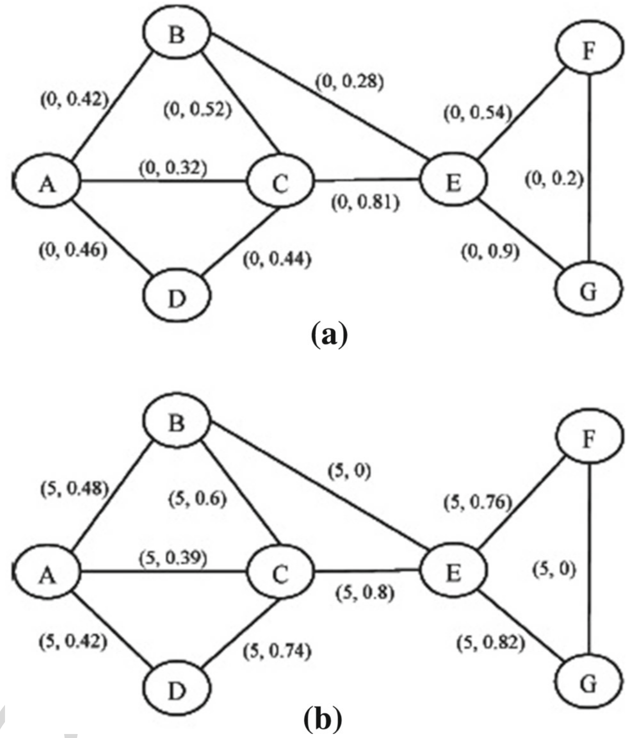

Fig. 4 Proposed VoEG model at **a** t = 0 s and **b** t = 5 s

this protocol to determine the expected number of successful hops (probability that there are n links available between source and destination), the expected distance to the next-hop node and the expected one-hop progress. In order to minimize number of hops between source and destination, P-GEDIR uses the concept of peripheral node. Peripheral node is defined as a border node, whose distance from source node is equal to the maximum transmission range R of the source node. They are used to avoid sending packets to an internal node within the transmission range of the source node and also, they are used to select the closest node to the destination in order to reduce the forwarding region size and to select a smaller number of Next Hop Vehicles (NHV). The P-GEDIR method is summarized through data flow diagram in Fig. 3.

P-GEDIR improves data delivery and achieves a high reliability. It ensures an efficient data delivery. The proposed protocol supports real-time application such as security-related applications. Unfortunately, due to the high vehicle speed in vehicular traffic environment, this protocol do not provide the quality of links when it is selecting the next-hop. Because, the border vehicles have higher probability to go out of range transmission during forwarding, so the packet loss increases.

– *An Evolving Graph-Based Reliable Routing Scheme for VANETs (EG-RAODV)*

In [45], Eiza et al. proposed the first reliable routing scheme based on Evolving Graph for VANETs named An Evolving Graph-Based Reliable Routing Scheme for VANETs (EG-RAODV). In order to ensure the QoS they developed VANET-oriented Evolving Graph (VoEG) model. VoEG model captures the evolutionary characteristics of the network topology, these characteristics are used to model the communication graph in a highway. Then, authors, developed a new EG-Dijkstra algorithm to find the Most Reliable Journey (MRJ) in the proposed VoEG. Also, they modeled link reliability by the mathematical distribution of the vehicle movements and their speed. Finally, they defined this link reliability as a probability that a direct communication link between two vehicles will stay continuously available over a specified time period. Figure 4 illustrates an example of the VoEG on a highway at two time instants: t = 0 s and t = 5 s.

The proposed EG-RAODV provides reliable routes by achieving the smallest number of link failures. It preserves bandwidth and reduces the overhead , thus meet QoS requirements of multimedia and real-time application. EG-RAODV protocol is compared with AODV and PBR. These latter are not relevant protocols. Hence, EG-

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RAODV protocol should be compared to more recent protocols in order to evaluate its performances.

– *Connectivity Aware Intersection based Routing protocol (ICAIR)*
Priyanga and Sundararajan proposed an Improved Connectivity Aware Intersection based Routing protocol (ICAIR) [81]. It is a geographical routing protocol which aims to establish a robust route between source vehicle and destination with higher probability connectivity. Thus, the intersections are selected dynamically, and forwarding strategy between two intersections is on prediction-based greedy mode. Finally, when route failure occurs, ICAIR uses a recovery strategy which is different from the original one. This difference lies in the fact that the vehicle transporting the packet carries it along the selected road segment and forward it when it moves into another vehicle's communication range.
ICAIR outperforms GPSR protocol which is considered as one of the most important geographic routing algorithm of VANET in terms of packet delivery ratio and average transmission delay. The strength of the proposed protocol stands out for its ability to provide robust path. However, to analyze performances of ICAIR, authors used a network which is composed from five to twenty five vehicles, thus, the behavior of this protocol in a dense network is unknown. Consequently, the scalability of the proposed protocol is not checked.

Algorithm 1 TLRC

Notations:
V_s: The source vehicle.
V_d: The destination vehicle.
$Stree_p$: The street through which packet p is delivered
len_2: The length of low density area of the street.
$P_{con}(k)$: The street connectivity of k^{th} street.

```
for each packet sent by V_s do
    if V_d is in Street_p then
        Greedily forward packet p to V_d.
    else if packet p is in the street between two intersections then
        Greedily forward the packet p to the intersection closer to V_d.
    else if packet p arrives at the intersection of Street_p then
        Create the candidate set for next street selection.
        Divide the street based on density and calculate len_2.
        Calculate P_con(k) and select the next street with the highest P_con(k) value.
    end if
end for
```

Fig. 5 TLRC algorithm

– *A Traffic-light-aware Routing Protocol based on Street Connectivity for urban vehicular ad hoc networks (TLRC)*
In [82], Ding et al. proposed a street-centric protocol called A Traffic-light-aware Routing Protocol based on Street Connectivity for urban vehicular ad hoc networks (TLRC). Firstly, authors explore the effect of traffic lights on vehicle distribution in a street, then they calculate street connectivity based on the distribution and density of vehicles in the middle area of a street in order to determine the next street at the intersection . Once the next street is selected, an opportunistic greedy strategy is used to forward packets between the two involved intersections.This process is illustrated in Fig. 5.
TLRC can avoid selecting a street with weak or disconnected links in the middle area but with many vehicles gathered at end sides by selecting a higher connectivity street as next street. The proposed protocol improves QoS in terms of end to end delay and packet delivery ration. When the packet encounters a network partition, it adopts a carry-and-forward strategy, the vehicle has to keep the packet until finding an appropriate neighbor vehicle or reaching an intersection. That allows to support a real time application.

– *Coalition Formation for Cooperative Service-based Message Sharing in Vehicular Ad Hoc Networks (COMES)*
In [83], authors proposed a distributed reliable message delivery problem in VANET named COperative Service-based Message Sharing in Vehicular Ad Hoc Networks (COMES). Figure 6 represents an example of service message sharing.
Authors modeled this problem as a coalition formation game among nodes. Nodes associate with a coalition based on the type of service message they process.In this model service-messages are distinguished from one another by their types. The nodes process different types of service messages and form a coalition based on the type of messages they are processing at that time. some nodes within a coalition could work as a relay, which was modeled as a network formation game to select exactly one relay among a group of potential relay nodes. This helps

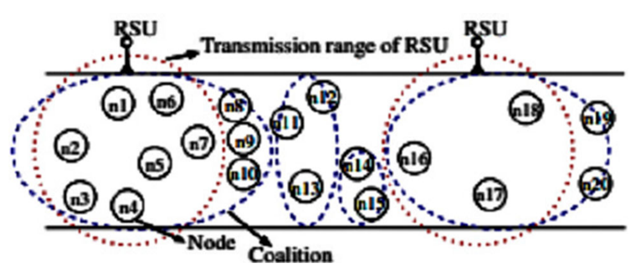

Fig. 6 Example of service message sharing

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nodes to improve their received incentives in a coalition by reducing the effect of the intermittent connectivity problem in VANETs. The strength of the proposed protocol lies in its ability to improve the packet reception rate and reduce transmission delay and also, it provides a reliable delivery messages. COMES improve the efficiency of the network and it is suitable to messaging application. However, the proposed protocol is not evaluated in real vehicular environment.

– *A Stackelberg game for street-centric QoS-OLSR protocol in urban Vehicular Ad Hoc Networks (Stackelberg game)*
In order to address the routing problem encountered when the OLSR protocol is used with the presence of passive malicious nodes in urban VANETs network, kadadha et al. proposed a multi-leader multi-follower Stackelberg game model [84], which helps to achieve adequate routing performances in VANET by motivating vehicles to cooperate as Multi Point Relay (MPR), in order to improve their reputation. The collected reputation increments are used to determine the set of nodes (followers) that an MPR (leader) will forward to in terms of the nodes reputation. The proposed protocol method outperforms the optimized link state routing protocol. It provides stable routes with high end-to-end delay and throughput. However, the performances evaluation was discussed only for V2V communication.

– *Connected Junction-Based routing Protocol for city scenarios of VANETs (CJBR)*
In [85], Zahedi et al. proposed a Connected Junction-Based routing Protocol for city scenarios of VANETs (CJBR) for city scenarios of VANETs. CJBR employs a new selection mechanism which is based on the use of RSUs in city road segments, as one of the selection metrics and excludes the traffic density metric from the process of junction selection. The main purpose of this protocol is eliminating the dependency of routing process on the current available traffic density inside the road segments. CJBR includes two stages of routing namely, routing at junctions and routing in road segments. Routing from a junction is done dynamically, it represents selecting process of the sequence of intermediate junctions which represents the best routing path between source and destination. Routing in a road segment represents the process of transferring data packets between each two consecutive junctions, where each data packet is forwarded from node to node in a multi-hop mode till it reaches its final destination or the next junction.
The Network Simulator three (NS-3) was used to evaluate the performance of CJBR, simulation results show that CJBR had the ability to route data successfully in different network connectivity with high packet delivery ratio and low end-to-end delay. However, since the proposed CJBR is based on RSUs, deploying new RSUs requires a lot of cost. Moreover, density parameter was not considered.

– *Cache agent based location aided routing using distance and direction for performances enhancement in VANET (CALAR-DD)*
Gurumoorthi and Ayyasamy proposed an hybrid routing protocol called Cache Agent based Location Aided Routing using Distance and Direction for performances enhancement in VANET (CALAR-DD) [86]. It is a fusion of geocasting and position-based routing with distance and direction.
The CALAR-DD protocol is based on two-stage. Firstly, node selects next hop vehicle (NHV) by using maximum distance with minimum direction and forwarding the packet until it reaches the expected region. At the second step the expected region becomes geocast region. Within this region, cache agent-based geocasting is used to find and forward the packets to the destination. Figure 7 explains the working nature of CALAR DD.
The simulation was performed on NS-3, results show that QoS of proposed protocol is improved in terms of packet delivery ratio, average delay, and re-transmission ratio. CALAR-DD provides short routs by reducing hop count. However, the proposed protocol is not efficient when vehicles are sparsely distributed, routes tend to disconnect. When a link failure appears, packet are dropped and a high packet loss rate occurs.

– *An Advanced Fitness Based Routing Protocol for Improving QoS in VANET (FBAODV)*
Suganthi and Ramamoorthy proposed an efficient Fitness Based Ad hoc On-demand Distance Vector, named (FBAODV) [87] with novel Received Signal Strength Indication (RSSI) computation for VANET. The main purpose focused on this work is to improve the QoS of the network before enabling communication. The stages

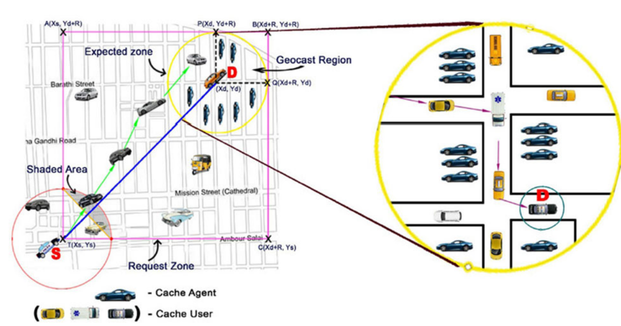

Fig. 7 CALAR DD working structure

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comprised in FBAODV are network formation, neighbour discovery, fitness function estimation, and routing. The network topology is constructed with several vehicular nodes, where an access point and gateway are also fixed. Then, links between the nodes are established by sending the RREQ and RREP messages. During fitness estimation, the node velocity and mobility are computed for selecting the most suitable nodes. Therefore, the QoS parameters, such as PDR, delay, throughput, and energy consumption, are calculated . Furthermore, the communication is established based on the value of QoS parameters calculates previously.
FBAODV is simulated on NS-2, simulation analysis show that various performance metrics like PDR, packet rate, overheads, and end-end delay have been increased. The proposed protocol improve QoS by reducing the amount of packet loss during data transmission. Also, the energy consumption of the network is efficiently reduced with increased packet delivery ratio and average throughput.

– *A Relay Selection Protocol for UAV-Assisted VANETs (LQFC)*
Considering the high mobility and cooperative data sharing of Unmanned Aerial Vehicle (UAV) He et al. proposed a relay selection protocol named LQFC with the SCF method for VANET [88]. Firstly, authors modeled and analyzed the Link Quality of Service (LQoS) from the Source Node (SN) to the neighbor node and the Node Forward Capacity (NFC) from the neighbor node to the Destination Node (DN). Then, the relay selection problem is formulated as a multi-objective optimization problem by jointly considering the LQoS and the NFC. Secondly, they decomposed the primal problem into two sub-problems and solved them by a graphical method. They proposed a relay selection protocol with the Storage-Carry-Forward (SCF) method. Moreover, an utility function with the Node Encounter Frequency (NEF) and the message Time-To-Live (TTL) is taken into account to delete redundant copies.

The opportunistic network environment (ONE) simulator to evaluate the performance of LQFC protocol is used. simulation results have demonstrated that the LQFC protocol can achieve significant performances gain in comparison with other schemes in terms of the message delivery ratio. This is because the designed LQFC protocol can take full advantage of the flexible deployment of UAVs. LQFC can be applied in smart city and Internet of Things (IoT) domains.

4.2 QoS routing protocols based on meta-heuristics

Meta-heuristics have been proposed in order to optimize and solve complex problems which can't be solved by purely mathematical approaches. They can be adapted to any type of problem in the optimization [89,90]. These meta-heuristics are a good approach to solve complex routing problems such as in VANETs. Researchers proposed routing protocols based on meta-heuristics for VANET networks in order to improve QoS.

In this class we will focus on the most popular meta-heuristic algorithms used to optimize routing protocols and we sub-classify these protocols into six subclass : Ant Colony Optimization, Artificial Bee Colony Optimization, Particle Swarm Optimization, Genetic Algorithm Optimization, Simulated Annealing, and Hybrid Optimization.

4.2.1 Ant Colony Optimization based protocols

Ant Colony optimization (ACO) was proposed in 1991 by Colorni, Dorigo and Maniezzo [91] to solve the commercial traveler problem. It has been improved since 1995 and applied to combinatorial optimization problems. Ant colony optimization is inspired by the behaviour of ants when they are searching for food as shown in Fig. 8. This behaviour allows ants to find the shortest routes between their food sources and nests. In the search process they deposit pheromone on the ground and they choose the direction that has higher pheromone concentrations [92].

ACO aims to find satisfactory solutions within a feasible computing time, rather than the optimal solution within a non-achievable time frame. Due to ACO features such as: adaptation to dynamic topology, evaluation of link transmission quality, path selection in real time and distributed management control, it can be easily adapted to routing in mobile ad hoc networks [93].

– *Ant Colony Optimization-AODV (A-AODV)*
Ant Colony Optimization-AODV (A-AODV) is an optimization of the proactive protocol AODV by implementing the ACO algorithm proposed by Mane and Kulkar [33]. Authors tried to identify the need for QoS improvement and to address the QoS limitations in VANET. To improve QoS, authors proceed in two stages: they use the ACO algorithm to optimize the AODV protocol and simulate the result obtained by the first step. Simulation was performed on the Network Simulator (NS-2) in an urban environment for transmission of multimedia data. Simulation results show that the end-to-end delay is reduced considerably after applying ACO for several densities of nodes, and the transmission time is reduced.

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The proposed protocol minimizes delay without affecting packet delivery ration. A-AODV is efficient in dense networks, and promise more realistic result. Unfortunately, this protocol was not verified by a real scenario.

– *Ant Colony Optimization Routing Algorithm Based on Evolving Graph (ACO-EG)*
Wang et al. combined between ACO optimization and route calculation using Evolutionary Graph theory, and they proposed the Ant Colony Optimization Routing Algorithm Based on Evolving Graph (ACO-EG) [67].

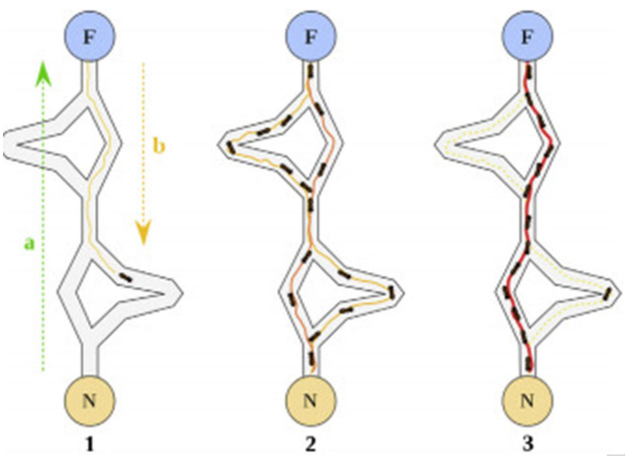

Fig. 8 ACO mecanism

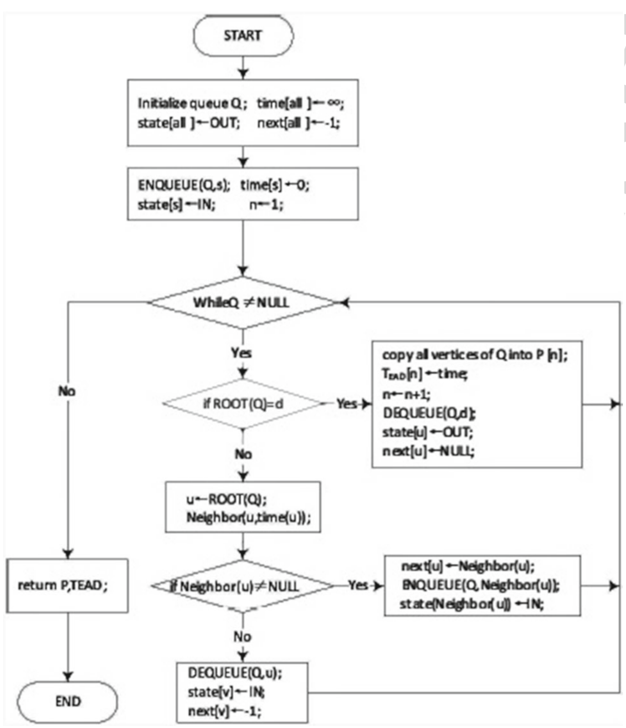

Fig. 9 JTA-EG algorithm flowchart

ACO-EG is a new traffic-adaptive routing strategy that calculates an optimal route and provides a solution to network congestion and frequent change in VANET topology. In [67], authors presented Journys Traversal Algorithm on Evolving Graph (JTAEG). Figure 9 represents the JTA-EG algorithm Flowchart.
This algorithm is based on a Depth First Search (DFS) [94] of graph theory, with the aim of finding the correct set of valid paths at specific levels of delay, and number of jumps (hope-count) within the Evolving Graph (EG). For the calculation of the optimal path, ACO-EG acts in three major components: Forward ants (Fants), Backward ants (B-ants), and Routing and Packet forwarding table. The route selection strategy is based on the intensity of the pheromone on the road, i.e., the route which has the most pheromone will be chosen from the table [93].
ACO-EG has the capacity to answer quickly to the frequent topology change, the ability to avoid congestion and to control it. ACO-EG protocol is suitable in high mobility environments. Unfortunately, because of ACO-EG attitude, some packets can be queued for a long period of time before being transmitted, and the time lost will be counted in the metric.

– *Situation-Aware QoS Routing Algorithm for Vehicular ad hoc networks (SAMQ)*
Eiza et al. proposed Situation-Aware QoS Routing Algorithm for vehicular ad hoc networks (SAMQ) [20]. Its purpose is to determine all possible routes between vehicles in communication subject to many constraints of QoS, and to choose the optimal route if there is one. To do so, authors formulate mathematically the routing selection problem as a multi-constrained optimization problem. They extended Situational Awareness (SAw) concept to propose a novel SAw model for multi-constrained QoS routing in VANET. Then, they combined this model with Ant Colony System (ACS) in order to compute an optimal route and ensure reliable data transmission. The performances evaluation was performed on OMNet ++, by considering PDR, Routing control overhead, Average transmission delay, and Average dropped data packets ratio. The comparison with the existing routing protocols shows that SAMQ offers better results in terms of PDR and minimize the routing control overhead.
Using the SAw concept and ACS mechanism in SAMQ algorithm for VANETs is very favorable to obtain a continuous and stable data transmission. However, the high number of packets control causes high packet loss, in addition, the ACS mechanism contribution toward a QoS routing in VANETs is still unresolved.

– *Adaptive QoS based Routing for VANET with Ant Colony Optimization (AQRV)*

Li et al. proposed Adaptive QoS based Routing for VANET with Ant Colony Optimization (AQRV) [95]. This protocol consists in choosing in an adaptive way the intersections through which the data packets pass to gain their destination. The selected route must achieve the highest QoS in terms of packet delivery ratio, connectivity probability, and delay. To do so, authors modeled mathematically the route selection problem as an optimization problem and they propose an ACO algorithm to solve it. Furthermore, in order to decrease network overhead, they proposed Local QoS Models (LQM). These LQMs are used to estimate real-time local and global pheromone in AQRV.
AQRV protocol is able to manage the rapid change of topology in VANET, and it reduces the search time for new paths, however it is based on road side units at every junction. Therefore, this causes the protocol to miss two important features of the Ant Colony system : self-organization and ability to adapt to failure of specific nodes (RSUs).

- *Ant Colony Based Dynamic Source Routing For VANET (ADSR)*
Kumar and Routray [96] implemented the proactive Ant Colony Optimization to a reactive path finding protocol Dynamic Source Routing (DSR) in order to overcome its drawbacks.
The main motivation for this work is to find an optimal algorithm that is able to provide the required QoS in all types of congested networks and conditions. In their method, when the packets are routed, they use a proactive method within the networks and a reactive method between networks. The two main stages of this method are: routes discovery and maintenance. In ADSR protocol, two special kind of ants are added to the route request and the route reply in DSR, which are the forward ant packets (Fants) and the backward ant packets (B-ants).
Simulation is performed on MATLAB, by considering three parameters. Results show that ADSR performs better compared to the other existing methods and achieves better performances in a congested network exposed to delays and link failures. But, the overhead is more important in the proposed solution than in the existing protocols.

- *QoS-aware multi-path video streaming for urban VANETs using ACO algorithm (QoS-ACOMpVS)*
Vafaei et al. proposed an efficient ACO algorithm to improve the QoS performances of routing paths in an urban VANET environment. QoS-aware multi-path video streaming for urban VANETs using ACO algorithm (QoS-ACOMpVS) [97] is a two-path model based on a disjoint algorithm to forward video streaming over various paths from the transmitter to the receiver vehicle. In order to reach high-quality video streaming in vehicular urban scenarios, the video packet is divided into different frames for transmission via different paths. In proposed protocol the video information is divided into separate paths and classified according to their priority. Authors formulated mathematically the QoS routing issue as a problem of constrained optimization and proposed an ACO-based technique to establish the primary and secondary paths. Moreover, to achieve high-quality video streaming, inter-frames are transmitted over the user datagram protocol and intra-frames are transmitted over the Transmission Control Protocol (TCP). TCP transmission delays are also minimized using a TCP-ETX, where ETX is the expected number of transmissions. TCP-ETX tries to estimate the expected number of transmissions necessary for sending a packet over a link successfully.
QoS-ACOMpVS was simulated on NS-2, results show that proposed protocol enhances the performances in terms of E2ED, PDR, overhead and TCP-ETX. Moreover, ant population in ACO may be modified in terms of network size. Consequently, scalability of proposed protocol is promoted by the use of ACO.

- *An adaptive intersection selection mechanism using ant Colony optimization for efficient data dissemination in urban VANET (AISM)*
Srivastava et al. Proposed an Adaptive Intersection Selection Mechanism using Ant Colony Optimization (AISM) [7]. Authors considered the intersection-based dynamic route selection with optimal QoS as an optimization problem. To resolve this problem an algorithm based on ACO has been used. AISM uses an intersection selection mechanism to establish a longer and stable route between two intersections for urban area VANET. It follows two Strategies: At first, it exploits prediction-based mechanism for real time road evaluation. Then, it forms the route between two selected intersections and forward data packets through that road segment towards the destination instead of a longer route.
By means of extensive simulation on NS-2, results show that proposed protocol enhance the PDR, E2ED. Also, it requires less hop counts as compared with others. The strength of AISM is seen in its capacity to works better because the packets are forwarded only within the predefined zone that prevents to move through longer path. Furthermore, it guarantees high connectivity and stability of the path that participates in data transmission. However, AISM has limitations in terms of overhead control.

4.2.2 Artificial Bee Colony Optimization based protocols

The Artificial Bee Colony Algorithm (ABC) proposed by karaboga [98]. ABC is an optimization algorithm based on

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the intelligent foraging behaviour of honey bee swarm. In ABC model, the colony is divided into three groups of bees: employed bees, onlooker bees and scout bees. Bees communicate by a language based on dances which are performed by the worker called “Scout” when it finds food. The aim of this dance is to recruit other bees by the transmission of the distance, direction and quantity of found food with a tactile, visual and olfactory perception. To deal with the VANET features a projection of ABC has been conducted in the VANET area, in particular to optimize routing protocols and provide better network performances [99].

- *QoS Swarm Bee Routing Protocol for VANET (QoS BeeVANET)*
  Bitam and Mellouk proposed QoS Swarm Bee Routing Protocol for VANET (QoS BeeVANET) [99], which is reactive, distributed and topology-based protocol. Authors were inspired by the autonomous bees communication in order to design QoS BeeVANET. In this protocol two kinds of packets are used to update the list of immediate neighbors of the node and the available QoS information. This packets are scout and forager. Scout is used in the route request and forager is used to transmit the communication data.
  The major phases of QoS BeeVANET are: Neighborhood connection discovery , Route discovery and Route maintenance phase. In order to discover the Neighborhood connection, nodes inform there neighborhoods if the links are active, if all nodes in the network broadcast a refresh packet periodically with its immediate neighbors. Then, forward scout explores the network to find a path from source to destination and QoS requirements. Once a destination is found, a backward scout is used to indicate the route to the source node. Finally, if a node detects QoS requirements violation (large delay or bandwidth insufficiency) or link disconnection, this node sends an error scout packet to the source node. Error scout packet is used specially to maintain route and to ensure the connections stability by detecting broken links and remove them from the routes table.
  QoS Bee VANET has been simulated using NS-2 in urban environment. QoS Bee VANET improves the average end-to-end delay and packet delivery ratio with an acceptable routing overhead. Nevertheless, in the event of a link failure, QoS Bee VANET may flood the network with control packets. Thus, data packets will be queued until the route discovery process is completed.

- *Multicast QoS swarm Bee routing for Vehicular ad hoc networks (MQBV)*
  Bitam et al. proposed the Multicast QoS swarm Bee routing for Vehicular ad hoc networks (MQBV) [100]. MQBV is an on-demand spatial routing protocol inspired from the bees communication method. MQBV broadcasts its route request to a limited number of neighbors (Spatial Zone) to find the multicast group. This type of broadcasting is called stochastic broadcasting. The main stages of MQBV are:

  - Route discovery, in this step a forward scout (route request) is used to find a rout from the source node to the multicast group. This step contains two cases: case one the multicast group head is known by source node, and second case the multicast group head is unknown by the source node.
  - Multicast tree construction from the head of the group to its members. In this step, node broadcasts a local scout to its neighborhood in order to search a group member and find the group head.
  - Multicast group publication, this step improves the communication of non-members multicast group, and allows them to reach the head of the group.
  - Finally, the Multicast tree maintenance step supports the detection of link failure and selects the new group head if the head of the group leaves the multicast tree.

  The proposed MQBV algorithm improves QoS in terms of end to end delay and packet delivery ratio, it is able to detect and preserve more input paths that can be used for parallel data transmission. Moreover, since it is an adaptive protocol, it keeps its best results whatever the speed of vehicles and allows the network to be less congested. Nevertheless, link life time is not considered and security of this protocol has not been confirmed.

- *Micro-Artificial Bee Colony based multicast routing in vehicular ad hoc networks (MACB)*

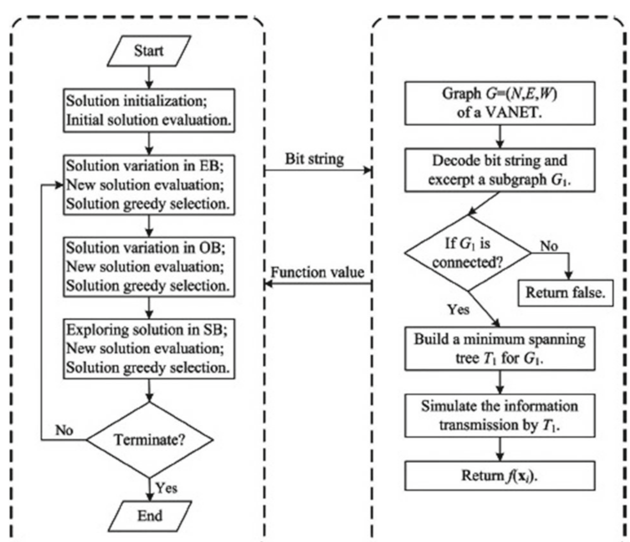

Fig. 10 Flow chart of applying MABC to the network example. EB: employed bee stage, OB: onlooker bee stage, SB: scout bee stage

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A Micro Artificial Bee Colony (MABC) algorithm is proposed by Zhang et al. [101] to deal with the QoS constrained multicast routing problem in VANET. By considering the delay cost, network lifetime and energy consumption as a QoS parameter, authors modelised a VANET as an undirected acyclic graph noted G. Then, they transformed routing problem to Steiner Minimum Tree (SMT) searching problem [102]. In MABC, the multicast tree is modeled as a simple binary string representation. The algorithm running time is divided into time slots in MABC. During each time slot, the VANET topology is assumed that is stable.
The colony of MABC is composed by scout bees, employed bees, and onlooker bees. Scout bees explore randomly the search space and generate Steiner nodes to achieve solutions. MABC algorithm is tested on three cases with increasing number of destiny nodes. Figure 10 represents the Flowchart of applying MABC to the network.

MABC improves multicasting life time and minimize delivery delay. However, in the absence of infrastructure link stability is affected by vehicles mobility. In order to repair instability of links MABC transmits control messages that cause a over-consumption of bandwidth. Moreover, MACB didn't consider the urban structure and didn't provide a mechanism to record communication lifetime. It also didn't consider a model of mobility during the simulation and didn't make a comparison with other protocols.

– *Optimized Fuzzy AODV (OFAODV)*
Fahad and Ali proposed an Optimized Fuzzy AODV (OFAODV) [103], it is an optimized multi-criteria multicast routing protocol that adopts adaptive route life for VANET networks.
Authors take into account three main problems of routing in VANETs in the associative form which are:

  – The blind diffusion of the Route Request (RREQ) during the road discovery phase,
  – The high rate of disconnected roads raised by the neglect of certain criteria during the road selection,
  – The confusion of using the lifetime of a fixed route, regardless of the state of the selected route.

OFAODV incorporates the principle of fuzzy system (artificial intelligence tool) to improve the decision-making process of AODV by using fuzzy controllers to evaluate the route cost and its life span based on multiple criteria (distance, direction, speed, future direction, and number of hops information). The generation of fuzzy knowledge base which depend on system knowledge and trial and error process manually is a very tedious and time consuming task, and does not guarantee the construction of an optimal system. As a solution, authors proposed an ABC optimization to extract an optimal rule set for all the proposed fuzzy controllers.
OFAODV improves network performances, with the proposed method RREQ packets broadcasting is eliminated and route selection efficiency is increased by reducing the route error and the overhead. Moreover, OFAODV is suitable in urban and freeway environments under different conditions of vehicle density. Nevertheless, fuzzy method has drawbacks the fact of expressing its knowledge in the form of rules in natural language, i.e., qualitative form does not prove that the system will behave optimally.

– *Multiconstrained QoS-Compliant Routing Scheme for Highway-Based Vehicular Networks(CB-QoS-VANET)*
CB-QoS-VANET is a unicast routing protocol based on clustering and ABC algorithm proposed by Lakas et al. [66]. It is an extansion of previous work presented in [104] by considering a multiconstrained routing optimization. Authors formulated mathematically a multiconstraned routing optimization problem by considering vehicular network as a undirected graph and QoS criteria. They used QoS metrics and mobility metrics in cluster head selection and optimal route determination. The clustering algorithm aims to improve clustering structure stability and to maintain the end-to-end communication. While the artificial bee colony approach is used to find the most QoS-compliant routes using scouts for discovering the network. The best route is determined by calculating a suitable function that takes into account both QoS and mobility metrics. The adjustment mechanism by the bee colony algorithm supported in CB-QoS-Vanet is done by combining QoS measurements in a formula that weighs the different service quality requirements. Finally, the network discovery algorithm is optimized by using a caching mechanism that reduces network overhead.
CB-QoS-VANET improves the QoS in terms of packet delivery ratio, end-to-end delay and provides a minimal overhead. Unfortunately, this protocol has not been tested in a high dense network. In this case, its behavior is unknown.

4.2.3 Particle Swarm Optimization based protocols

The Particl Swarm optimization (PSO) is developed by Kennedy [105], inspired by social behavior of Ants, bird flocking. In PSO, a set of particles forms a swarm. Every particle is defined by position and velocity. While the position defines a candidate solution to the problem space, the velocity is utilized to move the particle from position to another. In VANETs, PSO has been utilized in very few research work

– *Geocasting in Vehicular Ad Hoc Networks Using Particle Swarm Optimization (Geo-PSO)*

Geocast routing based on Particle Swarm Optimization (Geo-PSO) is proposed by kaiwartya and Kumar [65]. The main purpose of this protocol is to improve the quality of the selected NHV.
Given that several constraints are linked to the selection of NHV, authors thought to use PSO to select the most reliable NHV. They considered that each point of right semi-circle of transmission represents a particle, right semi-circle was searched for the best possible position of NHV. In the PSO, to evaluate the quality of each candidate solution NHV fitness function Q_{NHV} is used and it is calculated as:

$$Q_{NHV} = \varphi_1 LD + \varphi_2 PD - \varphi_3 NL - \varphi_4 ED - \varphi_5 TP - \varphi_6 HC.$$

Where $\varphi_i, i = 1, 2, ...6$ are constants which represent weight for respective components:
LD : Link Disconnection probability, PD: Packet Delivery, NL: Network Load, ED: End-to-End Delay, TP: Throughput, and HC: Hop-Count.
GeoPSO outperforms traditional protocols in terms of packet delivery and network load, and it reaches a very high percentage of packet delivery in a dense network as well as in a scattered network. Unfortunately, link failure influences the GeoPSO protocol strongly.

- *Optimal Configuration for Urban VANETs Routing using Particle Swarm Optimization (M-OLSR)*
Modified Optimized Link State Routing Protocol (M-OLSR) is a routing protocol proposed by zukarnain et al. [106]. In M-OLSR, authors tried to regulate the parameters of the ordinary OLSR protocol by using PSO algorithm, in order to adapt them to VANET requirements, and optimize the QoS parameters.
OLSR parameters optimization is done in two phases: simulation phase and optimization procedure. PSO algorithm is used in the iterative way to find the optimal solutions. A true variable-range solution vector is produced, and each one represents a new OLSR parameter. Then, fitness function in PSO is defined to give a specific weight to the employed performances metrics like delay, Normalized Routing Load (NLR), and packet delivery ratio (PDR).
This optimization provides efficient OLSR parameter configurations for VANETs, and allows OLSR to be appropriate for any VANET scenario. M-OLSR makes a VANET network more stable. Nevertheless, the high mobility has a negative effect on this protocol.

- *Particle Swarm Optimization based Routing Protocol for VANET (PSO-DREAM+SIFT)*
Kalambes et al. proposed a Particle Swarm Optimization based Routing Protocol (PSO-DREAM+SIFT) [107] to optimize the routing performances in VANET. In PSO-DREAM+SIFT protocol, authors combined between the location based routing protocol DREAM and the reactive protocol Simple Forwarding over Trajectory SIFT. They applied PSO technique in order to generate network navigation decisions by avoiding centralized control which reduce congestion and delays.
To analyze the performances of this protocol, simulation was carried on NS-2 simulator by considering some parameters, such as delay, energy, packet loss, network load and control overhead. The results show that PSO-DREAM+SIFT outperforms DSDV.
PSO-DREAM+SIFT improves QoS in terms of end-to-end delay, packet loss and bandwidth. It also, reduce latency and overhead.
The strength of PSO-DREAM+SIFT lies in its suitability for large network. However, in simulation of PSO-DREAM+SIFT protocol a small number of vehicles is used. Also, PSO-DREAM+SIFT protocol didn't reduced enough the energy consumption.

- *Multi-objective Dynamic Vehicle Routing Problem and Time Seed Based Solution Using Particle Swarm Optimization (TS-PSO)*
Time Seed Based Solution Using Particle Swarm Optimization (TS-PSO) has been proposed by Kaiwartya et al. [108] to solve the Multiobjective Dynamic Vehicle Routing Problem (M-DVRP) wich considers five objectives: geographical ranking of the request, customer ranking, service time, expected reachability time, and satisfaction level of the customers .
Authors divided the problem into smaller size DVRPs. Then, the time horizon of each smaller size DVRP is divided into time seeds and the problem is solved in each time seed using particle swarm optimization. In TS-PSO, authors considered a flexible time window, request vector (customers send their request to the central depot via VANET communication) and order vector(generated corresponding to the request vector). Request and order vectors are used to develop a mathematical model for M-DVRP.
Simulation was performed on NS-2 to analyze the performances of proposed TS-PSO. According to performances analyse of the proposed protocol, TS-PSO can be adapted to the dense network and real environment. Unfortunately, the network dynamicity influences largely the TS-PSO protocol.

- *Destination-Sequenced Distance Vector Routing protocol(DSDV) based on the Particle Swarm Optimization (PSO) and the Multi-Agent System (MAS) (PSO-C-MADSDV)*

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Harrabi et al. proposed a optimisation for Destination-Sequenced Distance Vector Routing protocol(DSDV) based on the Particle Swarm Optimization (PSO) and the Multi-Agent System (MAS) (PSO-C-MADSDV) [109]. In this protocol the data is forwarded over a set of groups with an optimal cluster head. This cluster head is selected by using PSO optimization algorithm. Performance evaluation is carried by comparing PSO-C MADSDV to MA-DSDV in terms of throughput, dropped packets rate and overhead. The clustering technique provides links stability and leads to reduce the number of unused paths and minimize the number of dropped packets rate. Thus, the throughput is improved as well as the routing overhead average. In [110] PSO-C-MADSDV is compared with Intelligent Based Clustering Algorithm in VANET (IBCAV) [111], Which is a protocol specially designed for
VANET. This comparison is used to analyze the PSO-C-MADSDV reliability.
PSO-C-MADSDV reduces the number of messages and increases the connectivity, as well as, communication becomes more stable and secure. However, this PSO-C-MADSDV needs to be improved to be better adapted to the real-time scenarios.

– *Particle Swarm Optimization based Routing Method for Vehicular Ad hoc Network (PSOR)*
In [112], Yelure et al. proposed Particle Swarm Optimization based Routing method for VANET (PSOR). It uses Geographic Position System (GPS) to identify the location of vehicles, and uses the distance and speed of the vehicle to determine next forwarding vehicle. In order to determine next forwarding vehicle, the protocol computes a fitness function. Subsequently packets are transferred in greedy forwarding mode.
Source node finds the neighbor node closer to the destination and determines its fitness value. The neighboring vehicle having the highest fitness value is selected as next forwarding vehicle and the packet is forwarded to that vehicle. The process is repeated iteratively until packet reaches destination node.
Simulation results indicate that the proposed PSOR achieves high performances in terms of throughput, delay, overhead. Moreover, it minimizes the network loop and provides network robustness. Unfortunately, the simulation was performed for fifty vehicles, hence the density parameters was not taken into account and scalability of the proposed protocol is not checked.

4.2.4 Genetic algorithm optimization based protocols

Genetic Algorithms (GAs) [113] are a bio-inspired populational-based meta-heuristic which allow solving problems in changing environments. It is verified that the GAs are able to find solutions sufficiently feasible [114]. Genetic algorithms are suitable for VANETs which represent high mobility and high changing environment.
In GAs, a population is a group of individuals (possible solutions). Each individual is represented by a chromosome. Individuals in a population are combined (through crossover) and modified (by mutation) to produce a new generation of solutions. When the solutions are combined, the attributes (genes) of the best quality solutions have a bigger probability to be passed over the next generation. This process is repeated over generations, and it improves the quality of the new population's solutions throughout the time [115]. Figure 11 illustrates the GA flowchart

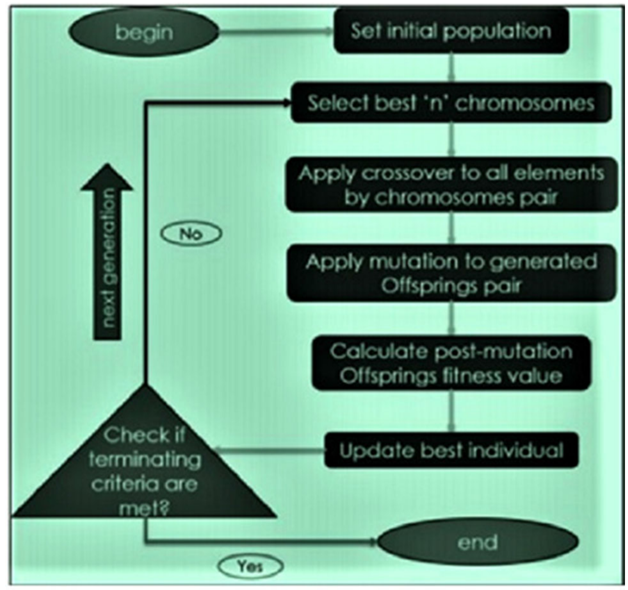

Fig. 11 Genetic algorithm flowchart

– *QoS Support in Delay Tolerant Vehicular Ad Hoc Networks (DTRP)*
QoS Support in Delay Tolerant Vehicular Ad Hoc Networks (DTRP) is an intersection-based geographical routing protocol proposed by Saleet et al. [116]. Its purpose is to select the road intersection through which packets must pass to reach the gateway to the Internet.
Authors formulated mathematically the selection problem as a constrained optimization problem, by taking into consideration QoS parameters namely (connectivity probability, end to end delay and hop count). Then, a GA is proposed to solve this problem in order to find an optimal or near-optimal route between vehicles and the Internet gateway.

```
Algorithm 1: BSC-genetic Algorithm
  Input: A_H, A_D, B, T, R
  Output: best chromosome
  Initialization
    Encode coordinates to chromosomes;
    Initialize population randomly;
  while fitness ≤ T do
    Evaluation and Selection
      Evaluate chromosomes by fitness function;
      Select optimal population for reproduction;
    Reproduction
      Crossover to generate new offsprings;
      Mutate to generate new gene;
  return best chromosome
```

Fig. 12 BSC genetic algorithm

Simulation was performed on MATLAB to compare DTRP with reference routing protocol, analytical and simulation results show that DTRP reach better performances than benchmark routing protocols. The use of GA optimisation allows the maximization of connectivity probability. Thus, QoS is improved in terms of end to en delay and hope count. Therefore this protocol is a suitable candidate for scale networks. Unfortunately, it is difficult to determine a new path.

– *A Genetic Algorithm-Based Sparse Coverage Over Urban VANETs (BSC-GA)*
Cheng et al. proposed a A Genetic Algorithm-Based Sparse Coverage over urban VANETs (BSC-GA) [117] with statistical analysis for traffic monitoring and management. The purpose of BSC-GA is how to deploy RSUs based on hot spots and, how to explore geometrical attributes of road segments. This BSC-GA is based on three phases: the first phase is clustering each region of the road network into various hot spots according to coverage value metric. The second phase is buffering operation. This phase is used to define the deployment location of candidates based on geometry. In the third phase, the problem of Budgeted Sparse Coverage (BSC) for the road network is transformed to a maximization problem which can be resolved by the use of genetic algorithm. Figure 12 represents the BSC-GA Algorithm. The proposed BSC-GA is simulated on NS-2 and SUMO, results show that BSC-GA improves QoS in terms of packet loss. It also, ensures a high network connectivity and link stability. However, when the number of RSUs decreases, a significant degradation of the coverage area occurs.

– *Routing Protocols for VANET: An Approach based on Genetic Algorithms (G-NET)*
Wille et al. proposed a routing protocol called Genetic Network Protocol (G-NET) [118], it is based on Dynamic Source Routing Protocol (DSR) and uses genetic algorithm to maintain and optimize routes.
G-NET retains the reactive aspect of the DSR protocol and benefits from its advantages, such as recording the entire route from the origin to the destination, and making a periodic updates based on functionality of the genetic algorithm. In G-NET protocol, the population evolution is used to improve the quality of routing in terms of reducing the latency of roads, while producing a range of the routes with possible gains if route failure occurs.
Simulation was performed on $NS-3$ and comparison is done with DSR and AODV.
G-NET is equivalent to DSR and superior to AODV in terms of average delivery ratio and routing overhead. Taking advantage of the DSR's features, G-Net can use the alternative routes before it initiates another flood for route discovery. However, the generation of periodic updating packet control increases routing overhead. Moreover, G-NET protocol lacks a comparison with recent protocols.

– *Genetic Algorithm Based QoS Perception Routing Protocol for VANETs (GABR)*
Genetic Algorithm Based QoS Perception Routing Protocol for VANETs (GABR) is a location-based routing protocol designed by Zhang et al. [119] to guarantee the QoS. Influenced by the links that breaks between vehicles and unsuccessful packet transmission, authors used a GA to optimize the routes between source and destination. GABR selects the next hop intersection in a dynamic way, and vehicle use the carry-forward strategy to deliver a data packet. The proposed routing solution integrates destination localization by searching for a connected path between source and destination. Subsequently, the genetic operation is as follows: all improved paths are explored by Intersection Based Routing (IBR), then the genetic algorithm is used sequentially to provide a path with optimal QoS. At last, the authors conducted a mathematical analysis of performances in terms of connectivity probability and transmission delay.
GABR protocol transmits the packets successfully and allows to obtain information in real time. Moreover, it can be adapted to the topology change. Unfortunately, the proposed scheme is complex to program in genetic algorithm, and the speed of the search process is slower.

– *Improved Genetic Algorithm-based Route Optimization Technique (IGAROT)*
Bello-Salau, Aibinu, Wang et al. designed a new rout metric which determines how suitable a communication link will be to route information between two nodes. They developed an Improved Genetic Algorithm-based Route Optimization Technique

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(IGAROT) [120], which is a variant of GA. This protocol guarantees better routing in VANETs.
IGAROT is used to determine the optimal routes required to communicate efficiently the road anomalies between the vehicles in VANET. In their paper, authors replaced the GA selection method with the K-Means clustering technique presented in [121]. They used the number of vehicles evolving in the VANET to initialize randomly the population. This latter serves as an initial solution, it forms new generations. This technique selects the correct chromosomes in two cluster groups which do not overlap by using the elitism selection probability. IGAROT algorithm updates the size of the correct cluster in the initial population size. The flowchart of the Developed IGAROT with Elitism Algorithm is illustrated in Fig. 13.
IGAROT protocol is able to detect road anomalies, that allows drivers to better navigate abnormal roads to reduce accidents caused by this anomalies. However, IGAROT didn't consider some metric of QoS, such as delay, PDR, and throughput. IGAROT should be implemented in real time VANET communication systems.

– *Genetic Optimized Location Aided Routing Protocol for VANET Based on Rectangular Estimation of Position (RALAR)*
Muniyandi et al. proposed a Genetic Optimized Location Aided Routing Protocol for VANET Based on Rectangular Estimation of Position (RALAR) [122]. It is based on a moving rectangular zone according to the nodes mobility. The idea is to reject the bad GPS location data and accept good ones. The RALAR protocol was optimized by using the Genetic Algorithm (GA) by selecting the most suitable time-out variable.
The proposed protocol was simulated on MATLAB, results show that it achieves an improvement in terms of regular network performances in VANET.
RALAR helps to reduce the search space for the desired route. Limiting of the search space decreases number of route discovery messages and rejecting weak GPS location data by using GA provides accurate routes. Consequently, routing packets is more reliable and network lifetime is prolonged. However, the speed of the vehicle is limited to 60-100 km/h. As a result, when the vehicle speed becomes higher, the proposed RALAR protocol performances might degrade.

4.2.5 Simulated Annealing optimization based protocols

Simulated Annealing (SA) is a meta-heuristic inspired by the experimental technique of solid annealing [123]. It is a probabilistic technique for approximating the global optimum of a given function, it is intended for solving difficult problems

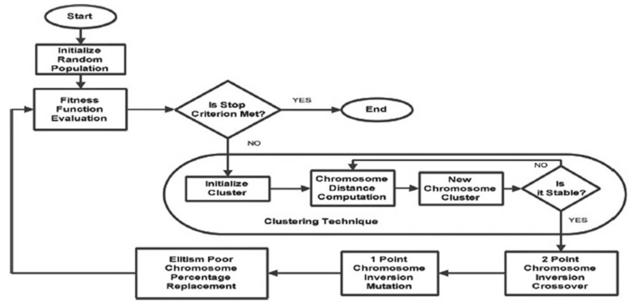

Fig. 13 Flowchart of the developed IGAROT with elitism algorithm

of optimization. The SA adaptation to VANET routing protocols aims to provide a controlled and decreasing randomness in the forwarding process [124].

– *A Routing Protocol for Vehicular ad hoc networks using Simulated Annealing algorithm and Neural Networks (RPVSANN)*
Bagherlou and Ghaffari proposed a Routing Protocol for Vehicular ad hoc networks using Simulated Annealing algorithm and Neural Networks (RPVSANN) [125]. It is a clustering based reliable routing protocol for VANET. The main goal of RPVSANN is to establish a connected chains of dynamic clusters, and to produce an efficient cluster structure for reliable routing. Authors used SA optimization and a suitable fitness function. Then, they used the Radial Basis Function (RBF) neural networks to select cluster head with considering important parameters, such as nodes degree, and coverage.
RPVSANN eliminates the flooding caused by broadcast and reduces delay in safety message transmission and bandwidth consumption. The packet delivery ratio and route discovery rate offered by RPVSANN is higher than PassCar [126]. Simulation results show that the proposed scheme has a lower throughput. Moreover, the scalability, the network lifetime and the packet loss ratio are not taken into consideration.

– *Optimization Techniques of Optimized Link State Routing Protocol in VANETs (OLSR-SA)*
Optimized Link State Routing Protocol (OLSR) [127] is a proactive routing protocol which increases the suitability for networks whose topological changes are frequent and fast as in VANET.
Batra et al. [128] modified OLSR routing protocol in order to increase its performances in VANET scenario. In their paper authors, implemented Simulated Annealing algorithm in OLSR (OLSR-SA). This optimization is used to obtain efficient OLSR parameters automatically and discover the best protocol configuration. Then, they performed simulation stage to assign a quantitative

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quality value to OLSR performances of computed configurations in terms of communication cost.
The communication cost *comm.cost* function is as follows:

$$Comm.cos = w2 * THR + w3 * E2ED - w1 * PDR.$$

Where $W_i, i = 1, ...3$ are biased weighs for respective components:
THR :Throughput, PDR :Packet Delivery Ratio and $E2ED$:End-to-End Delay.
The objective of this fitness function consists in maximize PDR and Throughput and minimize E2ED.
OLSR-SA outperform OLSR and OLSR-GA [128] in terms of PDR, end to end delay and throughput. Moreover, OLSR-SA provides a minimal communication cost and it is more scalable due to better QoS and communication efficiency. Unfortunately, authors have made a comparison of this protocol only with OLSR variants. In this case, effectiveness of OLSR-SA is not well checked.

4.2.6 Hybrid optimization based protocols

In our classification, the hybrid class includes routing protocols which combine between two or more meta-heuristic algorithms.

- *Intelligent-OLSR (I-OLSR)*
  Toutouh et al. proposed an optimization strategy which combines different meta-heuristics to improve OLSR protocol [53]. This strategy is used to determine the most finely as possible the configuration parameters of the OLSR protocol. OLSR has been chosen because it presents a series of features that make it well-suited for VANETs. Authors determined automatically the optimal parameters configurations of OLSR routing protocol by using PSO, Differential Evolution (DE), GA, SA. These parameters are used to optimize a weighted fitness function that takes into account three important performances parameters, such as end-to-end delay, Normalized Routing Load (NRL), and packet deliver ratio. To accurately evaluate the resulting protocol performances, authors carried a simulation phase in a set of realistic VANET scenarios.
  Coupling meta-heuristics and a simulation offers the possibility to customize efficiently and automatically any protocol for any VANET scenario. However the execution time of the algorithm, affects negatively this protocol specifically for ITS applications sensitive to the delay factor.
- *Enhanced and Integrated Ant Colony-Artificial Bee Colony oriented Multicast Routing (EIAC-ABCMR)*
  Malathi and Sreenath proposed an Enhanced and Integrated Ant Colony-Artificial Bee Colony oriented Multicast Routing (EIAC-ABCMR) [129]. It is formulated as a multicast tree determination problem that imposes the satisfaction of multi-constrained QoS by reducing delay, jitter, and cost with increased bandwidth to improve data transmission efficiency.
  To estimate the optimal multicast tree, authors combined the benefits of the ACO and ABC algorithms and used them mutually to reduce the overhead generated by multicast routing.
  EIAC-ABCMR implementation includes three steps: development of Multi-QoS constraint imposed multicast routing problem, optimal multicast tree determination by the use of the Integrated Ant Colony Artificial Bee Colony based meta-heuristic algorithm and finally, facilitation of multicast routing, by using the determined EIAC-ABCMR-based multicast tree.
  EIAC-ABCMR prevents stagnation and delayed convergence during the optimal prediction of the multicasting tree and ensure reliable data delivery in VANET. Unfortunately, the implementation of this protocol is tedious.
- *Generic Geographical Heuristic Routing protocol (GHR)*
  Urquiza-Aguiar et al. proposed a Generic Geographical Heuristic Routing protocol (GHR) [68]. GHR can be applied to any Delay Tolerant Network (DTN) geographical routing protocol that makes forwarding decisions at each hop.
  The proposed Algorithm combines between two meta-heuristics, such as Tabu Search (TS) and simulated annealing. The adaptation of both of them was done in [124]. The TS implementation was proposed as a list called tabu t of the last k nodes visited by a packet. The SA adaptation to VANET routing protocols aims to provide a controlled and decreasing randomness in the forwarding process. When there is no appropriate next forwarding node, GHR acts as a DTN approach that carries packets and searches the best forwarding and recovery nodes by considering all destination set members.
  GHR can be adapted to any routing protocol, it presents advantages for performances improvement in terms of packet delivery ratio of geographical routing protocols, Unfortunately, using TS optimization provides an additional delay.
- *Moth Whale Optimization Algorithm (MWOA)*
  More and Naik proposed a new algorithm, known as Moth Whale Optimization Algorithm (MWOA) [130]. Authors combine two meta-heursitcs in order to determine the optimal multipath for video transmission in VANET network. The proposed algorithm is designed with the integration of Moth Search (MS) meta-heuristic and Whale Optimization Algorithm (WOA). Firstly,

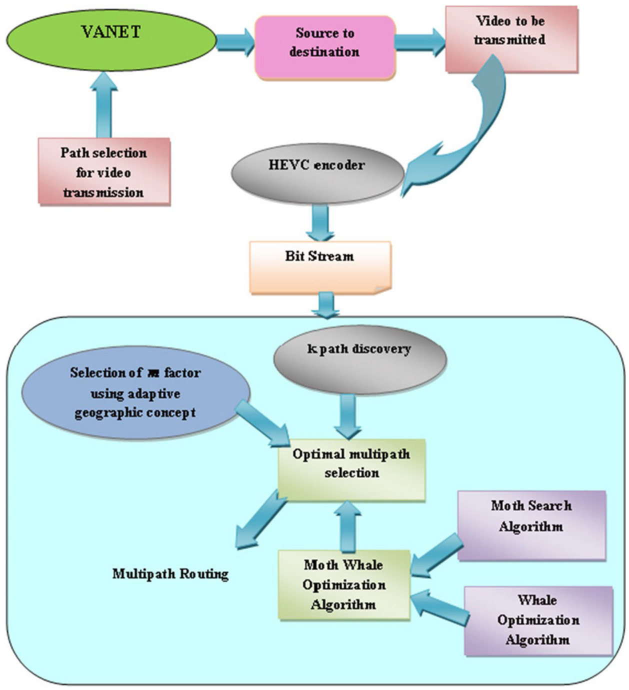

Fig. 14 Block diagram of MWOA protocol

They simulated VANET and estimated the number of possible routes for video transmission. Then, the optimal selection of the multipath is done using an adaptive geographic routing scheme based on the fitness measure. This latter is developed based on various QoS parameters. After encoding the video through High Efficiency Video Coding (HEVC), the packet transmission is done through the multipath which is selected optimally for the transmission of videos from the source to the destination. Fig 14 represents the block diagram of MWOA protocol. The strength of the proposed MAOW, lies in its ability to obtain the optimal solutions in an efficient manner within a short period of time. Therefor, it is very suited to safety applications since it can transmit video from the accident to other vehicles whith high QoS. The limitations of this method is the consideration of a single vehicle metric which is the position. Moreover, authors didn't consider the overhead which is an important metric to evaluate performance of proposed algorithm.

We conclude this section by Table 2. This table recapitulates the different classes based on algorithms and optimization techniques studied in our classification. In this table, we presented QoS Routing protocols not based on meta-heuristics and QoS Routing protocols based on meta-heuristics discussed above. In the first class, we mentioned the techniques used by each protocol.

Table 2 QoS Routing Protocols Taxonomy

QoS routing protocols not based on meta-heuristics		QoS routing protocols based on meta-heuristics					
Protocol	Technique	ACO	ABC	PSO	GA	SA	Hybrid
MURU	Estimated disconnection degree	A-AODV	QoS bee-vanet	Geo-PSO	DTRP	RPSANN	I-OLSR
Improving QoS in VANET using MPLS	Multi-Protocol Label Switching (MPLS)	ACO-EG	MQBV	M-OLSR	BSC-GA	OLSR-SA	EIAC-ABCMR
P-GEDIR	Probabilistic	SAMQ calculation	MABC	PSO-DREAM+SIFT	G-NET		GHR
EG-RAODV	Evolutive graphs + reliability calculation	AQRV	OFAODV	TS-PSO	GABR		MWOA
ICAIR	Position based Prediction+ delay estimation	ADSR	CB-QoS-VANET	PSO-C-MADSDV	IGAROT		
TLRC	traffic light features + connectivity calculation	QoS-ACOMpVS		PSOR	RALAR		
COMES	game theory	AISM					
Stackelberg game	game theory						
CJBR	Junction based routing						
CALAR-DD	geocasting and position-based						
FBAODV	Fitness function estimation						
LQFC	Utility function estimation						

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5 Comparison of studied QoS routing protocols

In this section, we compared the protocols studied according to a set of basic QoS parameters used to optimize routing protocols and the different QoS metrics (see section.2). We also considered vehicle metrics such as, direction, velocity and position. Direction and velocity are the most widely used metrics, because the velocity can been considered as an account for the behavior of the vehicular networks direction and direction is used to determine the progress rate of destination reachability. Vehicle density and position are other metrics commonly selected by researchers that guarantees the opportunity to have enough choice to select the best path. Also, due to the mobility present in a such network the use of GPS is a necessary assumption to improve QoS. The position of each node is important to make the best choice of route. Moreover, this comparison is carried according to other criteria, such as offered QoS, MAC protocol, Applications, etc. From Table 3, we see that nearly 90% of the surveyed protocols have implemented their propositions and evaluated their performances. The common simulators used are NS-2, OMNet++, MATLAB, SUMO, etc. Most of the proposed protocols have been tested in an urban environment. Because, due to the presence of obstacles, it is a greater challenge than highways, as there are quick topology changes.

As we see in the summary of Table 3, several QoS parameters are used by the different surveyed protocols. Most of proposals consider the delay parameter, due to its importance in supported applications particularly safety one. Safety messages are given the highest priority in VANET communication. Therefore, routing protocols should reduce the delay without affecting packet delivery ratio [33]. Furthermore, in order to meet an offered QoS over forwarding speed, link quality (link reliability, link life time, link stability and street connectivity) are some of the parameters that should be included in path selection. In all most protocols, the neighbor nodes parameter is taken in consideration to make a forwarding decision.

In order to evaluate the performances, researchers mainly focus on the E2ED, the routing overhead, the PDR and throughput. We conclude that the main purpose of most proposal is choosing the most reliable and stable routes that offers best QoS. Unfortunately, this is a very challenging task because of the nature of VANET network. Authors try to optimize the PDR without affecting E2ED or the bandwidth consumption. Also, the number of neighbor node is very important parameter to provide an optimal route. Indeed, stability of links is provided according to the density of the network.However, increasing this number in the network can increase the network congestion, which generates a very important overhead. We deduce that achieving a trade-off between all of these metrics allow authors to obtain routing protocols that offer a certain level of QoS. Actually, the trade-off mechanisms between the different QoS parameters in the VANET have been widely used. From our study, we conclude that each application requires different performance. Therefore, we can't assert that it exists a universal performance trade-off mechanism which can make all QoS parameters achieve the best performance. Then, we deduce that most of QoS routing protocol focus on either link efficiency or stability. So, due to the special characteristic of VANET such as rapid topology changes, the principal trad-off in vehicular network is mobility-link quality trade off and mobility-QoS performance trade-off.

In fact, in ICAIR protocol achieves the trade-off between high mobility in VANET and link connectivity by using position prediction and new recovery strategy. The accuracy of those position is significantly beneficial since it is possible to monitor the mobility of neighbors vehicles.
Also, most of QoS routing protocol based on meta-heuristics formulate the trade-off between QoS parameters and metrics as an optimisation problem subjected to QoS constraint. As example, we site the AQRV protocol which archives the trade off between route stability (connectivity probability), E2ED, PDR and overhead. This trade-off is formulated as an optimisation problem and an ACO algorithm is proposed to solve it.

From Table 3, we note that it is possible to achieve performance trade-off by the adaptation of meta-heuristics to routing protocols in VANET and they provide a great gain in QoS. Indeed, meta-heuristic algorithms are well-suited to high mobile ad hoc networks which generate frequent and fast topology changes. The ability of these meta-heuristics to adapt to VANET topology change and the high dynamicity of the nodes allows node to establish a stable routes and reliable communication. Thus, the choice of the right meta-heuristic is the key to improve routing protocols and provide the best QoS. In addition to meta-heuristics, there are several techniques that are adapted to routing in VANET in order to offer better performances such as the Estimation of Disconnection Degree (EDD) in MURU [79], the Evolving Graphs in EG-RAODV [45], the Game theory in stackelberg game [84]. Moreover, street parameters like traffic light features in TLRC [82] or junction in CJBR [85] are very important parameters to consider in conception of robust QoS routing protocols for VANET.

According to the Table 3, we note that a set of protocols are well-adapted to certain applications than others. A number of protocols are well-suited to offer minimum latency [45,106, 109,129]. Thus, they offer best QoS for comfort applications, such as live video and audio streaming and instant messaging. While, some protocols offer lower overhead and minimum packet drops [20,67,79,80,100,118,120]. So, they are more suited for safety applications.

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To summarize, each class represents some protocols which are better adapted for safety applications, while other protocols are suited to comfort applications. However, we notice that it exists protocols which are well adapted for both applications, we cite [33,66,95,101,103,107]. Also, there is no class of protocol which offer best QoS than another, more precisely no protocol can be determined as the best in terms of QoS.
Finally, we deduce that protocols perform optimally in a specified environment as shown in Table 3.

6 Challenges and research direction

There are several issues and prerequisite that should be considered when designing VANETs routing protocols, as the effectiveness of a successful deployment of VANET depends on the performance of its routing protocols. We briefly present the main challenges to be considered for routing algorithms on VANETs and open research areas that if well used, could improve the performances of VANET routing protocols. These include QoS, high speed and frequent topology changes, Scalability and security.

- QoS is an important issue to be considered by routing algorithms in VANETs. The different applications of VANET are expected to require different QoS such as, the distance between nodes, node position, link delay and reliability of links [131]. This challenge is difficult to be addressed especially in a highly dynamic network such as VANET. The frequent change in VANET topology and the lack of a central controller to synchronize and manage node activities could lead to channel under utilization. As a result, vehicular network suffer from link failures which leads the QoS decrease .
- As a solution, QoS can be improved by an efficient allocation of network resources, which is enforced through resource reservation with adequate infrastructure [132]. Also, QoS is improved by adaptation of meta-heuristic in routing protocol for VANET [67,100,118]. Moreover, using new technologies such as Software-Defined Networks (SDN), cloud computing, fog computing, as in [133] and the fifth generation technology (5G) cellular network are a promising solution to design enhanced routing protocols that achieve best QoS in VANET.
- Meta-heuristic such as ACO, ABC, GA and SA are considered as one of the most appropriate approaches to overcome VANET routing challenges. However, they have parameters that are not easy to adjust and demand high computational resources. As a result, it is very difficult to estimate the theoretical speed of convergence. As an example, the parallelization of the tasks related to the evaluation procedure will allow executing genetic algorithms using multiple processors and cores, reducing the computation time. The application of meta-heuristics in real test-beds so that the obtained simulation results can be confirmed and validated can be an interesting solution for reducing the amount of time required by simulations.
- High speed and frequent topology change : routing in VANETs is not only about link connectivity and availability of network resources, but also about resource mobility and speed. Since the network topology is rapidly changing, communication links suffer from fast variation and are vulnerable to disconnection. This problem gives rise to the challenge of reliability in vehicular communication networks.

  As a solution, for reliable and efficient vehicular communication, effective and competent loss packets recovery schemes which could adapt to such dynamic topology changing are required. Furthermore, designing MAC protocol that will span across network (routing) layer and transport layer, must solve the mobility issues. The MAC protocol must accurately estimate the state of the highly dynamic channel in order to design a reliable communication protocol that could adapt to such dynamic topology changing needs. [9,134].
- Inaccurate state information: due to the frequent changing in network topology and the speed at which vehicle travel, the maintained state information are inaccurate, thus leading to a wrong routing decision. This issue need to be investigated further.
  As solution, meta-heuristic methods can be investigated to control the dynamic properties of VANET by using self-organizing solutions, which are adaptive to frequent VANET changes caused by node's mobility, as in [33]. Also, the estimation of link quality is a promising methods to overcome this issue. In fact, designing link state aware protocols can efficiently improve VANET performance.
- Scalability: the vehicle density can suddenly grow significantly and becomes very large in a road segment. Operability in both sparse and high node density situations is very important for routing protocols [135]. As the network size increases, the routing QoS degrades due to excessive routing protocol overhead and unreliability resulting from broadcasts and network flooding. In such cases, the network may not provide the desired performance. routing protocol should be designed to address this issue by minimizing network congestion resulting from increasing nodes population is a crucial issue achieving routing scalability in VANETs.

  To overcome this challenge, designing a protocol based on Meta-heuristics algorithms can be of immense benefit in vehicular communication networks. Du to special characteristic of bio-inspired algorithms, they can efficiently handle a large number of nodes in VANET

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Table 3 QoS Routing Protocols Comparison

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
MURU [79]	2006	Provides an optimal route by predicting the quality of the path	Delay Link reliability Hop Count	E2ED, PDR	Velocity	NS-2	IEEE 802.11 DCF	Urban	DSR AODV GPSR	Safety applications
Improving QoS in VANET using MPLS [80]	2012	Offers a high reliability in terms of E2E delay, packet loss and throughput	Delay	E2ED,Ploss, throughput	Direction Velocity	SUMO + NS-2	IEEE 802.11p	Urban	AODV V2V- AD hoc AODV V2I-MPLS enabled	Safety critical message and Multimedia applications
P-GEDIR [52]	2013	Reduces delay and has high reliability of links progression of a single hop Maximizes performances in terms of the average number of successful hops and the expected progress of a single hop	Distance Neighbor nodes Hop Count	HC	Direction Position	MATLAB	Any	Urban	GEDIR	Multimedia and real-time applications
EG-RAODV [45]	2013	Provides stable and reliable routes Achieves the smallest number of the link failures, the longest road life and the lowest average end-to-end delay values	Link reliability Delay	E2ED, PDR, LF RReq	Velocity r	OMNeT++	Any	Highway lane traffic scenario (5000m)	AODV OLSR PBR	Multimedia and real-time applications
ICAIR [81]	2015	Offers robust paths with a high probability connectivity	Delay,Mobility Neighbor nodes Distance	E2ED, PDR	Position Direction	Any	IEEE 802.11	Urban	GPSR	Multimedia and real-time applications

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Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
TLRC [82]	2016	Avoids selecting a street with most vehicles gathered at the intersection Improves the delivery ratio and reduce end-to-end delay	Delay Street connectivity	PDR, E2ED	Density	SUMO + MOVE	IEEE 802.11DCF	Urban	GyTAR STAR	Real-time applications
COMES [83]	2015	Improves the packet reception rate and reduce transmission delay Provides a reliable message delivery in VANET	Delay Link reliability Neighbor nodes	PDR, E2ED	Velocity	Any	Any	Highway	Any	Messaging applications
Stackelberg game [84]	2018	Improves the network performances in terms of stability of MPRs Provides a routes with a high throughput and end-to-end delay	Neighbor nodes Mobility, security Delay, Hop count Street connectivity	E2ED,HC throughput	Velocity Position	NS3	Any	Urban	OLSR street centic Qos-OLSR	Multimedia and real-time applications
CJBR [85]	2019	Improves the network connectivity Eliminates the dependency on traffic density inside the road segments	Neighbor RSU Distance Delay	E2ED PDR	Density Position	NS-3 + SUMO	IEEE0802.11p	City	A-STAR ICAR	Real time applications
CALAR-DD [86]	2020	Offers a high reliability in term of average delay, packet delivery ratio Provides the shortest route by reducing number of hop	Distance Hop Count Delay Neighbor nodes	E2ED PDR HC re-transmission ratio	Distance Direction	NS-3	IEEE 802.11p	City	IDLAR M-GEDIR FL-DGR	Safety applications

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Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
FBAODV [87]	2020	Establish a reliable network communication Reduces packet delivery ratio	Delay	E2ED PDR overhead	Mobility Velocity	NS-3	IEEE 802.11p	City	VACO GSR EGSR	Safety applications
LQFC [88]	2020	Reduces the redundant copies	Link Quality Neighbor Nodes Hope count	E2ED, PDR Overhead HC	Velocity	ONE	IEEE 802.11	Urban	LQRS FCRS	Multimedia and safety applications
A-AODV [33]	2013	Reduces the minimum delay without affecting the PDR Data are forwarded more quickly with a significant delivery rate	Delay Distance	E2ED, PDR, PLoss	Density	NS-2	IEEE 802.11 IEEE 802.16	City	AODV	Comfort: Voice radio streaming and safety applications
ACO-EG [67]	2014	Maximizes PDR and Routing replay ratio Fast adaptation to topology change Controls and avoids congestion	Delay Hop Count ARRr, ARDt	E2ED, PDR	Velocity Direction	OPNET	Any	Highway	DSR AODV	Safety applications
SAMQ [20]	2015	Reduces overhead and maximizes PDR Provides the most reliable route and it reduces the risk that selected route fails Packet loss rate is minimized	Delay Link reliability Neighbor nodes	E2ED, PLoss bandwidth	Velocity	OMNet++	IEEE 802.11p	Highway	VACO MAR-DYMO	Safety applications and critical message
AQRV [95]	2016	Reduces network overhead by using LQM Minimizes network exploration time Improves routes stability	Delay Distance Neighbor nodes	E2ED, CP, PDR	Position	VANET MobiSim + NS-2	IEEE 802.11p	Urban	GSR CAR SADV IEGRP	Comfort applications, safety applications and critical message

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Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
ADSR [96]	2016	Maximizes the lifetime of the recorded route Provides the shortest route between a source and a destination	Delay Energy Mobility	E2ED,overhead, throughput	Velocity Density Direction	OMNet++	Any	Unknown	DSR	Safety applications and best-effort traffic
QoS-ACOMpVS [97]	2020	Provides network scalability It adapts to fast topology change	Delay overhead	E2ED,CP PDR,TCP-ETX	Position Velocity Direction	NS-2	IEEE.802.11p	Urban	AQRV EGSR IGRP GSR	Video streaming
AISM [7]	2020	Provides a stable routes and avoids link failure	Delay Neighbor nodes	E2ED,CP PDR,HC overhead	Position Velocity Direction	NS-2 SUMO Move	IEEE.802.11p	Urban	GeoSVR EGSR	Comfort ans Safety applications RAGR GSR
QoS bee-VANET [99]	2011	Minimizes delay and maximizes NOL Suitable for transmission in realistic vehicle networks that require QoS guaranty	Delay Hop count Neighbor nodes	E2ED, PDR Bandwidth, NOL	Direction	NS-2	Any	Urban	DSDV AODV	Safety applications and Comfort:Voice and radio streaming.
MQBV [100]	2015	Offers a low number of dropped packets and allows a good bandwidth utilization by reducing end-to-end delay and maximizing PDR The network is less congested and packets number received successfully increases	Delay bandwidth, Neighbor nodes	E2ED, PDR NOL	Velocity Hop count	NS-2	IEEE 802.11p	Urban/Highway	ROVER	Safety applications and critical message
MABC [101]	2017	Improving Network lifetime and it decreases delay cost	Delay Energy	E2ED	Direction	MATLAB	Any	IVC traffic	Any	Comfort and safety applications

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Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
OFAODV [103]	2018	Improves network performances in terms of PDR, throughput, E2ED and the number of control packets, under different vehicle density conditions.	Delay Distance Neighbor nodes	E2ED, PDR throughput NSCp	Distance Direction Velocity	SUMO +OMNeT++	IEEE 802.11p	Urban/Highway	AODV FLRBF FAODV	Safety applications critical message and Multimedia applications
CB-QoS-VANET [66]	2019	Takes into consideration the general requirements of QoS during the cluster formation process Optimizes the network discovery algorithm by using a cached mechanism that reduces network overhead Offers the best route between source and destination	Delay Link reliability Mobility	E2ED,PDR, PLoss,jitter, throughput NOL	Density	OMNeT++	IEEE 802.11p+ IEEE1609.4DCRC+/WAVE	Highway	SAMQ OLSR	Safety and critical messages and Multimedia applications
Geo-PSO [65]	2014	Reduces the number of copies of duplicate messages during the transmission process Selects the next hop vehicle with a very high reliability	Link reliability hop count	PDR, NL	Velocity	NS-2	IEEE 802.11p	Urban	PGEDIR	Real-time applications

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Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
M-OLSR [106]	2014	Offers a more stable network by reducing overhead and maximizing end-to-end delay It is appropriate for any VANET scenario	Delay	E2ED, NRL, bandwidth	Density	NS-2 + C++	IEEE 802.11p	Urban	OLSR-RCF OLSR-pso	Comfort:Voice and radio streaming
PSO-DREAM +SIFT [107]	2015	Avoids centralized control and it reduces congestion and delays	Delay Neighbor nodes Energy	E2ED, PLoss, bandwidth	Density	NS-2	IEEE 802.11	Urban	DSDV	Safety, multimedia and Real time applications
TS-PSO [108]	2015	Allows Communication via VANET in real time between deposits and customers, and betwee delivery vehicles and the depot Minimizes the service time	Delay	E2ED, NRL bandwidth	Velocity	NS-2	IEEE 802.11p	Urban	Any	Real time applications
PSO-C -MADSDV [109,110]	2016	Offers links stability	Delay Distance Neighbor nodes	E2ED, PLoss throughput overhead	Density Velocity Distance	JADE Platform + MATLAB	Any	Highway	MADSDV	Comfort:Voice and radio streaming
PSOR [112]	2020	Minimizes routing loops Provides routes with minimum delay Provides bility to cope up with changing topology	Distance Delay	PDR, E2ED throughput overhead	Position Velocity	VanetMobiSim	IEEE 802.11p	City	AQRV AntHocNet	Comfort:Voice and radio streaming
DTRP [116]	2010	Maximizes the connectivity probability of routes between nodes and the gateway to the internet	Delay Hop count	E2ED, HC	Density	MATLAB + SUMO	Any	Tow-way street	GPSR GPCR OLSR	Comfort:Voice and radio streaming

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Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
BSC-GA [117]	2014	Ensures high connectivity and link stability	Mobility	Ploss	Density Velocity	NS-2+ SUMO	IEEE 802.11	Urban	GPSR AODV	Trafic monitoring and management
G-NET [118]	2016	It offers an optimization and paths maintenance	Hop count	PDR, overhead	Density	Vanet MobiSim+NS-3	IEEE 802.11p	Urban	DSR AODV	Safety critical messages
GABR [119]	2018	Offers a minimum transmission delay and stability of links by increasing the probability connectivity Adapt to the topology change	Delay Distance	PDR, E2ED	Direction Density	Any	Any	Urban	IBR CAR	Real time applications and safety critical message
IGAROT [120]	2019	Improves vehicles communication on the roads, thus reducing accidents caused by anomalies on the roads	Energy Distance	Novel route metric (received signal strength, transmission power, frequency, path loss)	Density Velocity	Any	IEEE 802.11p	Any	Any	Safety applications
RALAR [122]	2020	It reduce the search space for the desired route Provides strong routes Network lifetime is prolonged	Delay Energy	E2ED PDR overhead energy consumption		MATLAB	IEEE 802.11p	City	LAR KALAR	Safety application
RPVSANN [125]	2018	Reduces delay and bandwidth consumption Offers stable and reliable communication	Delay Security Link reliability Neighbor nodes	PDR, throughput RReqr	Density Velocity Direction	MATLAB	Any	Highway (100km) 3 lane traffic	PassCAR	Safety critical message and multimedia applications scenario

Table 3 continued

Protocol	Year	Offered QoS	QoS parameter used	QoS evaluation metrics	Vehicle metrics considered	Simulator	MAC layer	Scenario	Ccomparison protocols	Applications
OLSR-SA [128]	2015	Minimizes the communication cost Offers an efficient communication	Neighbor nodes Distance Delay	E2ED, PDR, throughput	Position	NS-2	IEEE 802.11b	Any	OLSR-GA	Safety critical message and multimedia applications
I-OLSR [53]	2012	Optimizes the communication function cost by maximizing the RDP and minimizing NRL and the end-to-end delay	Delay Neighbor nodes	E2ED, PDR, NRL	Direction	SUMO+ NS-2	IEEE 802.11b	Urban	OLSR	Traffic monitoring
EIAC-ABCMR [129]	2017	Prevents stagnation and Delayed convergence during the optimal prediction of the multicasting tree	Delay Energy	E2ED, Ploss, throughput, bandwidth	Velocity	NS-2C+++	Any	1200 × 1200 square meters of terrain area	ABCBM	Real time applications RACOBMR BLABMR
GHR [68]	2016	Avoids loops and Select the next node with a certain degree of randomness No need to add any information to the hello messages	Distance Neighbor nodes Hop count	Ploss, PDR, E2ED, HC, %idle time	Density	EstiNet network simulator	IEEE 802.11p	City Greedy-DNT iAODV	MMMR	Non-real time applications
MWOA [130]	2021	Transmits a video from the accident to other vehicle with high QoS	Distance Delay	E2ED, PDR, troughput	Position	NS-2	Any	Highway	Adaptative routing MERVS MFO WOA GA	Video streaming

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because they are based on local and limited cooperation and communication among nodes when searching for routes.

– Security have a great impact on future deployment and application in VANET such as, safety-related messages, transportation efficiency, and entertainment content. Vehicles communicating within the infrastructure should allow users to decide what information should be exchanged and what information should be kept private. Also, The changing topology of the network makes the management of security [136] and privacy policies very difficult.

As a solution, to overcome this challenge, researchers have to incorporate new privacy and security mechanisms in the VANET infrastructure, as in the example of [137]. Designing appropriate authentication mechanisms and strong security protocols seems to be an interesting research axe in VANET [138]. Designing a new privacy mechanism based on meta-heuristic or Software-Defined Networks (SDN) as in [139] can overcome problems related to security.

7 Conclusion

Considerable work was completed on QoS routing protocols in VANET, the QoS routing in a such network is a challenging task due to its inherent characteristics. In this paper, we have presented an up to date survey of major QoS routing solution for VANET. The contribution of the paper are as follows:

– The basic concept of QoS in VANET have been described with providing details about most important QoS routing parameters and evaluation metrics.
– The classification of the protocols has been done on the basis of algorithm and mechanism used to design and improve the QoS of routing protocols in VANET.
– The protocols are selected so as to highlight the different approaches used to optimize QoS routing in VANET, based on our observation we have classified we have classified QoS routing protocols in VANETs into QoS routing protocols not based on meta-heuristics and QoS routing protocols based on meta-heuristics.
– For each protocol, the functionality, the strength and weakness have been described briefly. Finaly, a detailed comparison of all QoS routing protocols have been done and the basic challenges of QoS routing have been reviewed.

We believe that this survey is useful for VANET researchers, since it presents a global guide to QoS routing for VANET and it provides a vision on the tendencies emerging optimization approaches of QoS routing in a such network. In our study, we deduce that QoS performance is achieved by a trade-off mechanism between QoS parameter. Further research is needed to confirm this novel finding and classifies these trade-off mechanism into different categories. Also, in future we would like to make a comparison between the protocols of the two classes that we have defined with simulation.

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A survey on QoS routing protocols in Vehicular Ad Hoc Network (VANET)

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Abstract
Vehicular Ad Hoc Network (VANET) is an emerging new technology and a promising approach for Intelligent Transportation Systems (ITS) domain. Many researchers focused on the creation of reliable, scalable and efficient routing protocols for VANET and improve their Quality of Service (QoS). Communication among vehicular nodes which enable drivers to take appropriate decision needs a high reliability, therefore the design of a routing protocol that ensures a certain level of QoS, represents one of the most important challenges of the vehicular networks, because VANET are characterized by specific features, such as restricted mobility, high node speed and a very dynamic topology. keeping in view of the above, this paper provides a detailed description of various existing QoS routing protocols in literature with an aim to classify them. Based on the optimization methods used to improve routing protocols in VANET, we have surveyed and classified the routing protocols into two classes, QoS routing protocols not based on meta-heuristics and QoS routing protocols based on meta-heuristics.

Keywords Vehicular Ad-Hoc Network · Routing protocols · QoS · Meta-heuristics · Optimization