Vehicular Ad Hoc Networks: A Focused Survey

Advances and Current Issues

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Abstract **– Vehicular networks are a kind of technology that requires continuous researcher. In this article, we give an overview of the ITS (Intelligent Transportation System), showing current known problems in the VANETs (Vehicular Ad Hoc Networks) and proposed solutions in existing literature, with emphasis on the following topics: geo-localization, QoS (Quality of Service), and traffic safety.**

Keywords – VANET; issues; geo-localization; QoS; traffic safety.

I. Introduction

Due to population growth and industrial development around the world, vehicle traffic load is getting heavier every day, increasing the likelihood of accidents. This prompts automobile industries to manufacture their vehicles with ITS, in order to ensure a more secure and comfortable vehicle traffic.

To support ITS, the IEEE 802.11 group has produced the IEEE 802.11p protocol [1], which developed applications that include the exchange of data among vehicles using the road infrastructure, thus bringing the Internet to the car framework. Using dedicated wireless DSRC (Device Short-Range Communication), cars are able to communicate with each other through VANETs, i.e., vehicles have intelligent sensors able to detect the road conditions.

VANETs correspond to a field of vehicular networks which is widely recognized as an essential element for ITS. VANETs have the potential to support a wide range of applications and services [2]. So far, the focus has been mainly on security applications, such as road awareness, accident warning, traffic surveillance, which have a huge impact on avoiding traffic accidents and increase the safety of road transport [3][4].

One of the known definitions of VANETs is a type of wireless network where each node is a moving vehicle on the road; the vehicles communicate with each other in order to make the traffic safer and generally better. This type of node acts as a router transmitting a message to another node. This network has two types of communication, V2V (vehicle-to-vehicle), and V2I (vehicle-to-infrastructure). Its main function is to provide secure applications in real-time to users, thus delivering the data at the right time, reducing accidents and delays [18].

However, there are security-related issues, and problems with the management of the media. Wireless network, like VANETs, have a number of communication requirements to work well. The communication requirements have a large number of adverse effects on the characteristics of VANETs, e.g., multi-path disappearance and shading the wireless channel, fluctuating density nodes in different scenarios, and quick changes on the network topology.

Another problem is the creation of flexible services, able to adapt easily to their environment, so that one can connect to any device, while ensuring the safety and performance of the communication.

VANETs support from the simple exchange of information to the integration of highly complex infrastructure. The general application framework takes into account the dissemination of warning messages from those vehicles that could find accidents or dangerous situations, in order to provide useful information for drivers, wherever they might be, in restaurants, hotels and service stations, as well as entertainment: Internet, download multimedia, or chat among vehicles [5].

The rest of the paper is organized as follows. Section II presents the related work; Section III describes the current problems and the proposed solutions; and Section IV shows the conclusion and future works.

II. Related Work

Many researchers have been interested in solving issues related to VANETs and improving their advances. Some of these researches focus on an overview related to the general information pertaining to VANETs and others tackles a more specific topic. In this article, our approach is to tackle both of these scenarios, taking a better look at specifics problems and advances related to VANETs.

Gupta et al. [19] present general idea about VANETs, showing an overview that include basic information. The authors provide focus on the various aspects of VANETs, such as architecture, characteristics, challenges, glimpse of routing protocols, and simulation models used for VANETs. They clarify the advantages and disadvantages associated with sending information protocol among the nodes of VANETs; showing the difference to sending information on the highway and in the cities. Delay and interference are associated with each case. Their results show that the speed and distance influence the efficiency of information exchange, as there is a maximum time for sending such information. In an attempt to improve algorithms for sending

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and receiving data, they suggest that the network nodes should work as routers using routing tables.

Eze et al. [20] provide an overview of the current research state, challenges, potentials of VANETs as well as the ways forward to achieving the long awaited ITS. The authors present: a comparison of high-speed wireless communication technologies for vehicular networks, spectrum allocation issues in VANETs, message broadcasting, routing protocols, congestion control techniques in inter-vehicle communication, security, privacy, anonymity and liability, reliability and cross-layer approach between the transport layer and the network layer. With their analysis, they have determined the minimal prerequisites to QoS applications in VANETs. Then, the high reliability and the low latency are not guaranteed by any of the revised algorithms in their paper. The paper suggests that the challenge to develop a security solution capable of supporting the exchange of authentication, accountability and privacy, according to each vehicle's information should be disclosed to appropriate government agencies (transport authority) over the network. It is one of the biggest problems of security and privacy in VANETs.

Sanguesa et al. [21] show a clear guideline of the benefits and drawbacks associated with different schemes. The authors did an analysis of the most relevant broadcast dissemination available in a fair comparative scheme analysis by evaluating them according to the same environmental conditions, focusing on the same metrics, and using the same simulation platform, specially designed for VANETs, highlighting their features, and studying their performance under the same simulation conditions. The paper describes one of the biggest problems that the researchers have found when comparing their results with the existing state-of-art. Most researches have taken different approaches and they try to prove which approach has the best performance. They have proven those approaches in different environments with unrealistic parameters leaving inaccurate and unrepresentative conclusions. For this reason, their work has reproduced simulations using the same metrics for different tools, comparing the methods to the same simulation conditions in order to determine which method is the best for each situation.

Other researches, in these cases with specifics subjects, such as [5], designed a collaborative virtual environment that unifies the knowledge and is integrated with vehicles to endow the final user with the necessary information. The authors developed a model-driven approach that generates a groupware application to improve the collaborative work and access to services. The implemented tool facilitates the development and implementation of collaborative frameworks in VANETs. In this kind of collaborative system, it is not essential for all data to be received in a single node, which reduce duplication of information and increases the data flow exchange. However, this system does not consider the vehicle speed, or the environmental changes or handoff that could happen, showing that this solution requires other features in order to function in any VANETs structure.

Tabassum et al [7] developed an interference-aware high-throughput channel allocation mechanism, called HT-CAM that addresses the unique challenges of CRVANETs. They created conflict graphs of link-band pairs to extract non-interfering OBU (On Board Unit) pairs that can communicate simultaneously on a given channel, increasing the spatial reuse of the available channels. In addition, their work formulates a high-throughput channel allocation problem as a MILP (Mixed-integer Linear Programming) problem, showing that the proposed HT-CAM provides a better network performances compared to state-of-the-art protocols. The comparative graphs show that the HT-CAM technique can improve decision-allocation in the most efficient channel for communication in VANETs. To test the new technique efficiency they compared the TE-CAM [33] and CC-VANET [34] methods. As its results, Tabassum et al. [7] proved that their technique outperforms the other two methods in terms of network throughput, channel use, and the late delivery of end-to-end packages.

Gonzalez et al. [12] present an analysis of several protocols proposed in literature for message dissemination in VANETs. The authors proposed a protocol that sets and wait a time to relay candidates. They have demonstrated that it is possible to reduce the delay needed to cover a given area. For that, when they stop the beacon transmissions a warning message is detected and it does not provide a significant performance improvement. Nonetheless, by allowing a continuous channel access, it proves that the performance of any protocol might be greatly increased.

The state-of-art in VANETs is constantly developing, though much more research is required, as many fundamental issues remains. This paper differs from others because of the approach, bringing information and solutions by different authors in the same paper.

III. CURRENT ISSUES AND PROPOSED SOLUTIONS

Many important topics in VANETs are currently under intensive research and discussion. These issues and their background are presented in this section.

A. General Issues

The ordinary issues to VANETs are limitation in bandwidth utilization, frequent link disconnection, small effective diameter, security and privacy, among others [19].

Issue 1: Limitation in bandwidth utilization - There is no central coordinator that controls communication. The main idea is to allow usage of all users in this network to share the same bandwidth without causing harmful interference. VANETs face bandwidth allocations challenges due to the random number of users in the application. The time delay related to this issue is reduced by fair bandwidth utilization. If a vehicle wants to send a message and there is no medium for transmission, then it has to wait, which leads to high latency. Bandwidth is important to the congestion control. Bandwidth utilization is very important for sending large amounts of information, otherwise the system will be overload.

Issue 2: Frequent link disconnection - VANETs changes all the time and this happens dynamically and fast. This brings changes in the network topology. Because of the network high mobility and frequent fragmentation, the link disconnects often due to the short connection time between nodes in VANETS.

Issue 3: Small effective diameter - Maintaining complete global topology is impossible due to weak connectivity between nodes and results in issues when applying the existing algorithm.

Issue 4: Security and privacy – In VANETs, vehicles connect with other random vehicles without knowing their intention. It brings vulnerability to the users to succumb to different malicious attacks. The detection and prevention of attacks in VANETs should be properly designed to ensure the safety of users are not violated, in a real-time framework.

Issue 5: Routing protocols - Due to the above challenges, designing an effective protocol, which transfers maximum packets in minimum time, is not easy to implement. So the design of an efficient routing protocol demands advancements in MANET's architecture, to accommodate the fast mobility of the VANETs nodes in an efficient manner.

For the above issues, the proposed solutions are showing in Table I.

TABLE I. ISSUES IN VANETS AND PROPOSED SOLUTIONS IN THE LITERATURE.

Issue	Proposed Solution
Limitation in bandwidth	Use an algorithm that control congestion
Link disconnection	OLSR (Optimized Link State Routing Protocol)
Small diameter	Position-based Protocol
Security and Privacy	SMT (Secure Message Transmission)

To solve issue 1, the solution proposed by Dongre et al. [22], implements an algorithm that can control and detect the traffic congestion and can send only one message broadcasted by the vehicle, which reduces the overhead on the network, improving bandwidth utilization.

To solve issue 2, it is possible to use the OLSR (Optimized Link State Routing) or its variations. OLSR is an optimization over a pure link state protocol as it compacts the size of data sent in the messages, and reduces the number of retransmissions to flood these messages in the entire network [23]. Today the OLSR has its variations. Gautami et al. [24] have proposed a Meta-heuristic algorithm as optimization of the OLSR protocol to enhance the performance of individual search methods in VANETs.

To solve issue 3, the proposed solutions include position-based protocols, e.g., MFR (Most Forward within Radius) [27], LAR (Location-Aided Routing Protocol) [28], EGR (Energy-Aware Geographic Routing) [29]; they assume that the vehicle is equipped with GPS (Global Positioning System) device in order to find its own geographic position.

To solve issue 4, a combined group of protocols was presented, but the final choice was SMT (Secure Message Transmission) protocol [13]. The data is only transmitted in the communication among registered vehicles. This protocol ensures that the vehicle IDs are not exposed for anyone. SMT utilizes MAC (Message Authentication Code) to check the integrity and authentication of its origin.

B. Geo-localization

Currently, navigation technologies are GPS-dependent, which has several problems. The most important problem is price, especially if one is looking for an accurate GPS system. Cheap GPS devices are not precise and can become unusable for autonomous navigation [16].

Therefore, current researches intend to develop technology to obtain information about the position in real-time applications such as real time navigation, traffic behavior studies, and applications related to the location, such as forward collision warning application of the vehicle based central server [1].

In Fig. 1, we show the issues that the papers bellow tries to focus on.

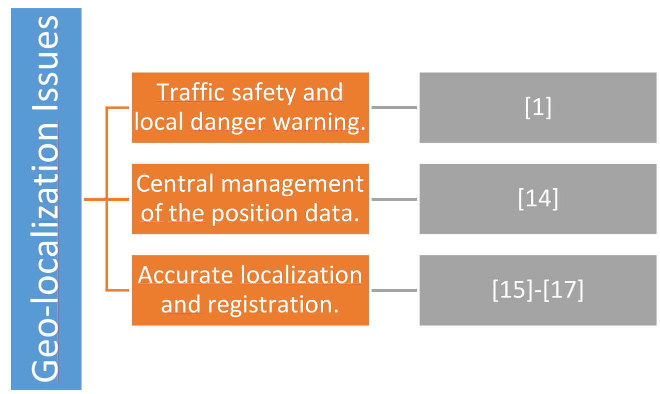

Figure 1. Relation between surveys and issues in VANETS.

Thenmozhi et al. [1] propose vehicle-to-vehicle model that allows moving vehicles to send geographical and speed data over VANETs to prevent accidents. Their method uses Dedicated Short Range Communication (DSRC) Wireless Devices and a repeater in vehicles that solves issues in four-way interior road junctions by sending the data signal for longer distances during local danger circumstances.

Mo et al. [14] consider the vehicle movement patterns (position, speed, and direction) can be stored in the form of a dynamic vector, which has implemented position updating in central MOD (Moving Object Database). It has a vehicle position data updating strategy with packet repetition based on Kalman filter prediction. An algorithm with packet repetition was designed; it can not only generate a position updating data according to a preset threshold, but also decides the packet repetition mode related to the distance of two adjacent vehicles in order to reduce data loss. The simulated results show that vehicle position data updating frequency was obviously reduced and the reliability of the communication is greatly improved through packet repetition mechanism by using this position updating strategy. Their experiment uses the colored noise Gauss to simulate the noise of the Kalman filter to predicted background. They choose the colored noise instead of white noise for the Kalman filter, which does not cover all the noise that might

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be generated. They also consider that the delay transmission is extremely small, which is not consistent with reality. As justification, they assume that the presence of transmission delay always makes position updating data outdated, so they decided not to allow position data to be stored in the database. For this situation they intend, as work, to research about how to ensure the positional deviation error under the control in the condition of high time delay.

Costea and Leordeanu et al. [15] have proposed a complete system to geo-localization from aerial images in the absence of GPS information. Their proposed pipeline includes contributions with efficient methods to road and intersection detection, intersection recognition with geometric alignment to accurate localization, followed by road detection enhancement. It proves that using learned high-level features is feasible and it is possible to achieve a high level of accuracy. It can be used as a GPS alternative, or in conjunction with GPS, bringing valuable contributions to the literature and to many applications that require offline or online, real-time processing. The limitation of this approach is that the high level of accuracy only happens if the geolocation is from images alone.

Gupta et al. [16] propose new approach to geo-localization position of a mobile platform. Their intent is to solve the problem of accurate mobile platform geo-localization as a combination of approximate geo-localization and accurate relative localization. The article presents the algorithmic and implementation details of their method and demonstrates it for several different types of maps from different regions of the world. The relevance of their results is a system that can provide a fully automatic global localization at a low infrastructure cost.

Ounia et al.'s [17] have as objective to minimize and simplify the computing process in the MS (Mobile Station) during its geo-location phase needed especially to handover. This work additionally considers designing EToA (Extended Time of Arrival) as extended version of ToA (Time of Arrival), following the same principle, using another aspect of the computational process. As a result, the proposed technique is convergent within a reduced number of iterations. Moreover, the implementation simplicity and low computational overhead constitute their major advantages.

C. QoS

Until now, no project has achieved a reliable, flexible and adaptable way that meet the requirements of safety and autonomous driving applications.

In order to guarantee the exchange of information and the reliability in ad hoc networks, the researches should take into account the implementation of QoS, where the routing protocols are the main idea. These protocols aim to choose the best route from source to destination, meeting the QoS requirements, and calculating the QoS parameters. The selection and improvement of these protocols have fundamental importance to improve QoS in VANETs [9].

The current proposed solutions give us an idea of the performance gains that were achieved so far, however, they are specific to a particular application and context and applied in all environments [8].

Nowadays, in the literature, the majority of routing protocols that implement QoS require additional exchange of messages control to determine the QoS parameters and do not consider the problem of congestion during transmission of the data. These protocols actually increase the overhead of routing, causing wear in time and energy during a device discovery path, increasing packet loss [9].

In Fig. 2, we present the issues most searched on QoS in VANETs that are presented in [4][8][9].

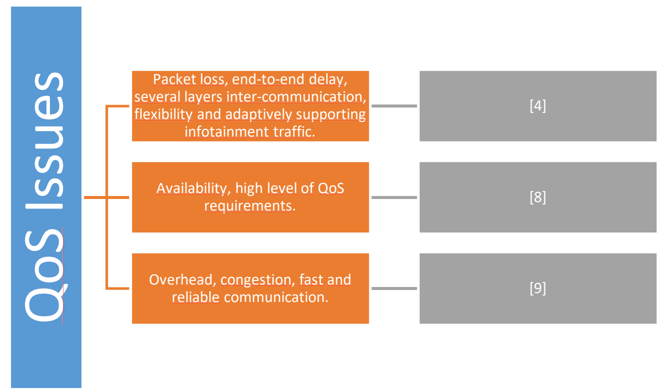

Figure 2. Relation between research and QoS issues in VANETS.

The main idea of the work by Rizzo et al. [4] is to design an architecture for the provision of various levels of QoS in VANETs. The basis of their approach is in CONTACT (Contact and Content Aware Communications for QoS support in VANETs). It was developed through the investigation of several communication strategies capable of adapting, at the same time, to the highly volatile and unstable vehicular environment, to content attributes and properties, and to a diversified set of application performance requirements.

Sumra et al. [8] present the SBC (Secure Business Communication) model and explain the components of the proposed model. It uses TPM (Trusted Platform Mobile) as its core component and TPM ensures a secure communication between user and business parties in VANETs.

With the purpose of reducing the overhead introduced to collect information from neighbor nodes and to obtain an accurate estimate of QoS parameters, Al-Ani et al. [9] describe a new approach for calculating QoS parameters locally and avoiding congestion during data transmission. It uses the SNMP (Simple Network Management Protocol) to estimate these values locally. With the help of the SNMP agent, the QoS parameters are calculated locally without exchanging any additional control message and without synchronization. Their approach evades any network overhead for QoS computation as compared to other QoS-aware routing protocols. This approach uses parallel and global search abilities of ACO (Ant Colony Optimization) algorithm to find multiple paths to the destination satisfying the specified QoS requirements. Their results show that the approach of QoS QoRA (Routing based on Ant Colony Optimization) protocol is scalable and performs well in high

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mobility, being a model to the congestion avoidance mechanism that evades any network overhead for QoS computation as compared to the other QoS-aware routing protocols.

D. Traffic Safety

In general, vehicle network applications are classified as secure applications and non-secure applications. Safety applications are used to notify drivers of urgent events on the road to avoid accidents. Non-secure applications are applications used by drivers or passengers to access the wireless network for entertainment as browsing websites, access email, and play games [10].

Emergency messages are considered an effective solution to improve road safety conditions. The notification allows drivers to have more time to react to avoid accidents, and to improve the safety of drivers and passengers. For this, the vehicles are equipped with intelligent sensors that help to detect road conditions, trying to minimize the problems of local risk and improves traffic management [1].

For the efficiency of these notifications to be immediate, the latency of transmission should be kept within the tolerable range, falling on the subject of QoS.

Among the articles referred in this work, three have related issues with traffic safety, as seen in Fig. 3.

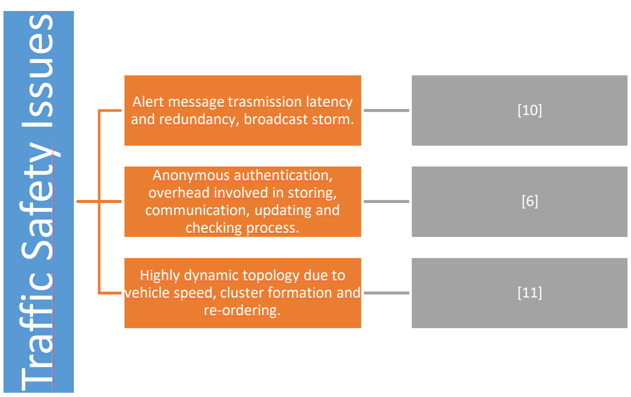

Figure 3. Relation between referred work and Traffic Safety issues in VANETS.

Chang et al. [10] have focused on the alert message dissemination in VANETs. Their idea proposes a fault-tolerant broadcasting protocol for disseminating the alert messages on highway. The proposed protocol designates two vehicles, which are the farthest and sub-farthest vehicles in the transmission range of the source vehicle as the relay candidates. In addition to this, they created an exponential back-off method that can effectively reduce the number of alert messages. This method improves not only the transmission delay of the alert messages but also the number of the alert messages in vehicular wireless networks, increasing the reliability of the system. Their simulation results showed that the fault-tolerant broadcast protocol outperforms the flooding method and the ACK (Acknowledgement) based broadcast protocol, in terms of the number of the alert messages, the number of the ACK messages and the total number of messages. However, it does not outperform the transmission delay of alert messages and penetration rate.

Wang et al. [6] introduce ECPB (Efficient Conditional Privacy-Preserving) authentication scheme based on group signature for VANETs. Though group signature is widely used in VANETs for security requirements, the existing schemes based on group signatures suffer from longer computational delays in the CRL (Certificate Revocation List) checking and in the signature verification process, leading to lower verification efficiency. In their scheme, membership validity (a validity period) is required when a vehicle applies for a group membership and this validity is used to check whether the vehicle is still a group member or not, which can be used as a substitute for the CRL checks. Neglecting the CRL checks will sharply decrease the costs incurred in the signatures verification. In addition, the proposed scheme also supports batch verification. Their experimental analysis proves that the proposed scheme exhibits improved efficiency over the existing schemes, in terms of verification delay and average delay. The security analysis and experimental results show that ECPB delivers higher efficiency verification requirements of VANETs, and satisfies the Privacy-preserving Communication for VANETs.

Ambareish et al. [11] proposed a beacon-based clustering algorithm achieving a significantly higher cluster stability than previous methods, like the CBLR (Cluster Based Location Routing) algorithm [11]. The basis of their approach is to use local mobility measure to decide which cluster heads should remain in their roles and which should change their state. In addition to the already existing states, the authors introduced an EN (Emergency State) for ambulances, police, and other emergency vehicles. In Table II, we present two characteristics of VANETs that result in the consequences that their paper tries to solve.

TABLE II. VANETS CHARACTERISTICS WITH RELATED ISSUES AND ITS CONSEQUENCES.

VANETs Characteristics	Related Issue	Consequences
Frequent connection drop of the network Highly changing topology	Frequent cluster formation and re-ordering	Decreases cluster stability

IV. CONCLUSION AND FUTURE WORK

This paper provided a summary of the most important subdivisions of vehicular networks, presenting the most accurate work in each subject of VANETs in order to enrich and encourage research and future work for the development of vehicle networks. It is worth noticing that the topics covered in the articles studied highlighted the need for performance improvements, control and management of VANET networks, as the main ideas of this work.

For future work, we intend to find a method to reduce the delay on transmission messages in VANETs, comparing our results with the existing methods in the state-of-art.

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