Performance Evaluation of Safe Avoidance Time and Safety Message Dissemination for Vehicle to Vehicle (V2V) Communication in LTE C-V2X

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***Abstract*—VANET has many opportunities to manage vehicle safety on the road efficiently. The standards from European Telecommunications Standards Institute (ETSI) for Intelligent Transport System (ITS) provide necessary upper-layer specifications for safety message dissemination between vehicles using Cooperative Aware Messages (CAM) and Decentralized Event Notification Message (DENM). Besides, mobile radio technology of Long-Term Evolution (LTE) in Release-14 comes with two modes of communication, which is mode 3 and mode 4 to support vehicle to vehicle communications. The relationship between vehicle time gap, speed, and UE transmit power significantly impacts the Packet Delivery Ratio (PDR) and throughput. With higher vehicle moving speeds, longer safe distances must be kept in ensuring safety. However, at longer safe distances, we have proven that communication may be lost because CAM messages cannot be exchanged successfully. As a result, no vehicle safety can be guaranteed using V2V communication. This may get worse in urban or cities environment where interference is dominant. Simulation results provide evidence that variable distance between vehicles cannot be ignored to ensure vehicle safety with successful message communication among them.**

Keywords—Time gap; safe distance; collision; VANET; CAM

I. INTRODUCTION

In recent years, vehicular systems have gotten a ton of consideration from specialists, mainly communicating a message for improving vehicle [1]. VANET is an exceptional and conceivably the most significant class of Mobile Ad hoc Networks (MANETs). The transmission of messages between vehicles within VANET is not enough to prevent vehicle collisions. Therefore, this research aims to study the safe distance between the vehicle and the message disseminate within a safe distance. Collisions between vehicles occur on roads on daily basis. Vehicle collisions occurred on roads because of human factors. For example, due to human behaviors tending to drive at high speeds, vehicles could not brake safely to avoid a collision with other vehicle because there is no sufficient braking time maintained. The time gap is the safe distance required for the vehicle to press the brake before a collision occurs. Based on the human factors driving with different speeds of the vehicle, the time gap is significant. Different vehicle speeds also require different time gaps because they have a proper distance between them before they stop. During braking, the vehicle must maintain a safe time gap for a safe distance to avoid the collision happen [21].

In this research, the focus is on vehicle communications in a mode 3 environment. The two major problems for moving vehicles are maintaining safe distances or safe time gaps between them to avoid collisions at the desired speeds. These are done by periodically exchanging safety messages using the CAM message as specified in the ETSI standards. Maintaining safe distances between any vehicles is paramount in avoiding collisions and ensuring safety. However, even with the dissemination of CAM messages between vehicles, a message that is received by any moving vehicle does not guarantee safety as it still does not meet the Safety Avoidance Time (AT) or safe time gap. A collision is still highly probable even if vehicles at the time of successful CAM message receptions, do not keep safe distances between them. There is a potential trade-off between safe time gap and vehicle safety, influenced by the transmit power. At higher speeds, the time gap required increases, hence the safe distances that must maintain between vehicles get larger, potentially leading to loss of communication. This research will study the relationship between vehicle time gap, speed, and UE transmit power significantly impacts the Packet Delivery Ratio (PDR), throughput. Simulation results provide evidence that variable distance between vehicles cannot be ignored to ensure vehicle safety with successful message communication among them.

The rest of the paper is organized as follows. Background is overviewed in Section II. Section III describes research methodology using avoidance time. Section IV addresses result and discussion. Finally, conclusions are given in last section of the paper.

II. BACKGROUND

The smart transportation system has become a new factor for the economic development. Intelligent Transport Industry has made great investment and dedicated development resources for the vehicle-to-everything technology, autonomous vehicles. One of the smart transportation systems is already in use that is Dedicated-short-distanced-communication (DSRC) and now next level for this is cellular-V2X by using IEEE 802.11p and 3GPP-LTE/5GNR which is being deployed as a new emerging smart transportation technology. The author described all the positive, negative factors and the challenges faced by these two technologies and how IoT technology can well collaborate and integrate with DSRC and Cellular-V2X to cope with the new economic challenges [21][23]. One of the smart transportation techniques in order to increase safety and efficiency along with decreased

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fuel consumption is to move vehicles in squad. In this situation, vehicles communicate with each other through radio signals in send any alert/safety messages while moving on road. The author [23] described that emergency message communication between vehicles-to-everything can be more efficient by redesigning platooning-application for vehicles along with considering the communication with 3GPP scheduled mode. There is not a single authorized algorithm for administration of resources. Therefore, vehicles forming a squad can communicate with one data packet at a time to occupy the communication medium. For platooning, the real time message packet delivery using 3GPP, can only be possible with distributed time slots for communication using IEEE 802.11p. Reliability and throughput of message packet delivery was simulated under variable traffic of data packets using cellular-V2X factors. In [25], the authors presenting an analytical survey regarding the new emerging cellular vehicle-to-vehicle and cellular vehicle-to-everything technologies and how the standard 3GPP wireless communication network is struggling to cope with the real time emergency communication and reliability challenges associated with C-V2V and C-V2X in both homogeneous and heterogeneous smart transport systems. The authors are mainly focusing with the challenges associated with the typical and more advanced reliable and secure traffic system by evaluating the wireless technologies for inter-connected vehicle communication. In this survey, different types of wireless communication methods and the applications used are classified along with the challenges faced by radio technology for inter-vehicle communication [27]. As the 5G network promises massive communication with reliable connection, it has brought a dynamic progressive change in wireless communications. As in Internet-of-vehicles, quick, safe and reliable message communication is required in order to meet requirements for the end-user as well as for the business purposes and 5G technology can well facilitate this purpose when it comes to vehicle-to-everything and autonomous-vehicle applications. The authors [27] describes that 5G technology advancement not only facilitate users in terms of vehicle communication but also provides us reliable and correct traffic alerts along with helping the environment by decreased pollution and mishap ratio. Therefore, this survey paper well advocates how 5G technology advancement and its communication protocols can facilitate vehicle-to-everything and internet-of-vehicles cellular networks by protecting the environment. In this era, everything related to vehicle-to-everything demands a safe, secure, reliable, trustworthy, environment and fuel friendly smart transportation system not only for the vehicles driven by humans but more needed for the autonomous vehicles [28]. To ensure all these economical, humanitarian and environment friendly requirements and to cope with the challenges associated with them, newly developed European and American technologies named “Europe-ITS-G5” and “DSRC (US-WAVE) are ready to be used on vast dimensions based on IEEE 802.11p. Other technologies like “C-V2X (LTE)” have less capability to integrate well with 5G technology in order to meet the new emerging future requirements for smart transportation system and inter-vehicle communication. The authors [28] presented a detailed analysis for the existing technologies and how vehicle industry is facing the challenges along with its positive and negative effects on transportation system. Internet-of-Vehicles is an emerging technology which needs a lot of development and improvements as it involves real time communication among heterogeneous vehicles [29]. Vehicles can be both human-driven and autonomous ones, but the challenge is to broadcast massive and instantly changing messages among vehicles to ensure safety along with ever changing over the time vehicle volume is another factor to be considered. Different studies have been done to understand the response spectrum and message communication using IEEE 802.11p of vehicle-to-vehicle single-hop communication along with resource distribution time slots among heterogeneous especially in traffic congestion. For multi-hop V2V message transmission, not only vehicles on road broadcast signals but also if they get disconnected then radio broadcasters along roadside were also being analyzed [29].

A. Safety Message Dissemination

VANET is a distinctive sort of portable correspondence where topology changes powerfully because of vehicles' high portability. Vehicles utilize two sorts of messages to refresh their status and to disseminate a message to other vehicles. Security message scattering in VANETs has been tended to in vast numbers of the distributed articles. The issues related to the congestion control with regards to VANETs. The essential issue brought about by the congestion control is the communicated storm issue that prompts organize clog and bundle crashes bringing about parcel misfortune. It examines a few varieties of direct flooding and different kinds of forwarding protocols to moderate this issue [5]. The cross-layer communication, known as Cross-Layer Broadcast Protocol (CLBP), for crisis message dispersal in VANETs. CLBP utilizes a measurement, considering physical channel conditions and the moving vehicles' speed to choose many messages handing-off hubs towards the goal. The creators of CLBP perform recreations to approve their plan. The other exploration paper [6] proposes a direction-based plan for security message dispersal and contrasts its presentation and the direct flooding [7]. Based on all the research from this current paper, it does not mention a safety avoidance model for message dissemination. Furthermore, most recent research does not mention a safety message successfully sent within a safe distance. Therefore, to ensure maximum data packet delivery, focusing on finding the optimal combination of Beacon Generation Interval and transmission range [18]. The author described that previous research work in VANET focused on uniform vehicular networks and they totally ignored the presence/interruption of other broadcasting or radio signals from wireless devices. Therefore, multi-variant wireless signals increase the complexity of inter- vehicle communication. The author presented critical review of two types of heterogeneous wireless communication technologies which are DSRC and C-V2X, afterwards suggested an approach for reliable communication between heterogeneous vehicles having multiple radio access devices. It claims that the proposed Quality-of-service-aware-Relaying algorithm (QR) provide efficient results for message broadcasting and relaying-count in contrast of other standard-protocols [18]. In this paper [19], author is focused only on V2V communication comprising on heavy vehicles like trucks by using platooning to ensure safe distances between heavy vehicles on road which increases traffic safety along with decreased fuel consumption. Cooperative-Adaptive-Cruise-Control is one of the devices to ensure safe V2V communication. The paper presented a comparison between two types of radio/wireless technologies which are IEEE 802.11p and 3GPP-Cellular-V2X. The later radio technology being used in proposed framework for V2V communication which consists of two modes that are Mode3 which is base-station-scheduled and Mode4 which is autonomously scheduled. Simulation results advocates that minimum feasible vehicle spacing between trucks in extra over-crowding of multiple radio message distribution by heterogeneous vehicles was more efficiently achieved with Cellular-V2X radio technology as compared to IEEE 802.11p [20]. In this paper the authors [6] described that by improving cellular-systems, V2X can be more efficient with increased throughput and decreased response time. It is acquired by replacing Long-term-Evolution-V2X with New-Radio-V2X as the prior one can provide primary road-safety-applications and later one can provide more enhanced smart road safety application systems. The author of this paper introduced Cellular-V2X as an essential technology either in terms of centralized or distributed network system to ensure primary and enhanced road safety applications with the development of Long-term-Evolution-V2X to New-Radio-V2X. Smart transportation system cannot rely on smart-single-vehicle system but it requires inter-connected smart heterogeneous vehicle system and to ensure this smart heterogeneous vehicle system, integration of Cellular-V2X and 5G smart technology has become crucial for autonomous and smart transportation. Moreover, it analyzed the possible issues to cope with the combination of 5G radar and Cellular-V2X communication system. The authors [26] advocates that the importance of vehicle-to-everything applications can never be ignored as they made drastic improvements in terms of traffic safety and reliability and lessen fuel consumption but due to high cost of smart vehicle applications, developers must test these through simulation before the release of actual application in market. They used ns3 simulator to test their proposed vehicle communication model using an open-sourced easier to configure, quick and simple simulation model to combine multiple communication heaps instead of single communication stack using IEEE 802.11p, C-V2X mode4, 3GPP and LET-transmission models. To handle emergency, speed and space alerts using ETSI standards, sample applications were presented.

B. *Collision Avoidance in VANET*

VANET uses several various safety applications for safety purposes. VANET is owned by a Cooperate Collision Avoidance System (CCAS) class which is also called Intelligent Transport Systems (ITS). Most of the collision avoidance systems in VANET research consists of two different approaches: proactive and reactive [8]. Proactive approach uses data through neighboring vehicles to prevent a collision. While reactive approach is activated when a vehicle sends emergency warnings messages to neighboring vehicles and an irrational behavior happens such as instant hard and strong braking and mechanical failures in the vehicle.

Based on the research, most of the system and design were proposed to use the same fundamental technologies, which are the Global Positioning System (GPS) wireless communication devices. However, when DSRC wireless technologies have been introduced, all the designs based on preventing rear-end collision scenarios have become one of the significant research areas [10]. An algorithm used to prevent a collision at the scenarios of road intersection has been proposed by the researchers [11]. This proposed significant concept is mainly focused on the scenarios of road intersection where an algorithm is implemented to prevent a collision occurred. By improving the ready used roadsides' infrastructures with an improved communication coverage and another traffic signal, it could significantly avoid collisions at the intersections. These researchers utilized an estimator that consolidates the measurement from in-vehicle sensor and GPS. Moreover, authors [9] also proposed an improved algorithm that is suitable for the curve’s environments. Apart from that, there are several works have been designed to enhance the warning system. As such, assistant of lane changing, forwarding collision, and intersection warning systems are designed to operate in different types of function. Now a days, safe and reliable method for massive vehicle transportation is vehicle patrolling able to communicate with each other using radio technology. Communicating emergency safety messages with each other ensures an improved traffic reliability and decreased fuel consumption. The authors [24] described that to ensure message delivery from the leading vehicle in a patrol to other vehicles to improve safety messages regarding geographical positioning of vehicles and to maintain safe distances among them, separating message broadcasting by using relays is the proposed method from the leading vehicle to other vehicles. In order to align variable information origins and restrict parameters for the reported vehicle squad positioning, an adaptive distributive-model-predictive-control (DMPC) was proposed in the research to avoid errors regarding vehicle geographical positioning. Therefore, consequently provides an effective framework for collision avoidance in V2V. In automatic vehicle driving, vehicles are programmed to understand its local commands and there is a great lack of understanding the emergency messages sent by other vehicles [30]. Therefore, relying on local radio environment is not useful and there should be other techniques for vehicle-to-network message transmission by using 5G technology or any Wi-Fi. Therefore, author presented an approach for make learning pattern better for autonomous vehicles in response in efficient manner using V2X learning system for better collision avoidance system.

C. *Packet Delivery Rate in V2V Safety Communication*

Most of the research does not mention and claim that the time gap(s) must be considered when sending and receiving a message. It is very crucial in order to ensure the rate of data packet delivery is maximum in vehicle-to-vehicle (V2V) safety (broadcast) communication. A beacon message is also called a CAM (Cooperative Awareness Message), where it broadcasts the position, the vehicle direction, the speed, and the other information or forms the backbone of the analysis done by the ITS Stations in range [15]. This paper also only focuses on PDR results on clustering head to sending and receiving a message. The cluster head of each cluster member will receive the forwarded packet from its cluster member. All the forwarded packets by the cluster members are probability calculated which is associated with the number of times the same packet is received during one interval [9]. The elected cluster head will continue to distribute it towards the transmission direction upon receiving the sent packet by the cluster member. In the conventional way of multi-hop broadcasting, every vehicle requires to disseminate the received data by simple re-broadcasting. However, this broadcasting method will create redundant data in re-transmissions, resulting in an unused radio channel occupation and interfering with the radio channel. Therefore, decreasing redundancy and at the same time to ensure its reachability is very crucial in order to improving data delivery in a VANET. Hence, the simple way and efficient approach to achieve this goal is to re-broadcast the probabilistically [12]. A lot of research is going on integration of vehicle-to-everything and device-to-device communication with the development of 5G technology but still many challenges are to be coped with integration of vehicle-to-everything and device-to-device communication. The author is presenting an approach for quality enhancement of message delivery over VANET by dealing with all possible antecedent issues. Considering vehicles as clusters by using adaptive-mobility-aware-path-similarity algorithm. Cluster head selection was proposed on numerous factors, one of them was future-path sameness. It used Bayesian-rule-based-fuzzy-logic algorithm for vehicle-to-vehicle and device-to-device communication. It used two kinds of safety messages which are “accident” and “traffic” for safe message distribution. The author [17], modeled the projected cellular-5G VANET in OMNET++ simulator and was aimed to increase packet delivery ratio, turnout and to decrease communication and distribution time of message in vehicle ad hoc networks [17]. The author [22] has described the undeniable importance of cellular-vehicle-to-everything(C-V2X) in today’s 5G technology for the Intelligent Transportation System (ITS). Undoubtedly, it played a vital role in providing increased turnout, faster message communication along with decreased waiting time but there are still challenges to be coped with. Some of them are heterogeneous vehicles and frequent radio signal losses between them in emergency situations to avoid vehicle collision or any damage. The author suggested an approach to deal with such emergency message communication links between vehicles along with assuring the Quality of Service by first selecting the best device for message broadcasting in order to avoid node-to-node delay with the help of a dedicated similarity-based communication link. In case, if it fails to search and select any such device to broadcast emergency message then alternate selection will be a pedestrian 5G base-station. To reduce bulk-messages, author suggested Chaotic-Crow-Search-Algorithm and simulation results via Omnet++4.6 simulator showed a little improved output and packet delivery ratio in emergency message communication along with a minor decrease in node-to-node message delay [16].

III. OVERVIEW OF METHODOLOGY

Fig. 1 shows the difference between lane 1, lane 2, and lane 3 with varying speeds V1, V2, and V3. Vehicle in all lanes must maintain different safe AT time [4] to avoid any rear-end collisions. To ensure the safe AT time is maintained, all vehicles will exchange safety messages to know each other’s exact road positions. In lane 1, vehicles A, B and C is assumed to be able to maintain safe distances by exchanging the safety message because at 40km/hr, the safe distances (or AT time) are small. Due to that reason, the amount of transmit power needed is also small and may not reach the maximum permitted transmit power level. When the received power is equal or larger than the received power threshold ($Prx \geq Prx(th)$), an exchanged safety message can be received, and a vehicle can ensure safe distance be maintained. In lane 3 for vehicle D and F, when the speed is increased to 100km/hr, the required safe distance (or AT time) to be maintained is large. Transmission of a vehicle safety message by vehicle F may not be received by vehicle D simply because received power is lower than received power threshold $Prx < Prx(th)$. Due to this reason, communication between vehicle D and F is lost. A safety message might not be received because the distance to be kept is large.

Fig. 2 shows the broadcast safety message between Vehicle A and Vehicle B. For any vehicle moving speed [4], the AT safe parameter is x (s) and actual AT parameter between these two vehicles is y (s). Vehicle A and Vehicle B will exchange a safety message, both will be sending and receiving. However, if at the time of successful message reception for both vehicles, $y < x$, there is no sufficient avoidance time maintained, a crash might still happen between these two-vehicles. This fundamentally means that even if a message is successfully received by a vehicle (vehicle A) from another vehicle (vehicle B), vehicle safety still cannot be guaranteed since no maintenance a proper safe distance (AT safe).

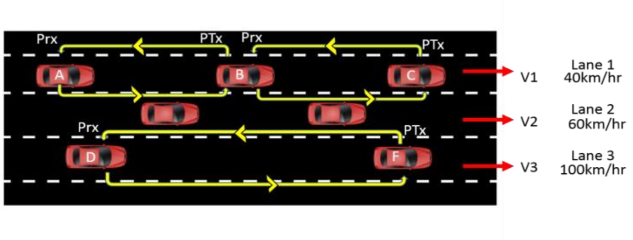


Fig. 1. V2V Message Dissemination within the AT time within difference Speed.

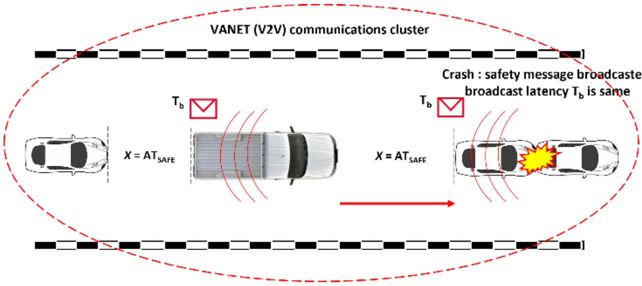


Fig. 2. V2V Communication with Safe AT (Avoidance Time).

A. Avoidance Time Concept

As indicated by the research and exploration on the delay of passenger vehicle, the analyst vehicle based on the security on passenger vehicle, time gap has been used instead of time headway. It is proved that the time gap represents the actual time which is only appears to the following vehicle to prevent collision of rear-end with a leading vehicle performing a uniform deceleration in a VANET. [2] It is fundamental for an after the vehicle to hold a protected after separation to the primary vehicle to consider enough opportunity to slow down upon the leading vehicle plays out a uniform deceleration to a halt. VANET time-gap approach could be used as a warning system to the following vehicles to avoid collision with the leading vehicles in a high traffic density area. Thus, TGFD is characterized as the accompanying vehicle's base time to decelerate and safely break without crashing the primary vehicle when both apply to the emergency breaks due to unexpected conditions. The time-gap following distance is defined as car speeding calibration and maintaining a pre-selected time-gap in between both vehicles, the leading vehicle and the following vehicle. The researchers discovered that time-gap is specified as the critical factor for safety, and proper time-gap calculations which could lead to a better performance and give allowances for in-vehicle distraction [2]. TGFD model for passenger vehicles must consider the passenger vehicle braking time and the time factors which are time perception, time decision, time broadcast, and time propagation in the VANET environment [3]. The Standards for Cooperative Awareness Message (CAM) and a Decentralized Environmental Notification Message (DENM) defines that communication should be delivered with the expected service requirement of maximum 100ms end-to-end latency (Final draft ETSI, 2014-09). The safety time gap was calculated by reference the VANET AT model for autonomous passenger vehicle as per below [4];

$$(\text{auto}) = Tb + Ts + Tpr + 0.28 \tag{1}$$

Ts is the reaction time of an autonomous vehicle system, and reaction time can be set in the range between 0.011s to 0.2s. The best time reaction is 0.011s since it is the fastest. The reaction time set for this study is 0.2s. Tb is the broadcast time, and Tpr is propagation time; the value of 0.28.

The braking time Tbr for a straight road can be calculated by converting to the time component. "v" is the speed in km/hr, and "a" is the deceleration m/s2. The value of 0.28 is a fixed value for the AT model [2]. By referencing from the $ATpv$(auto) model, the reaction time was set to 0.2s, and deceleration (it is the variable) was set to -8.8 m/s2 and input the overall stopping distance in the unit meter(m), that must be set in OMNET++ while running the simulation.

IV. SIMULATION AND RESULTS

In this research, Veins (Vehicles in Network Simulation) is used as a simulation tool which is a built-in simulation framework on OMNeT++ simulation environment. Veins recruits OMNeT++ simulation kernel for a discrete event simulation whereas all the simulation controls and data collections are performed by OMNeT++. Veins instantiate SUMO to model a vehicle movement to provides a modular framework for the custom applications simulation. An example to abstract away from a discrete event simulation of wireless channels is by controlling event routing between nodes and modeling signal processing. In this case, dedicated model libraries are used for simulating such as Internet protocols (IPs) or cellular network communications. Veins build on this basic concept to provide a suite of model that can be served as a framework in modular type for simulating applications. Based on the suite of IVC models, the implementation of custom and application-specific data generation and dissemination protocols could be done referring to the IVC models suite available in OMNET++, such as the safety and efficiency of traffic. Such application simulations and all Veins modules used are consolidated and connected to be executable. This executable application could be run as a GUI application or as a command-line batch simulation. The combination of precise channel and access models, behavior, and mobility feedbacks enables wide range captures of necessary factors to investigate intersection collision avoidance approaches. The running simulation of the vehicle shows in Fig. 3 that running via OMNET ++. This simulation will be running within the time that was already setting in the code.

A separate instance simulates the SUMO, as mentioned above, a road traffic simulator's vehicle movement, which started and controlled by the running simulation. Veins utilize the object subscriptions integrated with SUMO to improve its efficiency. When vehicles are generated or their states are changed, Veins allow it to call updates and push notifications from a running simulation. Fig. 4 shows the workspace for SUMO. This file of sumo will be integrated with OMNET++ when running the simulation.

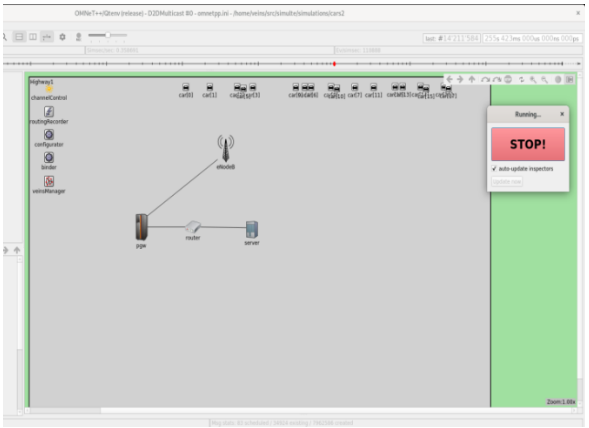
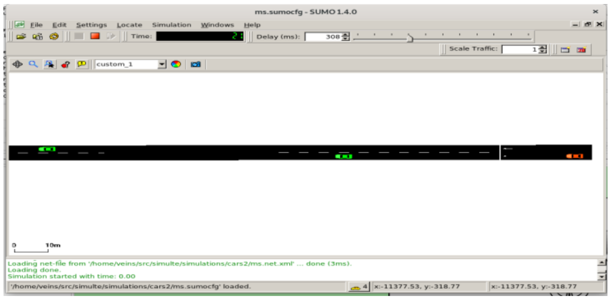


Fig. 3. Simulation Running in OMNET++.



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Loading net-file from '/home/veins/src/simulte/simulations/cars2/ms.net.xml' ... done (3ms).
Loading done.
Simulation started with time: 0.00
'/home/veins/src/simulte/simulations/cars2/ms.sumocfg' loaded.    4    x:-11377.53, y:-318.77    x:-11377.53, y:-318.77
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Fig. 4. SUMO Workspace.

The results were evaluated based on the time gap setting with different speed measures and vehicle density.

A. Packet Delivery Ratio (PDR) and Time Gap

Fig. 5 shows the graph for the results PDR with Time Gap setting. The PDR was decreasing when the density was an increase. The density set to 30 vehicles with a 50km/hr speed shows that highly PDR slowly decreases when the speed was increased. The density 100 of the vehicle shows that low PDR starts at the beginning 36 of 50km/hr until 120km/hr. This has happened because PDR does not been successfully sent when the density is increasing. The higher density, PDR will be affected, and message dissemination could not be successfully disseminated. Even the distance between vehicle to vehicle maintained it does not measure the message was successfully disseminated. This result meets this research objective, investigating the relationship between the safe vehicle time gap and the broadcast message's speeds. When vehicles maintain a safe time gap to ensure safety, which is to avoid collisions, the results show that this impacts the PDR and the distances between vehicles increases affecting message reception. The average difference PDR between densities 30 and 100 with 8 points of difference time gap setting is 5%. From Fig. 6 also while setting time gap(s) to the default value, the high of PDR was achieve. The results show that with a minimum time gap(s) setting, which is 4meter = 0.774s, the PDR slightly increases to 80% of PDR with low density 30. For the high density 100, the PDR slightly drop 40%, which means that in high density, the vehicular communication is dropping while sending and received message, and some communication is loss. Fig. 5 and Fig. 6 can be described that the time gap(s) setting affected the PDR. The larger and smaller distance was affected the vehicular communication when broadcasting a message.

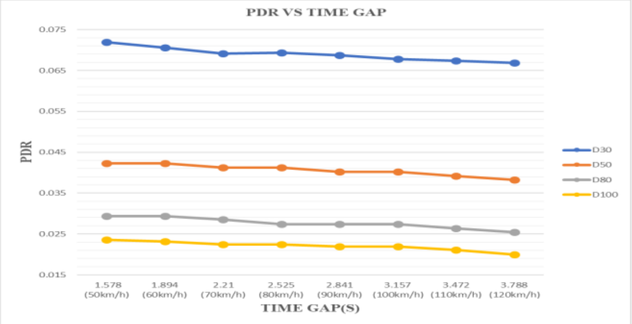

Fig. 5. PDR with Time Gap(s) Setting based on the Converted Time Gap(s) Speed.

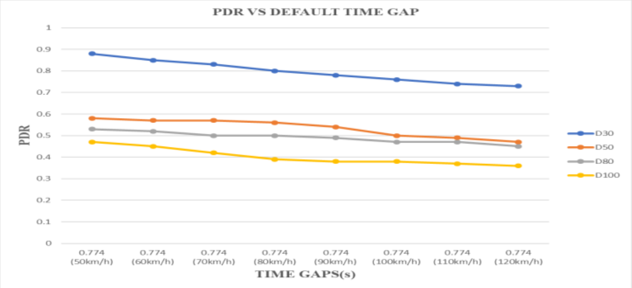

Fig. 6. PDR with Time Gap(s) Setting based on default Time Gap(s) Speed.

B. Throughput with Time Gap(s) Analysis Result

Fig. 7 shows the Throughput and Time Gap. For these results, the simulation was tested with the difference in speed and safety time gap. This figure shows that the throughput was decreased when the velocity and time gap is high. The successful message delivery rate over communication between V2V decreased when the simulation was run in high densities and velocity vehicles. This might be because the larger distance-time gap setting affected the packet arrive at their destinations successfully. This can be seen at time gap settings of 3.788s for vehicle speeds 120km/hr, respectively. Furthermore, these results meet with a problem statement discussed in Section 1, which is the communication between vehicles to the vehicle might be a loss of communication, even maintaining the safety distance. The average throughput between densities 30 and 100 is 213.72bps. From the average results, the successful CAM delivery over communication between V2V was decreased when the simulation was run in high densities and velocity vehicles.

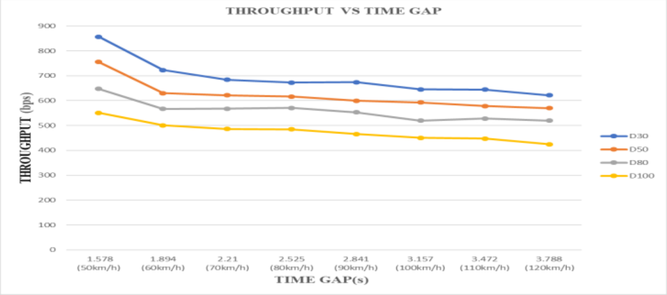

Fig. 7. Throughput and Time Gap(s).

C. Different UE Transmit Power with PDR and Time Gap(s) Analysis Result

Other simulation results were measured to investigate the packet delivery ratio (PDR) under different time gap settings with different vehicle speeds. The setting also under different vehicle densities and UE transmit power, as shown in Fig. 8. This figure shows that within 19dBm, the PDR was decreasing, which means that they send a packet of the message that was decreased and did not have been received successfully. The higher densities and speed with the high time gap, the PDR slowly decreases based on the different densities, the higher densities. The UE transmit power also affects the reception of messages shown with lower PDR. Higher mobility for vehicles, i.e., higher vehicle velocity, has a more substantial impact on PDR. This can be seen at time gap settings of 3.472s and 3.788s for vehicle speeds of 110Km/hr and 120km/hr, respectively. For UE transmit power was set to 27dBm above the standard also affected the message reception and slightly decrease when vehicle speed increase with higher mobility. Again, this result show that time gap settings with a difference of UE transmit power affects PDR and potentially vehicle safety.

D. Different UE Transmit Power with Throughput and Time Gap(s) Analysis Result

Fig. 9 shows the performance throughput with different speeds, densities, and UE transmits power 27dBm, 23dBm, and 19dBm. The 27dBm UE transmit power was set above the standard in ETSI. The rate of successful message delivery over communication between the vehicle to vehicle slowly decreased when the high densities have been tested. This can be seen at time gap settings of 3.472s and 3.788s for vehicle speeds of 110Km/hr and 120km/hr, respectively. This result shows that time gap settings with a difference of UE transmit power affect throughput and slightly decrease when vehicle speed increase with higher mobility and potentially affects vehicle safety. This result shows that in the highest safety time gap, 3.788s with 120km/hr, the throughput is in the lowest value for densities set to 30 and 50. When a vehicle to vehicle broadcast a message with high speed and the distance is more significant between the vehicles, some of the messages were not successfully sending and received by the vehicle.

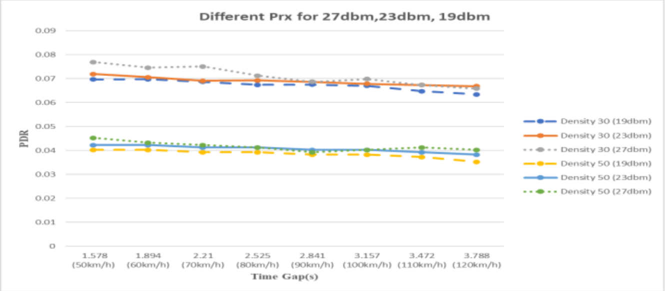

Fig. 8. Different Prx for 27dBm, 23dBm and 19dBm.

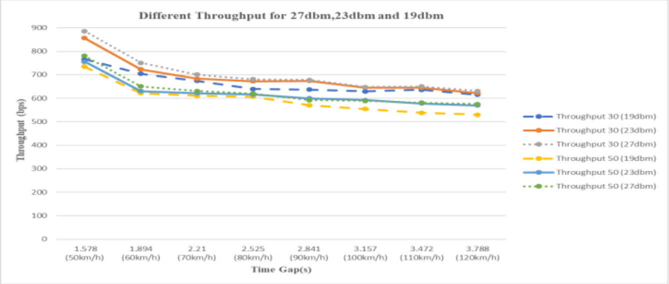

Fig. 9. Different Throughput for 27dBm, 23dBm and 19dBm.

E. *PDR for each of Vehicle with Different Speed, Time Gap, and UE Transmit Power*

This figure shows that the performance PDR per vehicle with different speed and time gap settings transmit power 23dBm. The rate of successful message delivery over communication between the vehicle to vehicle slowly decreases. This result shows that the distance between the vehicle affected the performance of PDR. The performance of PDR with the time gap formula shows that the lowest than the default time gap setting in veins simulation. The average difference between 60km/hr with default time gap setting and formula is 51%, and for 100km/hr is 53%. This can confirm that the distance between vehicles was affected by the CAM message.

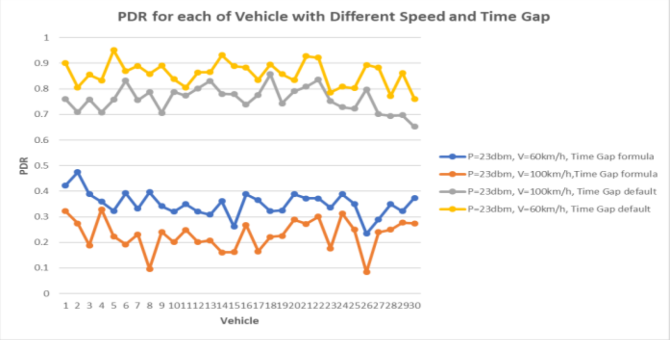

Fig. 10. PDR for each Vehicle with Different Speed, Time Gap, and UE Transmit Power.

V. CONCLUSION

The message dissemination between vehicle-to-vehicle communications impacts the packet delivery ratio and throughput based on the setting with different speed, time gap, and UE transmit power. Based on the findings, the relationship between vehicle time gap and speed impacted the packet delivery ratio (PDR), throughput, and UE power transmission. For the different speed and time gap, PDR's performance decreases while the speed was increase and while the vehicle's densities are increasing. It can be shown from the results that for vehicles to maintain safety on the road avoiding collisions, keeping a desired safe distance between them is essential, which means maintaining a proper time gap. However, the time gap is proportional to vehicle speed. As vehicle speed increases, the time gap also increases. The increasing time gap means increasing safe distances, and with the increase in safe distance, potential messages exchanged between all vehicles cannot be received. This will ultimately affect vehicle safety severely. It can also be shown that the Tx power of UEs also affects PDR, using a lower UE Tx power, while maintaining safe distances caused smaller message reception. Finally, it can be shown that even when vehicles exchanged safety messages between them to ensure safety, this does not necessarily guarantee safety as the distances between them grow apart (although safe), messages still cannot be received. The future work for this research is to evaluate the vehicle safety message dissemination performance under the influence of interference in an urban radio environment, the relationship and trade-off between PDR (successful CAM reception), UE transmit power, SNR and safe distances.

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