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Vehicle Sensing and Localization in Vehicular Networks

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Abstract. In this paper, we provide a review of vehicle sensing and localization in autonomous driving. In autonomous driving, the significant and essential operation is accurate vehicular sensing. Vehicular sensing is the most demanding area of vehicular communications and has many envisioned applications in traffic safety and congestion avoidance. We begin by providing a brief overview of the Vehicular Ad Hoc Network (VANET) architecture, including its types. Additionally, we delve into in-vehicle sensors and their classification. The number of sensors in cars continues to grow, driven by their advantages in preventing injuries, enhancing driving performance, and supporting ubiquitous applications centered around vehicle sensing. We study and compare the current and existing techniques of localization (synchronous and asynchronous) and approaches for vehicle positioning, which is used for communication-based (e.g., GPS information) and reflection-based (e.g., RADAR Cameras). Also, we have also reviewed the vehicle-to-vehicle/infrastructure communications (V2X) with an emphasis on the 5G perspective.

Keywords: 5G Localization; Localization; VANET; Vehicle Sensing

1. Introduction

The vehicular ad-hoc network (VANET) is also known as the network on wheels, which is used to provide communication between vehicular nodes. The main objective of VANETs is to build an intelligent transportation system (ITS). It is basically a subset of a Mobile Ad Hoc Network (MANET) in which nodes will allow car-to-car (V2V) as well as car-to-infrastructure (V2I) communication. Vehicular Ad hoc Networks (VANETs) are an emerging and demanding paradigm in wireless networking that supports a variety of applications in safety, traffic efficiency, and entertainment (Singh, Rawat, and Bonnin, 2014). The IEEE committee has developed the IEEE 802.11p standard for VANET Safety-related applications in Intelligent Transportation Systems (ITS) (Abbasi and Khan, 2018).

The U.S. Federal Communications Commission (FCC) has allocated a spectrum bandwidth of 75 MHz with a frequency of 5.9 GHz for vehicular communication which is known as the Dedicated Short Range Communications (DSRCs), facilitating communication between Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) systems. Faster communication and great safety between vehicles are said to be achieved by Dedicated Short Range Communication (DSRC)(Aziz *et al.*, 2022) In the past years, vehicular

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communication has shown rapid growth in the areas of sensing, computational, and communication capabilities. Various innovative services and applications, including traffic management, smart navigation, safety, infotainments, etc., have developed because of these great improvements in vehicular communications. By exploiting their sensing and communication capabilities, the vehicles can cooperate to create so-called vehicular sensor networks (VSNs) (Lee and Gerla, 2010). VSNs have peculiar characteristics at various levels, from communication, networking, and data processing perspectives.

The development of autonomous driving (automatic driving) is rapidly growing due to artificial intelligence (Han *et al.*, 2018). Its primary goals are to reduce car accidents, alleviate traffic congestion, and decrease greenhouse gas emissions by automating the transportation process (Perfecto, Del-Ser, and Bennis, 2017). The growing interest in this area has attracted many R&D investments not only by automobile industries but also by Internet companies and cellular companies. Vehicle positioning is one of the important operations of auto-driving and tracking other parameters such as size and trajectories. This information then serves as input for computing and control tasks of autonomous driving. The exchange of absolute location information among a group of nearby vehicles is facilitated through vehicle-to-vehicle (V2V) transmission. In this kind of data, there is a high latency with low reliability that has arisen from inaccurate Global Positioning System (GPS) information (Khakpour, Pazzi, and El-Khatib, 2017). Another approach involves deploying sensors, ranging from Light Detection and Ranging (LIDAR) to Radio Detection and Ranging (RADAR) and cameras. However, RADAR and LIDAR can sense line-of-sight (LOS) vehicles but are unable to see through large solid objects to detect blocked vehicles. On the other hand, cameras face challenges such as a low recognition rate, poor real-time performance, and the high cost of associated devices. Currently, for areas that are free from obstructions, global navigation satellite systems such as the Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), and BeiDou satellite positioning system (BDS) (Cui *et al.*, 2016) are widely used in vehicles. This is because these systems were designed for line-of-sight (LOS) environments. For non-line of sights (NLOS) environments like urban areas with tall buildings and tunnels, these systems are inaccurate. Thus, these systems must be integrated with other techniques such as short-range wireless positioning (Wei and Qi, 2011) in wireless sensor networks to improve accuracy (Khakpour, Pazzi, and El-Khatib, 2017). For example, a Chinese area positioning system (CAPS) based on ultra-wideband (UWB) signals has been proposed. It was found that even in NLOS environments, sufficient signal levels can be obtained at distances up to 200 m. Further, mmWave signals can provide centimeter-level ranging accuracy.

Vehicular communications have more attention due to more wireless technologies being integrated into vehicles for applications related to safety and leisure (infotainment), among others (Perfecto, Del-Ser, and Bennis, 2017). Fifth-generation (5G) cellular networks are being developed to support a variety of innovative wireless applications. 5G standardization committees and working groups are actively investing in enormous research efforts towards vehicular communication. The transition to 5G mobile communication and the modernization of 4G solutions have created good platform of vehicular communication (Babkin *et al.*, 2021) Unfortunately, the challenging wireless communication conditions derived from the mobility of vehicles, their relatively high speed, the dynamic topology of vehicular wireless networks, and its higher likelihood to produce inter-vehicular line-of-sight blockage are factors that pose significant challenges to be dealt with.

This review paper is structured as follows: In Section 2, we present a brief introduction to the general architecture of VANET, including network components, communication types, and layered network architecture. Section 3 introduces and reviews the in-vehicle sensor types and classifications. Section 4 covers vehicle sensing applications and their platforms. Section 5 discusses vehicular sensing transmission approaches for vehicle position. Section 6 presents the localization techniques of vehicular communications by using 5G. Section 7 addresses open research challenges and conclusion of the paper.

2. General Architecture

This section outlines the system architecture of VANET, including its components. Subsequently, we delve into the communication architecture of VANET, and finally, we discuss the layered architecture of VANET.

2.1. Main Components

The VANET system is divided into three domains by IEEE 1471-2000 and ISO/IEC 42010 (Emery and Hilliard, 2009) architecture standard guidelines: the mobile domain, the infrastructure domain, and the generic domain. There are two parts of the mobile domain: the mobile device domain and the vehicle domain. All cars and buses are in the vehicle domain, while all kinds of portable devices like smartphones and navigation devices are in the mobile device domain. The infrastructure domain further divides into the roadside infrastructure domain and the central infrastructure domain. Traffic lights fall under the roadside domain, and infrastructure management centers for traffic and vehicles are part of the infrastructure domain. The architecture development of VANET is still in progress, and it varies from region to region worldwide. According to CAR-TO-CAR (C2C-CC) (Manifesto, 2007), communication consortium, which is the major driving force of VC in Europe has, published its manifesto in 2007. According to the system, the architecture contains three domains: in-vehicle, ad-hoc, and infrastructure domains.

In the in-vehicle domain, there is an on-board unit (OBU) housing one or multiple application units (AUs), and there exists a wired or wireless connection between them. On the other hand, in the ad-hoc domain, vehicles are equipped with OBUs, serving as mobile units, while roadside units (RSUs) function as static nodes. RSU uses gateways in order to connect to the internet, and they can communicate with each other directly or by multi-hop. The infrastructure domain access is classified into two types: RSU and hot spots (HSs). The internet communication of OBUs is via RSUs or HSs. OBUs may also use cellular radio networks (GSM, GPRS, UMTS, WIMAX, AND 4G/5G) (Rashid and Datta, 2017).

2.2. Communication Architecture

VANETs can be classified into four types by communication architecture. Table 1 summarizes the key functions of each communication type (Lu *et al.*, 2014).

2.2.1. In-vehicle communication

It is becoming more and more important in VANETs research, and refers to the in-vehicle domain. In-vehicle communication systems, the performance of a vehicle in the form of all driver's fatigue and drowsiness will be detected, which is critical for driver, and also public safety.

2.2.2. Vehicle-to-vehicle (V2V) communication

In V2V communication, vehicle send messages to each other with information about what they're doing. This data would include speed, Location, the direction of travel, braking, and loss of stability.

2.2.3. Vehicle-to-road infrastructure (V2I) communication

It is the wireless exchange of data between vehicles and road infrastructure. V2I communication is typically wireless and bi-directional: infrastructure components such as lane markings, road signs, and traffic lights can wirelessly provide information to the vehicle and vice versa.

2.2.4. Vehicle-to-broadband cloud(V2B) communication

All the vehicles use a 4G/5G wireless connection to use the broadband cloud. This type of communication will be very useful in vehicle tracking and for driver assistance because the cloud server contains more traffic information and monitoring data as well as infotainment.

Table 1 Function of communication type (Lu *et al.*, 2014)

V2I	V2V	V2B	In-Vehicle
Data Collection Environment weather Road Condition	Lane Passing V2V Spacing DSRC	Data Processing Power Consuming Traffic Control	Data Processing Power Consuming Vehicle Condition
Driver Assistance			
Wireless Communication			

2.3. Layered Architecture for VANETs

The open systems interconnection (OSI) model is a conceptual framework that divides communication functions into one of seven logical layers. The session layer and presentation layer are omitted here, and a lower layer can be further partitioned into sub-layers in this VANET architecture (Hartenstein and Laberteaux, 2009).

3. In-Vehicle Sensors

Vehicle sensors are the most demanding area of VANET because sensors play a very important role in improving the performance of a vehicle, its operation monitoring and the status of its parts, also enhancing the driving experience. Due to an increase in the advancement of automotive functions, the number of sensors in vehicles also increases. Currently, some luxury vehicles have more than 100 sensors present to support various functions and to enhance their in-vehicle services. Nowadays, modern automobile designing can be done using different types of sensors.

There are many different types of sensors. According to W. J. Fleming he categorizes in-vehicle sensors into three groups according to their place of deployment in a vehicle: 1) powertrain sensors, 2) chassis sensors, and 3) body sensors (Nashashibi and Bargeton, 2008). According to the application domains vehicle sensors can be categorized as a) Sensors for Safety, b) Sensors for Diagnostics, c) Sensors for Convenience, and d) Sensors for Environment Monitoring, as shown in Figure 1.

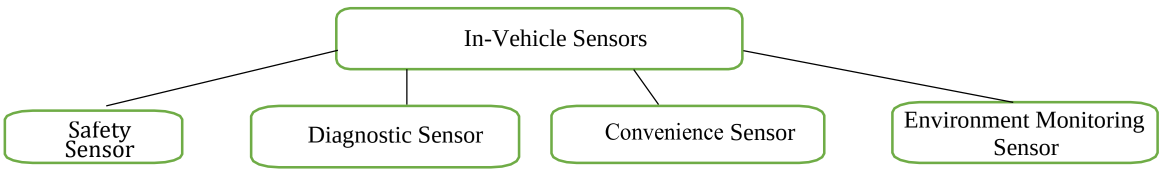

Figure 1 Categories of in-vehicle sensors

3.1. Safety Sensors

For safety-enhancing systems from driving accidents, a safety sensor is added to the vehicle (Abdelhamid, Hassanein, and Takahara, 2014). These safety sensors can be further classified into many types, as follows.

Distance Sensors, Night vision sensors, speed sensors, angular rate/ linear acceleration inertial sensors. This category of sensors has very much importance in ITS safety applications, and some examples are Blind Spot Detection, Lane Change Support, Lane Departure Warning, Lane-keeping

Assistance, Forward Collision Warning, Backup Crash Warning, Parking Assist, and Stop-and-Go systems.

3.2. Sensors for Diagnostics

These sensors provide on-board diagnostic services to the driver by detecting any components malfunctioning in a vehicle. With these alerts for drivers, they also keep track of these measures to use them in the next Diagnosis Service check to save time finding out the problems. These sensors are deployed in the powertrain area because they monitor the mechanical parts and engine of the vehicle. However, some of them can be used for diagnosing the chassis and body of the vehicle. The categories of diagnostic sensors are shown in Figure 2.

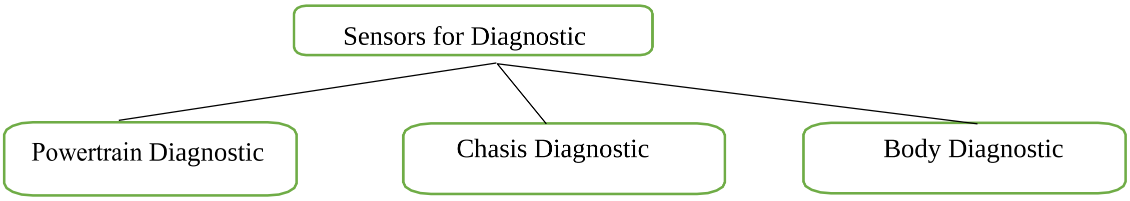

Figure 2 Categories of diagnostic sensors

3.3. Sensors for Convenience

These sensors are used to develop applications that provide more comfort to the drivers. They can be deployed in the vehicle compartment to provide direct convenience services for its occupants, while others are deployed to provide driving assistance and efficiency for drivers. A gas composition sensor, humidity sensor, temperature sensor, position sensor, and torque sensor are examples of it.

3.4. Sensors for Environment Monitoring

These are the surrounding environment monitoring sensors. They provide alerts/warnings about a hazard on the road to the ITS application. They also give information about traffic, road, and weather conditions. For example, a pressure sensor may be installed to measure ambient barometric pressure, and it can transmit this data to weather centers for analysis and reporting. As well, readings of temperature sensors that may be already deployed for the sake of adjusting the HVAC system can be utilized and reported to weather centers for real-time weather reports.

4. Applications of VANET

Vehicular Ad hoc Network (VANET) is a promising intelligent transportation system (ITS) technology; its applications can increase road safety with improved traffic efficiency and infotainments. Based on our reviewed data, safety and performance are two important things that can be utilized to arrange VANET applications dependent on their essential objectives (Talavera, Diaz-Alvarez, and Naranjo, 2019), so it can be categorized into two major types: Safety and non-Safety.

4.1. Safety Applications

These applications provide environmental data to the driver, which helps prevent road accidents. This environment data contains information on road accidents, unexpected animals, obstacles, pedestrians, drivers going in the wrong direction, road construction and maintenance, road surface, road topology, legal speed limit, weather status, and other factors. These applications can be applied in both the V2V and V2I domains of VANET. The V2V mode of communication is mainly used for safety-critical, while V2I is for safety-related applications.

4.2. Non-safety Applications

It can be categorized into various subclasses, such as infotainment applications, entertainment applications, traffic efficiency, and convenience applications. These applications have been rapidly growing in the market in recent years, including some mobile applications offered on smartphones (Prasan and Murugappan, 2016). These applications usually provide very useful data to the driver, including traffic information ,weather updates, and various Locations of hotels and restaurants (Ahmed and Gharavi, 2018).

5. Vehicle Sensing Positioning Approaches

In vehicular communication, wireless transmission is done using different approaches for vehicle position. These approaches are classified on the basis of their communications, reflections, and transmission-based and discussed as follows, and their comparison with their limitation is summarized in Table 1.

5.1. Communication-Based Vehicular Positioning

All the vehicles in vehicular communication communicate with each other and their positioning information by using GPS (Lu *et al.*, 2014; Yao *et al.*, 2011). The dedicated short-range communication (DSRC) protocol, which is a variant of IEEE 802.11 Wi-Fi, is used for connecting vehicles. This protocol has been examined in the scenario of a two-lane rural highway (Han *et al.*, 2018).

To support higher data rates and broader coverage than DSRC, the 3rd Generation Partner Project (3GPP) has initiated a standardization process to realize cellular-based V2X (C-V2X) (Domínguez and Mateo-Sanguino, 2019). In order to boost the data rate, the technology aims to implement in the millimeter-wave (mmWave) spectrum (Heath *et al.*, 2016). While using mmWave, the major challenge faced is the high overhead and alignment to cope with fast fading in channels between high-speed vehicles (Va, Choi, and Heath, 2017). In order to reduce this overhead, a new fast beam-alignment scheme is proposed (Perfecto, Del-Ser, and Bennis, 2017) that leverages matching theory and swarm intelligence to efficiently pair vehicles. An alternate technique for accelerating beam alignment is to leverage the information generated by either on-board RADAR (González-Prelcic *et al.*, 2017) or GPS (Ahmed and Gharavi, 2018) to deduce useful channel information. For beam training, alignment, and tracking, it is possible to use location-specific information stored in the cloud (Shit *et al.*, 2018). The two main challenges faced by communication-based approaches are reliability and latency of mission-critical scenarios such as accident avoidance at high speed.

5.2. Reflection-Based Vehicular Positioning

The global automotive industry seems poised on the brink of a brave new world, where connectivity and sensor technologies come together to create systems that all but eliminate life-threatening collisions and enable automobiles that drive themselves. The auto- driving vehicles are equipped with RADAR and LIDAR among Cameras and other sensors. These sensing technologies follow the reflection-based approach. In this approach, the sensors detect the reflections from vehicles and objects in the environment having the different mediums, microwaves, and laser light, respectively. The output of LIDAR is a dynamic high- resolution three-dimensional (3D) map for navigation purposes by using ultra-sharp laser beams to scan the surrounding environment (Ahmed and Gharavi, 2018).

The limitation of the reflection-based technologies (LIDAR and RADAR) is that these technologies can detect vehicles with Los since neither microwaves nor laser light can penetrate a large solid object like a building or truck. Also in severe weather, bright lighting, vibrating vehicles and rapid vehicle movement, this may not function properly (Teoh *et al.*, 2023) The latest commercial image processing system in reflection-based vehicles works well in the identification, tracking, and positioning of vehicles, but it has problems in the classification of vehicles if the camera is not calibrated.

5.3. Vehicular Positioning by Synchronous Transmission

In the synchronous transmission approach, a receiver attempts to estimate the position of a transmitter, and various signal processing techniques for positioning via synchronous transmission exist. In examples of (Shit *et al.*, 2018) and (Seow and Tan, 2008), this approach of a receiver estimates the position of the transmitter from the data of the transmitted waveform and the received signal.

Table 1 Comparison of vehicular positioning approaches

Approaches	Los	latency	Sync.	Size detection	Reliability
COMMUNICATION	No	High	Yes	No	Low (GPS/Aps dependent)
REFLECTION	Yes	Low	Yes	LIDAR,RADAR , Cameras	Low(Environment dependent)
SYNCHRONOUS	No	Low	Yes	No	Low (Need sync.)

6. Localization Techniques of Vehicular Communication Using 5G

The new exciting era of the fifth-generation (5G) mobile communication networks will be driven by several key enabling technologies (Åkerman *et al.*, 2018). All of them have opened new horizons in service delivery targeted to provide low latency communication with cloud computing by software-defined adaptivity and resource allocation on the radio and network layers, massive MIMO, new frequency bands and waveforms, device-to-device connectivity, etc.

Besides vehicular positioning, there exists an active research area to estimate the positions of mobile devices in cellular networks, a. k. a. localization. Localization is a highly desirable feature of future wireless networks. It involves a two-step procedure: first, measurements are processed to obtain distance and/or angle information, and then triangulation is performed to determine the positions of the user or vehicle. The localization method performance is affected in the presence of multi-path, due to the inability to correctly identify and/or estimate the measurements of the line of sight paths. Current progress in radio-based positioning exploits multi-path propagation using geometrical channel models. With the advancement in new standards in cellular communication, the concept of reuse for localization is available (Lemic *et al.*, 2016). Currently, with the introduction of 5G, the use of massive multiple-input multiple-output (MIMO) and millimeter-wave (mmWave) systems is attracting interest from the localization community. Indeed, a large-scale antenna system does not only offer advantages in communications by assigning the same time-frequency resources to multiple users, but it also has the potential for localization due to its high angular resolution (Heath *et al.*, 2016; Jungnickel *et al.*, 2014). Due to these benefits, localization has a lot of importance in 3GPP, and we can expect to see new dedicated signals and localization algorithms in the coming years.

6.1. Types of Localization Techniques

Localization techniques can be classified into various types (Shit *et al.*, 2018). We first review and compare some typical localization techniques in terms of LOS or NLOS environments and non-cooperative or cooperative processing, followed by recent research on 5G localization.

6.1.1. LOS or NLOS

In congested urban areas, the signals experience a lot of diffraction and reflection due to dense residential and office buildings, and LOS measurements from the signal source may not be readily available. There are plenty of research approaches that have been investigated in NLOS error mitigation techniques. One common approach to model NLOS measurements is to treat the effect of reflection and diffraction on range measurements as a positive stochastic bias (Lui, So, and Ma, 2010; Al-Jazzar, Ghogho, and McLernon, 2009; Al-Jazzar, Caffery, and Yo, 2007; Chan *et al.*, 2006). Another approach is based on ray tracing, where the geometry of signal propagation paths is analyzed (Wu, Xu, and Wang, 2015; Xu *et al.*, 2015; Bialer, Raphaeli, and Weiss, 2012;

Seow and Tan, 2008). Based on this assumption that individual propagation paths can be resolved, relationships can be established between range and AOA measurements, resulting in a more accurate model than merely treating NLOS effects as positive biases.

6.1.2. Non-cooperative or cooperative

Localization of all sources or sensors in the network is viewed as a mutual estimation problem in a cooperative localization scheme. In non-cooperative schemes where localization errors spread from one sensor to another, a cooperative localization technique usually aims to approximate all sensor positions by minimizing a global error function and generally performs better than non-cooperative methods. Joint estimation can be done either through a centralized optimization process where information from all sensors is sent to a central processor or through a distributed process where sensors perform local processing and exchange of messages with neighboring nodes. Distributed procedures are more reliable, versatile and scalable compared to centralized approaches and are more appropriate for ad hoc sensor networks.

6.2. Localization in 5G

Five features of 5G networks are high carrier frequencies, wide bandwidths, large antenna arrays, device-to-device (D2D) connectivity, and ultra-dense networking. Such properties are conducive to precise Location (Belmekki, Hamza, and Escrig, 2020). Positioning and knowledge of Location not only allows different location-based applications but also leads to significant improvements in the efficiency of 5G communication systems.

6.2.1. Indirect Localization

The theory of indirect localization is that the grouped channel parameters (AOD, AOA, TOA) are a function of the position parameters (user location, orientation, denoted by s as, as well as the incidence points of NLOS paths, denoted by π. There is a simple geometric mapping of $\pi = f(s, \pi)$. Now, the localization algorithm is intended to recover an estimate of s and/or mapping, given an approximation of π. The authors (Palacios, Casari, and Widmer, 2017) present a method for locating and mapping multiple access points, exploiting f(·) through angle-difference-of-arrival geometric relationships. A localization method based on the LOS route is proposed by (Shahmansoori *et al.*, 2018) to solve a low-dimensional minimum square problem. Approximate fundamental value limits were shown in the data. Bayesian methods are explored in (Kakkavas *et al.*, 2019) as opposed to the above point estimators. Using a Gibbs sampler, the high-dimensional states are calculated in a piece-wise manner, resulting in a low-complex position and mapping algorithm, even if the path to the LOS is not known. In (Kakkavas *et al.*, 2019), an approach is investigated using factor graphs, which is applicable even if there is no LOS road. Downlink mmWave signals from a single base station are used (Ahmed and Gharavi, 2018) to jointly estimate the vehicle's clock bias location, direction, setting, and climate.

6.2.2. Direct Localization

An alternative way to locate is to estimate the source location directly from the measurements, while intermediate parameters like the LOS route AOAs are not required (Weiss, 2004). The definition of direct localization was introduced in (Wax and Kailath, 1983) and subsequently extended to localization based on AOA (Wax and Kailath, 1985) and AOA-TOA hybrid. For LOS routes, however, all of these methods are established. Several direct localization techniques are aimed at multi-track scenarios, but they are not suited to AOA positioning and large-scale antenna systems (Bialer, Raphaeli, and Weiss, 2012).

The large-scale antenna allows multi-path component AOAs to be accurately estimated (Lu *et al.*, 2014). Recently, the technique of Direct Source Localization (DiSouL) is proposed by (Ahmed, Pierre, and Quintero, 2017), and the measurements obtained at each base station are processed jointly (Daniel *et al.*, 2017). It was explored in (Dardari and Guidi, 2018) the possibility of explicitly inferring the transmitter location for mm Wave. This illustrates the advantage of utilizing an antenna array with an embedded lens to either decrease the antenna size or enhance the localization performance.

7. Open Research Challenges

The following review addresses research challenges in realizing cooperative vehicular communication dreams. Effective implementation of wireless communication in the vehicle environment requires certain intrinsic problems to be addressed, ranging from the development of technological software and implementation to economic concerns.

A. Broadcasting in Vehicular Communication

The proposed VANET systems require a large number of electronic messages/data packets to be sent, stored, and processed. Text/Message broadcasting was regarded by automotive wireless networking researchers as an attractive alternative approach partly because of its low cost and partly because of its support for vast potential data packet volumes. Many researchers have considered various broadcasting techniques and mechanisms. These techniques include restricted and unrestricted digital service solutions for bandwidth as well as satellite broadcasting solutions that have already incorporated data services for real-time traffic. By limiting the message transmission range directly to the Location of interest, this issue could be reduced or eliminated, thereby eliminating excessive overhead network. This concept is called location-aware broadcasting.

B. Spectrum Allocation

The high mobility of vehicles has become a significant constraint in VANETs (Abboud and Zhuang, 2015). The complex spectrum-sharing behavior of vehicle users is closely related to road topology, vehicle traffic conditions, vehicle service demand and spectrum availability. On the one hand, the high mobility of vehicles impacts the availability of heterogeneous 5 G network spectrums. Accurate models of mmWave propagation are therefore needed.

C. Ultra-wide Band

Ultra-wideband (UWB) refers to radio technology operating in the 3.1–10.6 GHz frequency band (an incredible 7.5 GHz bandwidth) and capable of supporting short-range communication at a data rate of up to 480 Mb/s and a very low energy level (Qu, Wang, and Yang, 2010). UWB systems have a number of unique advantages, such as resistance to severe wireless channel fading and shadowing, high time-domain resolution suitable for localization and tracking applications, low cost, and low processing complexity (Oppermann, Hämäläinen, and Iinatti, 2005). A recent study of measurement (Lu *et al.*, 2014) also models small-scale fading within the vehicle that was not previously considered. With an underlying wireless model, how identifying the most suitable communication techniques at the PHY layer is a critical issue for intra-vehicle sensor networks based on UWB.

D. Multi-path Propagation

In urban areas, V2V communication's line-of-sight (LOS) direction is often obscured by the intersection of buildings. Buildings are important elements in VANET, as these barriers can limit vehicle-to-vehicle connectivity. While on a highway, the trucks on a communication path may introduce significant signal attenuation and packet loss (He *et al.*, 2014). For designing efficient V2V communication systems, accurate simulation of the propagation environment is of prime importance.

E. Localization System

Important VANET safety applications require more robust and precise localization systems. A natural solution for VANETs is to integrate a navigation device into each vehicle. However, satellite-based positioning systems (e.g., GPS, Galileo) present some unwanted problems, such as not always being available (e.g., problems of reception in tunnels due to lack of signals or bridges due to vehicle position imprecision: above or below the bridge). Several localization techniques have been proposed to calculate the position of mobile nodes (Ren *et al.*, 2017), namely Map Matching, Dead Reckoning, Cellular Localization, Image / Video Processing, Localization Services, Differential GPS Technique, and Relative Distributed Ad Hoc Localization. However, no single technique can satisfy all critical applications ' requirements at the same time, such as availability anywhere and anytime, with high accuracy and reliable position calculation. Thus, in the localization systems, the study of models to predict the position of vehicles over time becomes a good alternative.

F. Security, Confidentiality, Anonymity, and Accountability

Safety is one of the problems that require careful consideration before VANETs are planned and deployed on our motorways. There are several potential threats to the vehicle communication system, ranging from false (or fraudulent) messages that can interrupt traffic or even risk the privacy invasion of the driver. VANET's major security and privacy challenge is how to develop a security solution that can support the trade-off between authentication, liability, and privacy, given that all. Vehicle information (both security and non-safety-related information) must be disclosed by the network to appropriate government agencies (transport authorities) (Abdelgader *et al.*, 2018).

G. Future traffic and mobility forecast

In a VANET, we would expect drivers and passengers to connect in other networks with individuals, applications, and services. This cooperation can be useful in providing the customer with a good service, such as traffic conditions, weather, and route information. Vehicle traffic forecasting and agility help drivers know about road conditions and current events and then choose alternative routes to prevent congestion and potential accidents. The vehicles in each region should cooperate. They store, process, and share data through their sensors. The data can also be transmitted to the traffic authorities that make decisions and convey to the drivers (Mekki *et al.*, 2017).

8. Conclusions

In this paper, we have reviewed an overview of the state of the art of VANET infrastructure with its different architecture classifications. We have also reviewed the vehicle sensors and their major classifications, followed by the various types of applications in vehicular communications. Then, we discussed various vehicular sensing transmission approaches with respect to their working and limitations. We have also conducted a qualitative comparison of the aforementioned transmission approaches based on essential parameters such as Line-of-Sight (LOS), Reliability, Detection size, and latency. Additionally, we have delved into localization techniques and the concept of passive coherent location using 5G. Finally, we have outlined potential challenges and identified areas for future improvement in vehicle sensing.

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