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A Study of V2V Communication on VANET: Characteristic, Challenges and Research Trends

Ketut Bayu Yogha
[1]Program Studi Teknik Informatika, Fakultas Industri Kreatif dan Telematika, Universitas Trilogi
Email: ketutbayu@trilogi.ac.id

Abstract – Vehicle to Vehicle (V2V) communication is a specific type of communication on Vehicular Ad Hoc Network (VANET) that attracts the great interest of researchers, industries, and government attention in due to its essential application to improve safety driving purposes for the next generation of vehicles. Our paper is a systematic study of V2V communication in VANET that cover the particular research issue, and trends from the recent works of literature. The paper is essential to give reader a brief description about recent V2V Communication studies especially focus on characteristic, challenges and future research trends. We begin the article with a brief V2V communication concept and the V2V application to safety purposes and non-safety purposes; then, we analyze several problems of V2V communication for VANET related to safety issues and non-safety issues. Next, we provide the trends of the V2V communication application for VANET. Finally, provide SWOT analysis as a discussion to identify opportunities and challenges of V2V communication for VANET in the future. The paper does not include a technical explanation. Still, the article describes the general perspective of VANET to the reader, especially for the beginner reader, who intends to learn about the topic.

Keywords – V2V communication, VANET, vehicular communication

I INTRODUCTION

An autonomous vehicle positioned as an interactive robot or agent system that capable of autonomously overcome the various situation in the driving task. An autonomous vehicle is limited in perception, calculation, and decision-making processes from multiple interactive robot system addressed to overcome safety internallyAmessages can be forward based on the highest pheromone intensity from source to destination. Some example of the trajectory-based routing algorithm in unicast communication protocol are Greedy Perimeter Stateless Routing (GPSR) [13][38], ACO-based Routing [39][40], and PSO-Based Routing [41][42][43]

II. V2V COMMUNICATION IN VANET

V2V communication utilizes Wi-Fi technology known as Dedicated Short Range Communication (DSRC) between each vehicle and GPS technology that offers a detail positioning view through the communication exchanges with similarly equipped vehicles. DSRC is a special purposes communication designed for the vehicular vehicle to provide a short-range communication with a neighbor vehicle or with the environment to gain a cooperative driving situation [10]. The DSRC uses 75 MHz spectra for vehicular communication and utilizes the radio technology based on IEEE 802.11p with 3 to 27 Mbps of bandwidth[8]. Several components are required to provide the V2V communication. These components integrated and mediated communication protocol explained in Figure 3.

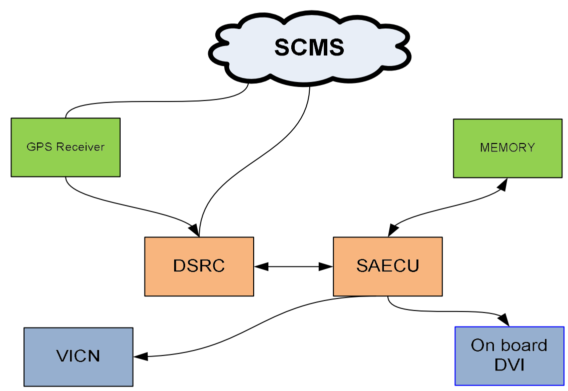

Figure 3. V2V Communication Components

DSRC is a dedicated radio unit that works as the data receiver and transmitter. The GPS receiver responsible for providing vehicle position and time; the data will become an input to DSRC while Memory capable as a storage to store the information from the Safety Application Electronic Control Unit (SAECU). SAECU capable of enhancing safety by calculating input from DSRC and memory and Vehicle's Internal Communication Networks(VICN). SCMS is the facility to ensure security certificates while the communication occurs among the vehicles.

A. V2V Communication Applications

Based on works of literature, we present various applications of V2V communication, categorize for two broad purposes: safety purposes and non-safety purposes
Safety Purposes. The primary goals in this category are to minimize the safety issues by providing guidance or other information for the driver to prevent or anticipate road accidents such as pre-crash or post-crash situations, blind spot anticipation, intersection assistance, etc. The V2V

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communication designed for safety-critical, which means that it requires strict allowable latency in the count of milliseconds and maximum communication range in meters[44]. V2V safety purpose given in Table 2.

Table 2. V2V Safety Purposes

No	Safety purposes	Services
1	Collision Warning System	a. Pre-crash avoidance warning b. Post-crash avoidance warning c. Blind-spot warning d. Blind-intersection warning
2	Cooperative Driving System	a. Lane-change warning b. Safety Platooning formation

Consider an example shown in Fig 4. A post-crash avoidance warning involving three vehicles where the blue vehicle obtaining a broadcast warning messages from the another vehicles that encounter collision around the blue vehicle by means that the vehicles involved in the accident give the warning signals to another vehicles around the communication range to help driver to react properly to avoid the accident or to slow down the vehicle to prevent another crash,. This ability utilize ad-hoc communication among vehicles.

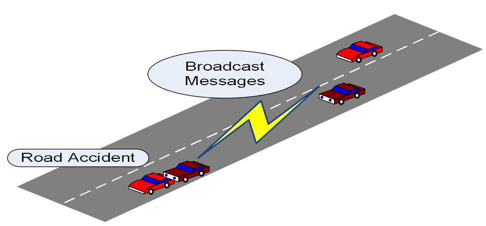

Figure 4. Post-Crash Avoidance Warning

Another high-risk collision spot generally is in the intersection. Figure 5 illustrated blind side possibility while the vehicles crossed the intersection. Each car in the DSRC range will receive a broadcast message from another vehicle and vice-versa that inform the position and direction of each other vehicles movement in a specific area that potentially risks both of the cars in dangerous situation. The ad-hoc communication essential to coordinating the move in a formation/platoon situation.

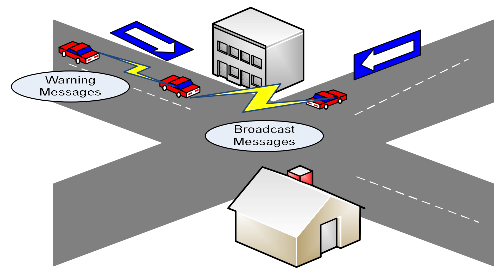

Figure 5. Blind-intersection warning

The vehicle's platoon should be able to follow the leader by continuously maintain and anticipate dynamic situations along the road—the illustration of the vehicles' detachment shown in Figure 6.

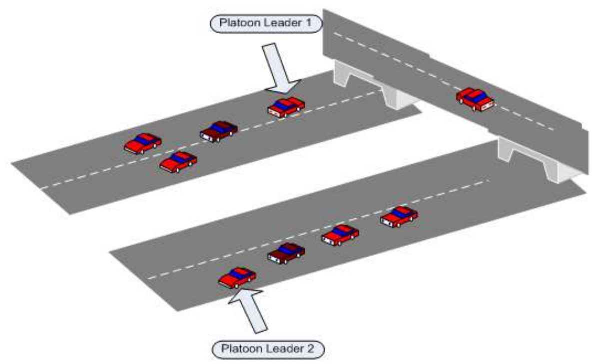

Figure 6. Platooning of Vehicles

The message exchangeability among the vehicles intends to minimize potential accidents and enhance the safe driving within the car with driving assistance features for both autonomous vehicles and non-autonomous vehicles [45]. Furthermore, V2V communication will strengthen the safety support in five-level autonomy in autonomous vehicles where the combination between AI, Vehicle technology, IoT, and communication ability will accelerate the massive use of autonomous vehicles in the future[8][6].

In general, the non-safety purposes is apart from the safety aspect of driving, many other services such as mobility, environment, infotainment, etc. are provided inside the vehicles [44] that require a various point of technology to build it. In this study, we focus on services that make or have a correlation with ad-hoc message exchanges, especially using the V2V communication platform. The detail Non-Safety facilities shown in Table3.

Table 3. Non-safety Purposes

No	Non-Safety purposes	Services
1	Advance Navigation	a. Traffic flow improvement, b. Dynamic eco-routing, c. Congestion Warning.
2	Eco-fuel consumption	

V2V communication enables advance navigation by utilizing information exchanging by other vehicles to provide information about traffic conditions, congestion warnings, or road accident information by combining with

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GPS and IoT technology to guarantee traffic fluidity and circulation[11]. The system combines GPS information and a realtime information from the surrounded vehicle in communication ranges then the navigation module calculates both data to decide the alternative routes available to avoid the congestion before the car passes the congestion spots.

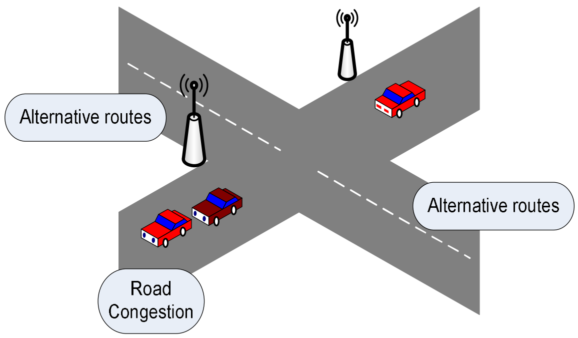

Figure 6. Congestion Warning Services

Figure 6. Describe the illustration of congestion warning services in V2V communication. The traffic information is essential to maintain vehicle movement on various traffic conditions, which have implications for efficient fuel consumption, optimize travel time, and obtaining driving comfort [46].

III. CHALLENGES OF V2V AS A DRIVING COMMUNICATION IN VANET: A BRIEF REVIEW

VANET is a geographical routing protocol that contains unique network characteristics due to particular purposes implementation in vehicular communication that requires a different approach from the global networks[47]. VANET is specifically designed as the next level of driver assistance system to enhance the safety issues in the automotive industry shortly. Moreover, It requires particular purposes of communication protocol to support mobility, quality of services, safety, etc. in the driver assistance system both implemented in autonomous vehicles or non-autonomous vehicles.

A frequent movement of large scale vehicles has implications for several consequences and challenges that must be solved to maintain the functionality of the networks. In VANET, several problems are emerging and become a fundamental issue in VANET[27].

A.Dynamic Topology

A constant movement in a highly active network situation, making the topology of the network continually changing over time, hence establishing and maintain communication is difficult; this situation is called dynamic topology issues. It needs a proper approach to keep the communication process below maximum latency time that implies to quality of services of the network

The establishment of communications between vehicles requires the knowledge of the node positions and their movements, which are very difficult to predict due to the mobility pattern of each car over a dynamic network connection and topology[6].

B.Dynamic Network Connection

Since the vehicle is moving in a highly active network situation over time, it will be resulting in the "ON/OFF" connection along the way. Moreover, the condition can be worst in the presence of radio obstacles that potentially interfere with the communication channel. When the congestion occurs, a path between two nodes wishing to communicate and ensure continuous communication in well-state services, but on the other hand, in the case of low vehicle density, it will inflict frequent disconnection that possible to produce high-rate of failure connection. Both situations require a robust routing protocol to recognize the situation and provide an alternative link rapidly to ensure the quality of communication.

C.Real-time Constraint

The messages exchanged in the VANET network mostly do not cost high resources and high data rates. Unfortunately, the issues are to keep end-to-end delay stays minimum is essential to maintain excellent quality services. For example, sending the warning message broadcast must have a minimum delay to keep the real-time services, or as a consequence, the warning message will no longer be helpful to anticipate the accident or avoid a collision.

D.Quality of Services (QoS)

QoS defined as a standard requirement that needs to meet while establishing end-to-end connections to maintain data exchanges[47]. Various factors and constraints should consider earlier to keep good QoS as each application has its own QoS standard. A right routing approach is essential to efficiently set up new routes when the other one is no longer available due to the changes of various variables such as vehicle velocity, position, topology, distance, etc.

E.Data Security and Privacy issues

The implementation of multiple intelligent on-board potentially stores a large amount of personal information that record individual activities and habit besides the vehicular trajectory data itself, this issues possibly affect the public acceptance issue for VANET system beside Dependability, and vulnerability of leakage of personal information issues. Moreover, another threat could emerge from manipulating the messages or recording the trajectory of the vehicle remotely[6].

IV. THE TRENDS OF V2V COMMUNICATION FOR VANET

As one type of communication in VANET, V2V communication developed along with the development of VANET research itself. Many key important topics in vehicular communication are currently under intensive study and discussion to be enhanced or modify the potential advantages of V2V communication in VANET[27]. V2V ensure the safety and non-safety applications[44], Eco-driving and reduce carbon emission[48], traffic congestion control[19], advance cooperative driving[18][2][20], crash avoidance system[15], *etc*. to offer the next level of safety and driving comfort.

A. Intelligent Transportation System (ITS)

The application of ITS is essential for modern urban traffic operation. The ITS combines several technology such as Information technology, sensing anf electronic technology, GPS, computational ability, angineering and even the geographical information system. Several urban city or country have been implement the ITS such as Macao intelligent system[49], ITS for good transport and public transport in Italy[50], multi modal ITS in Russia[51], ITS for railway operation in St. Petersburg[52], Central Infrastructur of ITS in Taiwan[53], Central Infrastructur of ITS in Bangkok[54], ITS for freight expedition in Zimbabwe[55], ITS in UK [56], and ITS in China[57]

The previous research proposes by Molosaine. N.R. *et al.* [12] said that it would become an alternative solution in the modern transportation system to reduce road accidents. The idea emerges based on the fast improvement of wireless technology that enables interconnection between Vehicle to Vehicle(V2V) and Vehicle to Infrastructure (V2I), the interconnection is more efficient than just isolated systems to obtain the transportation solution shortly. For example, to minimize road accidents, driving efficiency by avoiding road congestion. Wireless communication is the technology that enables to interconnect various components of the transportation communication system such as sensors, vehicles, and road infrastructures. The wireless technology is the most vital technology that improves vehicular communication, especially V2V communication in VANET. Where VANET will play a significant role in the development of ITS[12].

Daniel. A. *et al.* [11] said that V2V communication for VANET would automate interaction among vehicles and infrastructure to provide a higher level of safety, comfort, and competence in vehicular communication as the architecture model shown in Fig7. In the illustration, the base station responsible for gathering and analyzing the data from the actual information in map databases and CCTV cameras pointed at the specific road, including the traffic signal data and other potential traffic congestion.

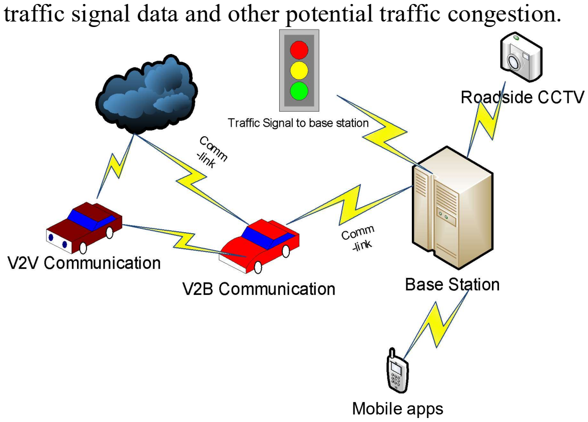

Figure 8. System Model for cooperative communication in ITS

The base station in Figure 8 is essential to provide information as an input for intelligent navigation assistants inside the vehicles in a collaborative environment or the smartphone through a specific application installed on the phone. After receiving the information, the vehicle can utilize it and makes an optimal decision regarding the available path selection at that time. The involvement of Big data and deep learning also accelerates the development of ITS. Zhu. L. *et al.* [58] proposed the architecture model of conducting Big Data analytic in ITS and detail explanation about each aspect component in the architecture shown in Figure 9.

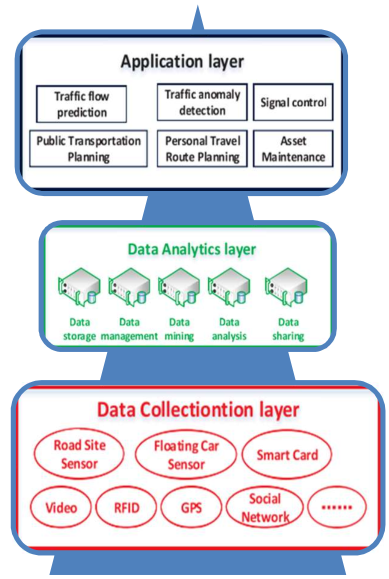

Figure 9. Big Data Analytics Architecture in ITS

The architectures consist of three levels of layers which are Data Connection Layer (DCL), Data Analytics Layer (DAL), and Application Layer (AL). DCL gathering and provides the necessary data for the upper layer. A large amount of information collected from the various sensors, videos, GPS, social networks, etc. DAL will receive data from the DCL and then utilize multiple data analytics methods before sending it to the data storage. DAL also manages the data, analysis, mining, and sharing of the data to the upper layer. DAL is a central point of the architecture. Application layer extracts and utilize the process result from the previous sheet and apply it to different transportation condition such as traffic prediction, traffic guidance, emergency, etc.

Several method and approach proposed to enhance the ITS implementation such as Big Data Analytics for ITS using hadoop[59], Cooperative sensing and mining system for ITS[60], an agent-based approach for ITS[61], then deep-learning approach for ITS [62], a data-driven based of ITS[63], GIS-based ITS[63], GIS-based ITS[64], and the implementation of LiDAR technology to support ITS[65][66]

B.Crash Avoidance System(CAS)

Safety issues are critical in the development of vehicle technology, and all stakeholders must guarantee to enhance safety as one of the top priorities to create safer transport. Ghatwai. et al. (2017) said that a 95% fatal accident caused by human error, the victim number possibly reduce by designing a precision driving assistance system. One of the essential driving assistance features is a crash avoidance system[15]. Several projects developed to ensure the

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system effectively supports driving assistance in the last ten years.

One of the significant projects in the crash avoidance system is PreVent Project. PreVent is an integrated safety platform by advancing current sensor technology with communication technology to speed up the market introduction and penetrated the advance vehicle safety system. PreVent emerged because of the slow commercialization of vehicle safety platforms due to a lack of sensor performance and high production costs that impact low public trust and awareness of these potential vehicle safety systems[16]. The project divided into two main activities, Vertical Function Fields (VFF) and horizontal movements. The VFF focus to make electronic safety zone inside and outside (environment) the vehicle to support the driver while driving on the road and in an accident situation. The VFF function includes several features: Safe speed and following secure functions, Lateral control support functions, Intersection safety functions, and Collision mitigation functions

The horizontal activities focus on safety functions integration and evaluate legal, safety impact by different stakeholders and create dissemination strategies for the expert in the fields, regulator, and public. PreVent is a well-established prototype for the future development of vehicle safety technology both for the autonomous and non-autonomous vehicle by combining various technology that intends to support the vehicle safety and creates, promotes, disseminates, and executes the development of vehicle security.

Connected Vehicle Crash Avoidance (COVCRAF)[14] emerges as an alternative from a previous collision avoidance system that depends on a sensor-based mechanism to detect and avoid the road hazard condition. In a sensor-based order, the information gathered from the environment depends on the internal sensor capability without receiving information from other vehicles around the vehicles at various road conditions. As a result, we can not synchronize the movement simultaneously to respond to the actual situation as a group of cars. COVCRAF is a Cooperative onboard Road Hazard Signaling (RHS) that utilized V2x technology to enhanced awareness of the driving conditions. COVCRAF enables direct interaction among the nearby vehicles by continuously send information about the presence of hazardous driving situations by using wireless communication to enhance safety driving on the road. The V2V platform used when a group of vehicles makes direct communication to create interaction as a response to road hazard situations.

Another potential communication strategy potentially used in the crash avoidance system is a Long-Term Evolution Vehicle (LTE-V)[67].]. LTE-V is a scheduling strategy that utilized radio resources to shared information among a group of users (vehicles) efficiently to share the radio resources; it requires two types of scheduling strategy, A Dynamic Scheduling(DS) strategy and Semipersistent Scheduling (SPS).

DS can use in various services with a control signal overhead; it is the most flexible scheduling strategies in LTE –V. The second strategy is SPS that design to support Voice-over-Internet Protocol (VOIP), SPS allocates a traffic channel periodically without interferences mechanism from control messages during traffic conditions [67]. LTE-V potentially used in the crash avoidance system due to its performance that reduces the minimum delay transmission during messages interchanges among vehicles that effectively used in the crash avoidance system in the future[68].]. Future research in LTE-V continues to grow to analyze any aspects of LTE-V performance in various cases in the crash avoidance system and any other condition in VANET.

C.Advances Cooperative Driving Ability (ACDA)

Cooperative Driving Ability (CDA) [20]] mostly used to support safety and non-safety services that consist of several features described in Table 2 and Table 3. In the last decade, the development of GPS technology, IoT, and social media has triggered enormous research and project in VANET communication technology, especially in integrating VANET technology with those emerging environments. The challenges that emerge in the integration process are exponentially proportional to the benefits and opportunities of VANET research in the future[18].

We explore several opportunities related to the implementation of CDA for VANET both to support safety and non-safety application. First, traffic congestion avoidance, Congestion problem is not directly related to safety issues. Still, it is potentially associated with another question, such as time efficiency, high fuel consumption, environmental problem, or even reduce national productivity, especially in a densely populated city. The congestion can be in the local area, but the impact is significant in the broader field of the country, especially related to the economy and transportation efficiency[17]. In conclusion, it is vital to develop traffic congestion methods as an alternative solution besides exists approach that utilizes the GPS-based system and social media as a source of traffic information.

Brennand. C. et al. (2017) proposed Fast-offset Xpath Service (FOXS). The service reduces the possibility of being in a traffic jam by classified and suggests various alternative routes to vehicles, FOXS developed using fog computing paradigm. As a simulation result, FOXS reduce 70% of the stop time, which is estimated to decrease 29% $CO2$ release by the vehicles in the air. FOXS also 11.5 % reduce the packet collision metric and reduce 30% messages delay in communication evaluation.

Hsu. C. et al. (2017) examined several potential congestion avoidance procedures in V2V communication to evaluate and validate the congestion avoidance procedure [19]. Hsu. C. et al. (2017) emulate 80 Onboard equipment or reference unit that transmitting signal in 10 Hz-800Hz in the simulation. The test procedure based on the simulation result of busy channel percentages. Each of the congestion algorithms tested using the 80 reference unit. As a threshold, if the simulation detects three or four reference unit in busy states that indicate the potential of road congestion, the percentages is between 50% to 80%. The optimal congestion algorithm should be below the situation by creating alternative routes or channels. The study validates the result by using GPS data-generation

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from the virtual vehicles to measure the performances of the algorithm[19].

D.Cooperative Car Parking System(CCPS)

The enormous number of vehicles that stream to a car park during the rush hour or holiday season will deliver to the congestion inside the car parking area to circulates the movement of the vehicle in a limited parking space. The condition impacts the significant time and fuel consumed for each car as they search for the parking space. Aliedani. A and Loke. S (2017), The average elapsed time for the vehicles to find the available parking space is 20 minutes due to the limited parking space that does not support the adequate information for the driver in a contention level to find the parking spot[21].

In general, the sensing technology used to arranges the occupancy situation and reservation mechanisms development to reduces the level of competitiveness among the vehicles to find the spot. Several car parking approaches proposed to support that conventional way to reduce the average elapsed time for the car to find the parking space in a specific area. The Co-Park (Aliedani proposes a cooperative Car Parking Algorithm. An et., al[21]. Using the multi-agent-based approach and utilize the DSRC protocol, CoPark project simulates the cooperation among the vehicle by exploiting autonomous software agent that enables to do V2V communication in DSRC ranges. An initial belief function works as a heuristic to be communicated with other cars to provide the parking space information from in DSRC ranges. The idea potentially reduces the level of competitiveness among the vehicles and, at the same time, offers realtime local information that essential to minimize the time elapse and decision to make for the driver.

Adewumi. O, et al. (2014)) proposed a heuristic-based algorithm to optimize the parking space allocation—the project tested inside the university parking area. The Pattern search algorithm and particle swarm pattern search investigated to answer two main problems: minimizing the conflict related to available reserved spaces to the user and determines the number of authorized parking spaces to be issued for an unreserved parking slot[69]. As a result, Adewumi. O, et al. (2014) build the hybrid algorithm called Particle Swarm Pattern Search (PSPS) to prevail better performance than the separate algorithm.

Another research proposed by Correa. A. *et al.* (2017) suggests an infrastructure-based network around the parking area to support cooperative vehicle communication. The study aimed at a parking system that possible to accommodate both ordinary vehicles and an autonomous car equipped with vehicle communication technology utilize a road-side facility around the parking area using the V2I concept. The Idea is to overcome the GPS limitation in a positioning accuracy by creating a tree-based searching to select the parking space based on historical data and distribute the information through the vehicles using available infrastructure in the parking area[68]. The simulation shows that the system is near effective performance by considering various communication ranges and autonomous car penetration rates [69].

Another cooperative car system such as Development of agent-based CPS for smart parking system[70], smart indoor parking system based on collaborative palnning of parking space[71], and the implementation of Markov chain as a model baed prediction for parking avaibility[72].

E.Platoon/Formation

Besides Congestion control and parking services, The V2V communication also has a potential implementation as a formation or platoon control[18]. According to Abunei. An *et al.* (2019), 1.35 million people die yearly in various road accidents worldwide. Platooning potentially reduces the road accident or vehicle collision; it also potentially reduces fuel consumption and enhances safety and driving comfort while running as a platoon[73]. Jia proposed the study of platoon-based cooperative driving. D, and Ngudoy. D (2016). They explored and study the relationship between V2V communication and platoon based cooperative driving by designing a consensus-based controller to optimize the movement of platoon vehicles. To build the design, Jia. D, and Ngudoy. D (2016) focuses on the microscopic traffic level by providing a theoretical foundation about V2Vcommunication with cooperative driving behavior to create and maintain formation while moving in the traffic[18].

Several parameters must be meet the requirement such as speed synchronization, space arrangement, type of platoon formation, platoon size, inter-vehicle communication strategy, and time headway [74]. So, it is essential to investigate potential disturbance and stability issues to maintain the formation, which is indirectly related to the problem of driving safety when the configuration of a group of vehicles is running. Studli. S. et al. (2017) investigate several potential control issues such as disturbances amplification, stability, sensitivity analysis of platoon vehicles, as they are performing a cyclic formation or bi-directional formation[74]. Bian. Y., et al. (2019) explores predecessor factors of following strategy to reduce time headway as an essential requirement while performing a stable string the formation. A new method proposed called Constant Time Headway (CTH).With a lower time headway and sufficient information topology matrix obtained better performance of consistent platoon performances[23].

Abunei. A. et al. (2019) introduce a customizable and low-cost V2V platform various VANET standards in 5.9 GHz and 700 MHz bands called Velocity-based Vehicles Platooning (VVP), it is one of the most significant improvements in vehicles communication technology nowadays. VVP enables a group of vehicles to maintain the distance among them in a high-speed situation, and it synchronized any movement in a small group of cars. VVP based on leader-follower synchronization that harmonizes leader and follower movement in various control variables: velocity, steering angle, inertia, and vehicle position using the V2V communication in DSRC range. The system is 10% more efficient in reducing fuel consumption and reduced gas emission[73].

The simulation process simulates the 5.9 GHz and 700 MHz bands to examine the performance in an emergency. As a result, the 700 MHz has better performances in harsh

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situation compare with the other one. The result is essential as an alternative solution for the future development of the On-Board Unit (OBU) that currently used a 5.9 GHz band as they based communication frequency. Another research proposed by Kim. J and Han. Y (2019) focuses on onV2V communication in the group cast platooning scheme by formulating Markov Decision Process is used to optimizing join retransmission control to maximize the time headway in a single-line vehicle platooning[75]. Single-line vehicle platooning can be used in various types of land transportation such as car[22], bus platooning[76], truck platoon[10].

Platoon based cooperative driving ability attracts the great interest of researchers and industries attention in due to its essential application to improve safety driving, security, or even fuel efficiency by reducing air drag and maintaining constant speed in various road conditions. Several projects developed worldwide to extend the platoon ability in multiple types of vehicles, such as semi-autonomous truck expedition and heavy-duty truck [77][78][79] and a platoon of a vehicle for passenger car[80]. The research and development for the formation of the truck are higher than for passenger cars due to the financial ability and less risk of safety issues for the passenger.

F.Cooperative Lane Changes Protocol (CLCP)

The increasing number of vehicles that are running every day in every city worldwide is an important aspect to support the economic movement in every country. Unfortunately, this routine and essential activity also potentially caused many traffic accidents worldwide with a lot of the number of casualties which indirectly impact the economic losses and images of the country[81]. The active safety driving assistant is essential to enhance the driving safety and comfort by minimizing driver error or anticipating various harsh conditions the road[24][26]. Recently, several car manufacturers and research institutes around the world struggle to provide and improves an optimal driving assistant, especially in developing the lane change assistant system for autonomous or non-autonomous vehicles that provide proper decision to make the lane change in safe and efficient ways[82].

Ruina. D. et al. (2014) define that lane change warning system must guarantee two significant aspects, the car following scheme and collision avoidance scheme to anticipate the emergency, in examples, direct collision with another vehicle or other transportation modes. V2V communication is significant to enhance the lane change warning system by providing realtime information from the local environment around the car. In the last ten years, the safety system usually depends on sensor-based in OBU without collecting data from the surrounding environment such as vehicle or road infrastructure in an emergency caused by vehicle movement on the road. Ruina. D. et al. (2014) proposed a central lane change logic system in the following Figure 10.

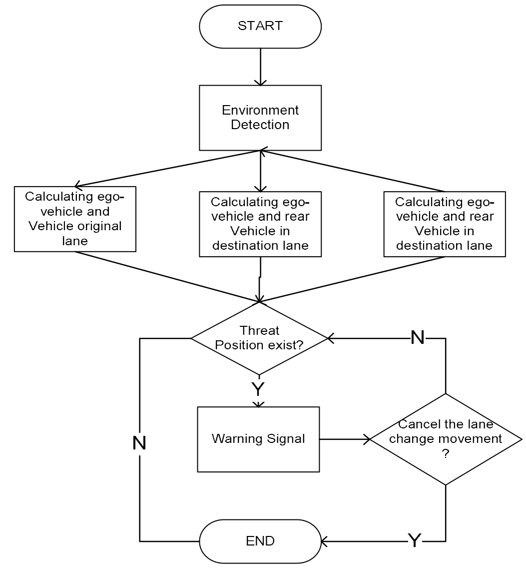

Figure 9. The lane change logic system

Figure 10 describes if there is a potential collision threat that exists in the current situation. The system will generate the warning system; otherwise, the warning signal will be inactive, and the lane change aborted. The V2V communication work as support features to gather data from another vehicle as an input to be calculated and the proposed decision whether the system will give an alert or aborted the warning regarding anticipate the situation. To maintain continuous communication, so the system can make proper lane changing decision, a reliable and intensive connection is obligatory. Wang. L. et al. (2018) proposed a simple communication scheme using ACK messages to ensure constant communication. Based on the simulation result, Wang. L. et al. (2018) claim that communication capability not only elevating the driving safety but also increasing the efficiency of road traffic[82].

Calculating the data and create proper decision is another important aspect of the lane- change control logic system. Recently, the development of a machine learning algorithm has been rapidly growing research in the field, especially in the lane change system. Liu. X. et al. (2019) used a deep learning method to improve the decision-making process while the lane change is needed. The proposed model uses a historical driver experiences from the driving log and the V2V memory effect as a situational maneuvers assessment. Liu. X. et al. (2019) claim that the Deep Learning Networks (DNN) model achieves higher identification accuracy not only in a lane-changing decision but also the reason to keep the lane maneuver compare with the conventional machine learning[83]. Sakr. A. et al. (2018) analyzing the performance of three supervised-learning techniques, the forest random, vector machine, and decision tree with gradient boosting. The proposed research is essential as guidance for future research to choose the most efficient among the three supervised-learning techniques[84].

Cui Y. et al. (2020) proposes a LiDAR-based system as an innovation in V2V communications technology. Light Detection and Ranging (LiDAR) used to identify and

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predict the lane change situation. The system accommodates a real-life situation where not all vehicles can be connected, and there is a conventional car that is not supported by V2V technology, it is more than 60% is not equipped by vehicle communication technology. LiDAR provides an alternative solution to accommodate those unconnected vehicles by use LiDAR as a roadside guiding facility for the mixed-traffic condition. The LiDAR system work as a data collector to record real-time data as training input to the back-end system. The back-end system will identify and predict vehicle movement in the future based on previous condition records by LiDAR[25].

VI. DISCUSSION

To describe the trends, we provided a chart designated the sixty works of literature related to represents the distribution of V2V communication research trends in VANET application in figure 11.

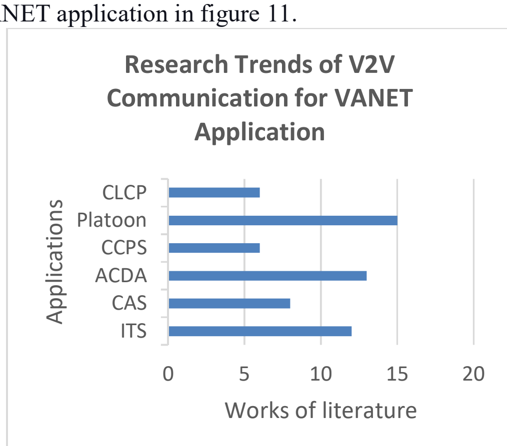

Figure 10. Research Trends Chart of V2V Communication for VANET Application

Figure 10 shows that the implementation of V2V communication for platoon has the highest research interest(25%), followed by ACDA research(21%), and ITS(20%). The lowest research interest is CLCP (10%) and CCPS (10%). The chart cannot be generalized as a big picture of overall research trends around the world, but we hope to give a brief overview of V2V implementation in a smaller scope of application on VANET

We define several aspects which can accelerate and obstruct the development of VANET to support the vehicular technology in near future from various point of views such as economy, legal, infrastructure, public, community acceptance, and the related technology itself. We used A SWOT matrix to analyze the correlation between strength, weakness, opportunity, and threat define in Table 4.

Table 4. SWOT Analysis

V2V	Strength(S)	Weakness(W)
Opportunity(O)	- Wireless based network development, - IoT & Big Data - Progressive AI development - Growing Autonomous Vehicles industry, - Government support, - Adolescent Technology - Global trends in mobile vehicular environment	- High cost in R&D, - More expensive product, - Government Infrastructure support, - Different safety Standard Regulation, - Algorithm performance and validation
Threats(T)	- world economy fluctuation, - Public Trust in a safety issue - Legal issue - Unclear market segmentation	- High-cost R&D, - Expensive product, - conflict of interest (regulator developer)

Table 4 shows that the expansion utility of wireless technology combined with the IoT and Big Data Analysis directly impacts vehicular research to exploit and integrated those technologies to create a more intelligent vehicle. On the other hand, artificial intelligence and growing autonomous vehicles boost the VANET research rapidly in some regions such as North America, Europe, and East Asia, which well-known as a center of car production and development. Unfortunately, the opportunity development in the vehicular industry is also facing several weaknesses related to high-cost R&D, which impacts the price rising for the consumers. Different safety standards and regulations related to the safety issue in different regions retard the industry to exploit the opportunities in any aspect of technology development. Although the existing algorithms are robust and reliable, there is still challenging to validate and examine their performances in various conditions, regulation, and different safety standards.

This emerging industry also facing severe threats and weakness, especially in fundamental economic aspects such as world economic fluctuation that impact the R&D and makes the limitation in market segmentation. The low Public trust to use the vehicles equipped with V2V communication to enhance safe driving requires the car producer to continuously improving the safety technology and disseminating it to a vast community that will raise the cost without unpredictable profit in short and middle terms.

Although VANET is a progressive innovation in the vehicular industry soon, The development of VANET is also inseparable from the challenges to resolve in hierarchical stages for a long time. The situation opens up research opportunities in various fields and development opportunities for university and research institutions. Still, it will require a lot of resources in the development and dissemination of the technology to gain the public trust to buy and use the vehicles equipped with this VANET technology. As a growing field of research, these challenges will slow down VANET implementation, especially to boost the application of autonomous vehicles shortly.

V. CONCLUSION

The study explores and provides review literature of fundamental V2V communication in VANET. Several challenges and trends are elaborated. The V2V communication in VANET potentially improves the future transportation that provides a higher standard of safety driving, enhances the driving comfort, and supports the big idea of ITS both to answer the safety issue or non-safety issues in the future. Unfortunately, the study also found that VANET technology still used in limited segmentation and needs further research to implement VANET in a vehicle effectively. A SWOT matrix describes several fundamental factors that need to solved by all stakeholders, such as a legal problem, global economic fluctuation, low public trust, the multi-standard problem in a different region, the regulations, infrastructures problem, and high-cost of R&D

REFERENCES

[1] Li, D., Liu, M., Zhao, F., & Liu, Y. (2019). Challenges and countermeasures of interaction in autonomous vehicles. *Science China Information Sciences*, *62*(5), 3–5. https://doi.org/10.1007/s11432-018-9766-3

[2] Wang, N., Wang, X., Palacharla, P., & Ikeuchi, T. (2018). Cooperative autonomous driving for traffic congestion avoidance through vehicle-to-vehicle communications. *IEEE Vehicular Networking Conference, VNC*, *2018-Janua*, 327–330. https://doi.org/10.1109/VNC.2017.8275620

[3] Wang, Y., Yao, J., & Chen, G. (2018). An evolving super-network model with inter-vehicle communications. *Journal of the Franklin Institute*. https://doi.org/10.1016/j.jfranklin.2018.07.036

[4] Mchergui, A., Moulahi, T., Alaya, B., & Nasri, S. (2017). A survey and comparative study of QoS aware broadcasting techniques in VANET. *Telecommunication Systems*, *66*(2), 253–281. https://doi.org/10.1007/s11235-017-0280-9

[5] Caballero-gil, C., Caballero-gil, P., & Molina-gil, J. (2015). *Self-Organized Clustering Architecture for Vehicular Ad Hoc Networks*. *2015*. https://doi.org/10.1155/2015/384869

[6] Liang, W., Li, Z., Zhang, H., Sun, Y., & Bie, R. (2014). Vehicular ad hoc networks: Architectures, Research issues, Challenges and trends. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *8491*, 102–113. https://doi.org/10.1155/2015/745303

[7] Demba, A., & Moller, D. P. F. (2018). Vehicle-to-Vehicle Communication Technology. *IEEE International Conference on Electro Information Technology*, *2018-May*(1), 459–464. https://doi.org/10.1109/EIT.2018.8500189

[8] Özdemir, Ö., Kılıç, İ., Yazıcı, A., & Özkan, K. (2016). A V2V System Module for Inter Vehicle Communication. *Applied Mechanics and Materials*, *850*, 16–22. https://doi.org/10.4028/www.scientific.net/amm.850.16

[9] Shaikh, S. N., & Patil, S. R. (2016). A robust broadcast scheme for vehicle to vehicle communication system. *Conference on Advances in Signal Processing, CASP 2016*, 301–305. https://doi.org/10.1109/CASP.2016.7746184

[10] Gao, S., Lim, A., & Bevly, D. (2016). An empirical study of DSRC V2V performance in truck platooning scenarios. *Digital Communications and Networks*, *2*(4), 233–244. https://doi.org/10.1016/j.dcan.2016.10.003

[11] Daniel, A., Paul, A., Ahmad, A., & Rho, S. (2016). Cooperative Intelligence of Vehicles for Intelligent Transportation Systems (ITS). *Wireless Personal Communications*, *87*(2), 461–484. https://doi.org/10.1007/s11277-015-3078-7

[12] Moloisane, N. R., Malekian, R., & Capeska Bogatinoska, D. (2017). Wireless machine-to-machine communication for intelligent transportation systems: Internet of vehicles and vehicle to grid. *2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2017 - Proceedings*, 411–415. https://doi.org/10.23919/MIPRO.2017.7973459

[13] Moussaoui, B., Fouchal, H., Ayaida, M., & Mermiz, S. (2016). Unicast routing on VANETs. *Proceedings of the 2016 Federated Conference on Computer Science and Information Systems, FedCSIS 2016*, *8*, 1089–1092. https://doi.org/10.15439/2016F262

[14] Outay, F., Bargaoui, H., Chemek, A., Kamoun, F., & Yasar, A. (2019). The covcrav project: Architecture and design of a cooperative v2v crash avoidance system. *Procedia Computer Science*, *160*, 473–478. https://doi.org/10.1016/j.procs.2019.11.062

[15] Ghatwai, N. G., Harpale, V. K., & Kale, M. (2017). Vehicle To vehicle communication for crash avoidance system. *Proceedings - 2nd International Conference on Computing, Communication, Control and Automation, ICCUBEA 2016*, 1–3. https://doi.org/10.1109/ICCUBEA.2016.7860118

[16] Matthias Schulze, Tapani Mäkinen, Joachim Irion, Maxime Flament, T. K. (2008). *Preventive and Active Safety Applications Integrated Project*. 198.

[17] Brennand, C. A. R. L., Filho, G. P. R., Maia, G., Cunha, F., Guidoni, D. L., & Villas, L. A. (2019). Towards a Fog-Enabled Intelligent Transportation System to Reduce Traffic Jam. *Sensors (Basel, Switzerland)*, *19*(18), 1–30. https://doi.org/10.3390/s19183916

[18] Jia, D., & Ngoduy, D. (2016). Platoon based cooperative driving model with consideration of realistic inter-vehicle communication. *Transportation Research Part C: Emerging Technologies*, *68*, 245–264. https://doi.org/10.1016/j.trc.2016.04.008

[19] Hsu, C., Fikentscher, J., & Kreeb, R. (2017). Development of potential methods for testing congestion control algorithm implemented in vehicle-to-vehicle communications. *Traffic Injury Prevention*, *18*(S1), 51–57.

[20] Desai, P., Loke, S. W., & Desai, A. (2017).

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Cooperative vehicles for robust traffic congestion reduction: An analysis based on algorithmic, environmental and agent behavioral factors. *PLoS ONE*, *12*(8), 1–20. https://doi.org/10.1371/journal.pone.0182621

[21] Aliedani, A., & Loke, S. W. (2018). Cooperative car parking using vehicle-to-vehicle communication: An agent-based analysis. *Computers, Environment and Urban Systems*, *October 2017*, 101256. https://doi.org/10.1016/j.compenvurbsys.2018.06.002

[22] Hasrouny, H., Samhat, A. E., Bassil, C., & Laouiti, A. (2018). Trust model for secure group leader-based communications in VANET. *Wireless Networks*, *6*, 1–23. https://doi.org/10.1007/s11276-018-1756-6

[23] Bian, Y., Zheng, Y., Ren, W., Li, S. E., Wang, J., & Li, K. (2019). Reducing time headway for platooning of connected vehicles via V2V communication. *Transportation Research Part C: Emerging Technologies*, *102*(March), 87–105. https://doi.org/10.1016/j.trc.2019.03.002

[24] Liu, Z. Q., Zhang, T., & Wang, Y. F. (2019). Research on Local Dynamic Path Planning Method for Intelligent Vehicle Lane-Changing. *Journal of Advanced Transportation*, *2019*. https://doi.org/10.1155/2019/4762658

[25] Cui, Y., Wu, J., Xu, H., & Wang, A. (2020). Lane change identification and prediction with roadside LiDAR data. *Optics and Laser Technology*, *123*(September 2019), 105934. https://doi.org/10.1016/j.optlastec.2019.105934

[26] Peng, T., Su, L., Zhang, R., Guan, Z., Zhao, H., Qiu, Z., Zong, C., & Xu, H. (2020). A new safe lane-change trajectory model and collision avoidance control method for automatic driving vehicles. *Expert Systems with Applications*, *141*. https://doi.org/10.1016/j.eswa.2019.112953

[27] Eze, E. C., Zhang, S. J., Liu, E. J., & Eze, J. C. (2016). Advances in vehicular ad-hoc networks (VANETs): Challenges and road-map for future development. *International Journal of Automation and Computing*, *13*(1), 1–18. https://doi.org/10.1007/s11633-015-0913-y

[28] Tilahun, S. L., & Tawhid, M. A. (2018). Swarm hyperheuristic framework. *Journal of Heuristics*, *25*(4), 809–836. https://doi.org/10.1007/s10732-018-9397-6

[29] Chiu, K. L., & Hwang, R. H. (2012). Communication framework for vehicle ad hoc network on freeways. *Telecommunication Systems*, *50*(4), 243–256. https://doi.org/10.1007/s11235-010-9401-4

[30] Zeadally, S., Hunt, R., Chen, Y. S., Irwin, A., & Hassan, A. (2012). Vehicular ad hoc networks (VANETS): Status, results, and challenges. *Telecommunication Systems*, *50*(4), 217–241. https://doi.org/10.1007/s11235-010-9400-5

[31] Cheng, J., Cheng, J., Zhou, M., Liu, F., Gao, S., & Liu, C. (2015). Routing in internet of vehicles: A review. *IEEE Transactions on Intelligent Transportation Systems*, *16*(5), 2339–2352. https://doi.org/10.1109/TITS.2015.2423667

[32] Ferreiro-Lage, J. A., Gestoso, C. P., Rubiños, O., & Agelet, F. A. (2009). Analysis of unicast routing protocols for VANETs. *Proceedings of the 5th International Conference on Networking and Services, ICNS 2009*, 518–521. https://doi.org/10.1109/ICNS.2009.96

[33] Bilal, S. M., Bernardos, C. J., & Guerrero, C. (2013). Position-based routing in vehicular networks: A survey. *Journal of Network and Computer Applications*, *36*(2), 685–697. https://doi.org/10.1016/j.jnca.2012.12.023

[34] Saleh, A. I., Gamel, S. A., & Abo-Al-Ez, K. M. (2017). A Reliable Routing Protocol for Vehicular Ad hoc Networks. *Computers and Electrical Engineering*, *64*, 473–495. https://doi.org/10.1016/j.compeleceng.2016.11.011

[35] Zhou, Q., Fan, Y., & Wei, C. (2012). Heuristic routing protocol research on opportunistic networks. *Proceedings of the 14th IEEE International Conference on High Performance Computing and Communications, HPCC-2012 - 9th IEEE International Conference on Embedded Software and Systems, ICESS-2012*, 1704–1707. https://doi.org/10.1109/HPCC.2012.254

[36] Liu, Z. Y., Zhou, J. G., Zhao, T., & Yan, W. (2009). An opportunistic approach to enhance the geographical source routing protocol for vehicular ad hoc networks. *IEEE Vehicular Technology Conference*, 1–5. https://doi.org/10.1109/VETECF.2009.5378797

[37] Suhendra, T., & Priyambodo, T. K. (2017). Analisis Perbandingan Algoritma Perencanaan Jalur Robot Bergerak Pada Lingkungan Dinamis. *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)*, *11*(1), 21. https://doi.org/10.22146/ijccs.15743

[38] Hu, L., Ding, Z., & Shi, H. (2012). An improved GPSR routing strategy in VANET. *2012 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2012*, 1–4. https://doi.org/10.1109/WiCOM.2012.6478416

[39] Silva, R., Lopes, H. S., & Godoy, W. (2013). A heuristic algorithm based on ant colony optimization for multi-objective routing in vehicle Ad Hoc networks. *Proceedings - 1st BRICS Countries Congress on Computational Intelligence, BRICS-CCI 2013*, 435–440. https://doi.org/10.1109/BRICS-CCI-CBIC.2013.78

[40] Rajesh Kumar, M., & Routray, S. K. (2017). Ant Colony based Dynamic source routing for VANET. *Proceedings of the 2016 2nd International Conference on Applied and Theoretical Computing*

e-ISSN: 2614-8404
p-ISSN: 2776-3234

and Communication Technology, ICATccT 2016, 279–282. https://doi.org/10.1109/ICATCCT.2016.7912008

[41] Koulinas, G., Kotsikas, L., & Anagnostopoulos, K. (2014). A particle swarm optimization based hyper-heuristic algorithm for the classic resource constrained project scheduling problem. *Information Sciences*, *277*, 680–693. https://doi.org/10.1016/j.ins.2014.02.155

[42] Abba, S., & Lee, J. A. (2017). Bio-inspired self-aware fault-tolerant routing protocol for network-on-chip architectures using Particle Swarm Optimization. *Microprocessors and Microsystems*, *51*, 1339–1351. https://doi.org/10.1016/j.micpro.2017.04.003

[43] Okulewicz, M., & Mańdziuk, J. (2017). The impact of particular components of the PSO-based algorithm solving the Dynamic Vehicle Routing Problem. *Applied Soft Computing Journal*, *58*, 586–604. https://doi.org/10.1016/j.asoc.2017.04.070

[44] Singh, P. K., Nandi, S. K., & Nandi, S. (2019). A tutorial survey on vehicular communication state of the art, and future research directions. *Vehicular Communications*, *18*, 100164. https://doi.org/10.1016/j.vehcom.2019.100164

[45] Balzano, W., Murano, A., & Vitale, F. (2016). V2V-EN - Vehicle-2-Vehicle Elastic Network. *Procedia Computer Science*, *58*, 497–502. https://doi.org/10.1016/j.procs.2016.09.084

[46] Cherkaoui, B., Beni-Hssane, A., Fissaoui, M. El, & Erritali, M. (2019). Road traffic congestion detection in VANET networks. *Procedia Computer Science*, *151*, 1158–1163. https://doi.org/10.1016/j.procs.2019.04.165

[47] Boussoufa-Lahlah, S., Semchedine, F., & Bouallouche-Medjkoune, L. (2018). Geographic routing protocols for Vehicular Ad hoc NETworks (VANETs): A survey. *Vehicular Communications*, *11*, 20–31. https://doi.org/10.1016/j.vehcom.2018.01.006

[48] Darwish, T., Abu Bakar, K., & Hashim, A. (2017). Green geographical routing in vehicular ad hoc networks: Advances and challenges. *Computers and Electrical Engineering*, *64*, 436–449. https://doi.org/10.1016/j.compeleceng.2016.09.030

[49] Li, D., Deng, L., Cai, Z., Franks, B., & Yao, X. (2018). Intelligent Transportation System in Macao Based on Deep Self-Coding Learning. *IEEE Transactions on Industrial Informatics*, *14*(7), 3253–3260. https://doi.org/10.1109/TII.2018.2810291

[50] Benza, M., Bersani, C., D'Incà, M., Roncoli, C., Sacile, R., Trotta, A., Pizzorni, D., Briata, S., & Ridolfi, R. (2012). Intelligent Transport Systems (ITS) applications on dangerous good transport on road in Italy. *Proceedings - 2012 7th International Conference on System of Systems Engineering, SoSE 2012*, 223–228. https://doi.org/10.1109/SYSoSE.2012.6384180

[51] Malygin, I., Komashinsky, V., & Tsyganov, V. V. (2017). International experience and multimodal intelligent transportation system of Russia. *Proceedings of 2017 10th International Conference Management of Large-Scale System Development, MLSD 2017*, 1–5. https://doi.org/10.1109/MLSD.2017.8109658

[52] Seliverstov, Y. A., Malygin, I. G., Komashinskiy, V. I., Tarantsev, A. A., Shatalova, N. V., & Petrova, V. A. (2017). The St. Petersburg transport system simulation before opening new subway stations. *Proceedings of 2017 20th IEEE International Conference on Soft Computing and Measurements, SCM 2017*, 284–287. https://doi.org/10.1109/SCM.2017.7970562

[53] Lin, L. T., Huang, H. J., Lin, J. M., & Young, F. F. (2009). A new intelligent traffic control system for Taiwan. *2009 9th International Conference on Intelligent Transport Systems Telecommunications, ITST 2009*, 138–142. https://doi.org/10.1109/ITST.2009.5399369

[54] Poolsawat, A., Ayutaya, K. S. N., & Pattara-Atikom, W. (2009). Impact of intelligent traffic information system on congestion saving in Bangkok. *2009 9th International Conference on Intelligent Transport Systems Telecommunications, ITST 2009*, 153–156. https://doi.org/10.1109/ITST.2009.5399364

[55] Muchaendepi, W., Mbohwa, C., & Kanyepe, J. (2019). Intelligent Transport Systems and its Impact on Performance of Road Freight Transport in Zimbabwe. *IEEE International Conference on Industrial Engineering and Engineering Management*, *2019-December*, 80–83. https://doi.org/10.1109/IEEM.2018.8607409

[56] Nkoro, A. B., & Vershinin, Y. A. (2014). Current and future trends in applications of Intelligent Transport Systems on cars and infrastructure. *2014 17th IEEE International Conference on Intelligent Transportation Systems, ITSC 2014*, 514–519. https://doi.org/10.1109/ITSC.2014.6957741

[57] Zhu, T., & Liu, Z. (2015). Intelligent Transport Systems in China: Past, Present and Future. *Proceedings - 2015 7th International Conference on Measuring Technology and Mechatronics Automation, ICMTMA 2015*, 581–584. https://doi.org/10.1109/ICMTMA.2015.146

[58] Zhu, L., Yu, F. R., Wang, Y., Ning, B., & Tang, T. (2019). Big Data Analytics in Intelligent Transportation Systems: A Survey. *IEEE Transactions on Intelligent Transportation Systems*, *20*(1), 383–398. https://doi.org/10.1109/TITS.2018.2815678

[59] Vidya, V. M., & Deepa, N. (2019). Big data analytics in intelligent transportation systems using hadoop. *International Journal of Recent Technology and Engineering*, *7*(6), 75–80.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

[60] Wu, F. J., Zhang, X., & Lim, H. B. (2014). A cooperative sensing and mining system for transportation activity survey. In *IEEE Wireless Communications and Networking Conference, WCNC* (pp. 3284–3289). https://doi.org/10.1109/WCNC.2014.6953075

[61] Chen, B., & Cheng, H. H. (2010). A review of the applications of agent technology in traffic and transportation systems. *IEEE Transactions on Intelligent Transportation Systems*, *11*(2), 485–497. https://doi.org/10.1109/TITS.2010.2048313

[62] Veres, M., & Moussa, M. (2019). Deep Learning for Intelligent Transportation Systems: A Survey of Emerging Trends. *IEEE Transactions on Intelligent Transportation Systems*, 1–17. https://doi.org/10.1109/tits.2019.2929020

[63] Zhang, J., A, A, A, A, A, A, A, & A. (2011). Data-driven intelligent transportation systems: A survey. In *IEEE Transactions on Intelligent Transportation Systems* (Vol. 12, Issue 4, pp. 1624–1639).

[64] Wang, X., & Yan, S. (2011). Design and implementation of intelligent public transport system based on GIS. *2011 International Conference on Electric Information and Control Engineering, ICEICE 2011 - Proceedings*, 4868–4871. https://doi.org/10.1109/ICEICE.2011.5777492

[65] Anand, B., Barsaiyan, V., Senapati, M., & Rajalakshmi, P. (2019). Real time LiDAR point cloud compression and transmission for intelligent transportation system. *IEEE Vehicular Technology Conference*, *2019-April*, 1–5. https://doi.org/10.1109/VTCSpring.2019.8746417

[66] Eckelmann, S., Trautmann, T., Ußler, H., Reichelt, B., & Michler, O. (2017). V2V-Communication, LiDAR System and Positioning Sensors for Future Fusion Algorithms in Connected Vehicles. *Transportation Research Procedia*, *27*, 69–76. https://doi.org/10.1016/j.trpro.2017.12.032

[67] Li, W., Ma, X., Wu, J., Trivedi, K. S., Huang, X. L., & Liu, Q. (2017). Analytical Model and Performance Evaluation of Long-Term Evolution for Vehicle Safety Services. *IEEE Transactions on Vehicular Technology*, *66*(3), 1926–1939. https://doi.org/10.1109/TVT.2016.2580571

[68] Li, J., Zhang, Y., Shi, M., Liu, Q., & Chen, Y. (2020). Collision avoidance strategy supported by LTE-V-based vehicle automation and communication systems for car following. *Tsinghua Science and Technology*, *25*(1), 127–139. https://doi.org/10.26599/TST.2018.9010143

[69] Correa, A., Boquet, G., Morell, A., & Vicario, J. L. (2017). Autonomous car parking system through a cooperative vehicular positioning network. *Sensors (Switzerland)*, *17*(4). https://doi.org/10.3390/s17040848

[70] Sakurada, L., Barbosa, J., Leitao, P., Alves, G., Borges, A. P., & Botelho, P. (2019). Development of Agent-Based CPS for Smart Parking Systems. *IECON Proceedings (Industrial Electronics Conference)*, *2019-October*, 2964–2969. https://doi.org/10.1109/IECON.2019.8926653

[71] Shi, Y., Pan, Y., Sun, X., Xie, R., Chen, W., & Shen, S. (2018). Collaborative Planning of Parking Spaces and AGVs Path for Smart Indoor Parking System. *Proceedings of the 2018 IEEE 22nd International Conference on Computer Supported Cooperative Work in Design, CSCWD 2018*, 496–500. https://doi.org/10.1109/CSCWD.2018.8465323

[72] Tilahun, S. L., & Di Marzo Serugendo, G. (2017). Cooperative multiagent system for parking availability prediction based on time varying dynamic markov chains. *Journal of Advanced Transportation*, *2017*. https://doi.org/10.1155/2017/1760842

[73] Abunei, A., Comsa, C. R., Caruntu, C. F., & Bogdan, I. (2019). Redundancy based V2V communication platform for vehicle platooning. *ISSCS 2019 - International Symposium on Signals, Circuits and Systems*, 9–12. https://doi.org/10.1109/ISSCS.2019.8801781

[74] Stüdli, S., Seron, M. M., & Middleton, R. H. (2017). Vehicular Platoons in cyclic interconnections with constant inter-vehicle spacing. *IFAC-PapersOnLine*, *50*(1), 2511–2516. https://doi.org/10.1016/j.ifacol.2017.08.449

[75] Kim, J., Han, Y., & Kim, I. (2019). Efficient Groupcast Schemes for Vehicle Platooning in V2V Network. *IEEE Access*, *7*, 171333–171345. https://doi.org/10.1109/ACCESS.2019.2955791

[76] Tripathy, R., Harmalkar, J., & Kumar, A. (2019). A functionally safe dual-bus platoon architecture for future smart cities. *Proceedings of the International Conference on Trends in Electronics and Informatics, ICOEI 2019*, *2019-April*(Icoei), 682–686. https://doi.org/10.1109/icoei.2019.8862618

[77] Bhoopalam, A. K., Agatz, N., & Zuidwijk, R. (2018). Planning of truck platoons: A literature review and directions for future research. *Transportation Research Part B: Methodological*, *107*, 212–228. https://doi.org/10.1016/j.trb.2017.10.016

[78] Larson, J., Liang, K. Y., & Johansson, K. H. (2015). A distributed framework for coordinated heavy-duty vehicle platooning. *IEEE Transactions on Intelligent Transportation Systems*, *16*(1), 419–429. https://doi.org/10.1109/TITS.2014.2320133

[79] Kokkinogenis, Z., Teixeira, M., D'Orey, P. M., & Rossetti, R. J. F. (2019). Tactical level decision-making for platoons of autonomous vehicles using auction mechanisms. *IEEE Intelligent Vehicles Symposium, Proceedings*, *2019-June*(Iv), 1632–1638. https://doi.org/10.1109/IVS.2019.8814122

[80] Maiti, S., Winter, S., & Kulik, L. (2017). A

e-ISSN: 2614-8404
p-ISSN: 2776-3234

conceptualization of vehicle platoons and platoon operations. *Transportation Research Part C: Emerging Technologies*, *80*, 1–19. https://doi.org/10.1016/j.trc.2017.04.005

[81] Dang, R., Ding, J., Su, B., Yao, Q., Tian, Y., & Li, K. (2014). A lane change warning system based on V2V communication. *2014 17th IEEE International Conference on Intelligent Transportation Systems, ITSC 2014*, 1923–1928. https://doi.org/10.1109/ITSC.2014.6957987

[82] Wang, L., Iida, R. F., & Wyglinski, A. M. (2018). Coordinated Lane Changing Using V2V Communications. *IEEE Vehicular Technology Conference*, *2018-Augus*, 1–5. https://doi.org/10.1109/VTCFall.2018.8690643

[83] Liu, X., Liang, J., & Xu, B. (2019). A Deep Learning Method for Lane Changing Situation Assessment and Decision Making. *IEEE Access*, *7*, 133749–133759. https://doi.org/10.1109/ACCESS.2019.2940853

[84] Sakr, A. H., Bansal, G., Vladimerou, V., & Johnson, M. (2018). Lane Change Detection Using V2V Safety Messages. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, *2018-Novem*, 3967–3973. https://doi.org/10.1109/ITSC.2018.8569690