A platoon driving scheme based on vehicular cloud computing technology

Cite as: AIP Conference Proceedings **2400**, 020017 (2022); https://doi.org/10.1063/5.0112156
Published Online: 31 October 2022

Lamia Faris, Foad Salem Mubarek and Wesam M. Jasim

A Platoon Driving Scheme based on Vehicular Cloud Computing Technology

Lamia Faris[a], Foad Salem Mubarek[b], Wesam M. Jasim[c],

College Of Computer Science and Information Technology, University Of Anbar,Iraq.

Corresponding author:[a]den.lamia.faris@uoanbar.edu.iq

[b]co.foad.salem@uoanbar.edu.iq

[c]co.wesam.jasim@uoanbar.edu.iq

Abstract.

Improvement of driving safety and increasing road capacity is one of the most important aspects of the Intelligent Transportation System (ITS). The platoon of autonomous vehicles is one of the ITS applications used to decrease the congestions and accidents on the roads. In addition, forming the vehicles in the platoon can decrease fuel consumption and provides passengers with more comfortable trips. This paper proposes a new scheme to improve platoon driving using Vehicular Cloud Computing concepts. The scheme improves the communication technology of the platoon according to Dedicated Shorted Range Communication (DSRC) protocol by broadcasting the safety message via Vehicle to Vehicle (V2V). Furthermore; the vehicles exchange the data with the Road Side Unit (RSU) through the vehicle to Infrastructure V2I. The stability of the platoon which is the major problem of platoon driving is achieved through using the cloud computing capability in the RSU. This capability is satisfying through the connection between the leader vehicle and RSU to keep the distance stable among platoon members. The performance of the proposed scheme was evaluated using several parameters such as; End-to-End (E2E) delay, response time, and throughput. The VANET mobility simulation (VANET MOBISIM) mobility is used to generate a real map with the Manhattan grid model. The proposed scheme proves its efficiency by increasing the vehicle density in the roads and by adjusting the DSRC modulation. The Simulation results showed improvements as compared to the existing schemes.

Keywords: platoon, Autonomous Vehicle, Vehicular Cloud computing, DSRC, VANET, Network, ITS, V2V, V2R

INTRODUCTION

The Intelligent Transportation System ITS systems technology which designed to develop and enhancement the autonomous vehicle applications, traffic management, accident treatment, and to improve the safety and efficiency of the highway and urban system[1]. One of the most important ITS application is a platoon. The platoons are a group of cooperative vehicles moving with a small space distance among them to improve road capacity, traffic safety, and reduce pollution. The vehicles connect through wireless communication inV2V and V2I communication technology[2]. The more suitable and secure communication technology in a platoon is the dedicate short range communication DSRC wave with only standard medium access protocol for VANETs is IEEE 802.11p [3].This protocol is work based on the existing 802.11 standards to investigate the necessities of V2V and V2I communications in a high mobility VANETs environment. Based on the high dynamic topology changes and low latency restrictions in VANETs, V2V communication is applied to send the safety message to neighboring vehicles [2]. this work, we propose a communication system to the platoon which consists of one vehicle with a leader followed by five autonomous vehicles, The headway of our platoon is constant,two-meter to avoid collision of an autonomous vehicle with its leader... The communication system is based on V2X technology by using DSRC waves and equipped with VANET. The system tested urban mobility

1st Virtual International Conference on Sciences
AIP Conf. Proc. 2400, 020017-1–020017-12; https://doi.org/10.1063/5.0112156
Published by AIP Publishing. 978-0-7354-4248-1/$30.00

by using a real map of the Manhattan grid. Then the communication system was enhanced via connecting the platoon's leader with the vehicle cloud to assist the leader to make a successful decision on the roads.

The rest of the paper is organized as follows: section 2 overview of related work on communication of platoon. In section 3 the structure of platoon and the scenario of the proposed system. In section 4 present the simulation environments and communication model. The experiments, relevant results, and analysis are shown and discussed in the following Section 5. While the conclusion and future work are shown in section 6

RELATED WORK

The communication system in a platoon is based on the IEEE 802.11P protocol system**.** Many studies analyze the performance of platoon communication ***Mani Amoozadeh et al.*** [4] develop the protocol of management platoon for Cooperative Adaptive Cruise Control (CACC) system with V2V communication by sent the beacon message from the leader vehicle with driver to followers which are autonomous vehicles. ***Zeng et al.*** [5] the authors propose a design to join the wireless communication with the control of platoon, they analyzed the effect of stability. Then test the end-to-end latency of the vehicular autonomous platoon and improve the control parameter in a way to meet the stability and reliability of the platoon. ***Weiming Zhao et al.*** [6] introduce the design of a platoon consist of a number of the autonomous vehicle leading by human-driven vehicles (HVs) exchange the real-time information by connecting via vehicle-to-infrastructure (V2I) communication and vehicle-to-vehicle (V2V) communication. ***Pedro Fernandes*,** [7] suggests an algorithm to reduce the communication delay of the IEEE 802.11P protocol via DSRC wave to keep the control and string stability of platoon when the deceleration exceeding a certain threshold***. ShahramRezae et al.*** [8] describe a new schema to mitigate the congestion and delay in a platoon communication system, by reducing the interval time of broadcasting message which will mitigate the congestion of channel of DSRC communication from 20% to 5%. **Lamia Farris Tulaib *et al.*** [9] suggest a schema of one leader with one autonomous vehicle and test the end to end delay and respond time with the DSRC technology.

Our scheme supposed that platoon required more efficient real-time communication and as latency time decreases the platoon driving being more safe and reliable. So, with some modifications in safety message, our scheme establishes a new enhancement by reducing the latency time and mesure other metrics.

THE PROPOSED COMMUNICATION SYSTEM

In this paper, the communication system model of a platoon is implemented. The scenario followed in our work is a platoon consisting of a first vehicle led by a professional driver, followed by five self-driving vehicles. The leader broadcast the modified safety message to the follower vehicles through VANETs. The message contains the speed, velocity, acceleration, direction and the ID parameters of the leader. The safety message is sent to another vehicle in a V2V communication manner. Then, via a V2I technology, the leader vehicle is exchanged the safety message with RSU via an ad-hoc network when it enters the RSU environment. The information is gathered from the sensors, cameras, GPS, and any other technology equipped on the road. Then this information is sent to the Road Side Unit RSU through V2I or vice versa to provide the leader of a platoon with real-time advice. This information is related to traffic congestion, any accidents in the roadway, localization, traffic conditions, etc. The system is tested with the number of metrics and measured parameters such as E2E delay, response time, and throughput in a real map of Manhattan grid using the VANET MOBISIM mobility generator. The Contributions of this paper are implementation of some modification in DSRC safety messaging to exchange the information between the leader and the autonomous vehicle and studied the response time of this implementation proved with the mobility of real map of Manhattan grid that can use DSRC safety messaging in IVC communication of platoon without increasing any additional message overhead. And improve the communication of platoon using two services of vehicle cloud in the platoon; the storage service and the monitoring service, to keep the stability of the platoon by sensitive the environments and monitoring the road safety.

The Platoon Scenario

The proposed platoon structure consists of one normal vehicle which is a leader, five autonomous vehicles as followers. One RSU in the center of roads connects with other RSUs along the road, which affords access to cloud and real-time data services to platoon vehicles. The number of platoon members increased with 5 in every time (5,10,15,20,25) and estimate the effect of this increment in the communication of platoon, the estimation being via a number of measured parameters such as delay, response time, packet delivery ratio. Fig 1 shown the schema of our system

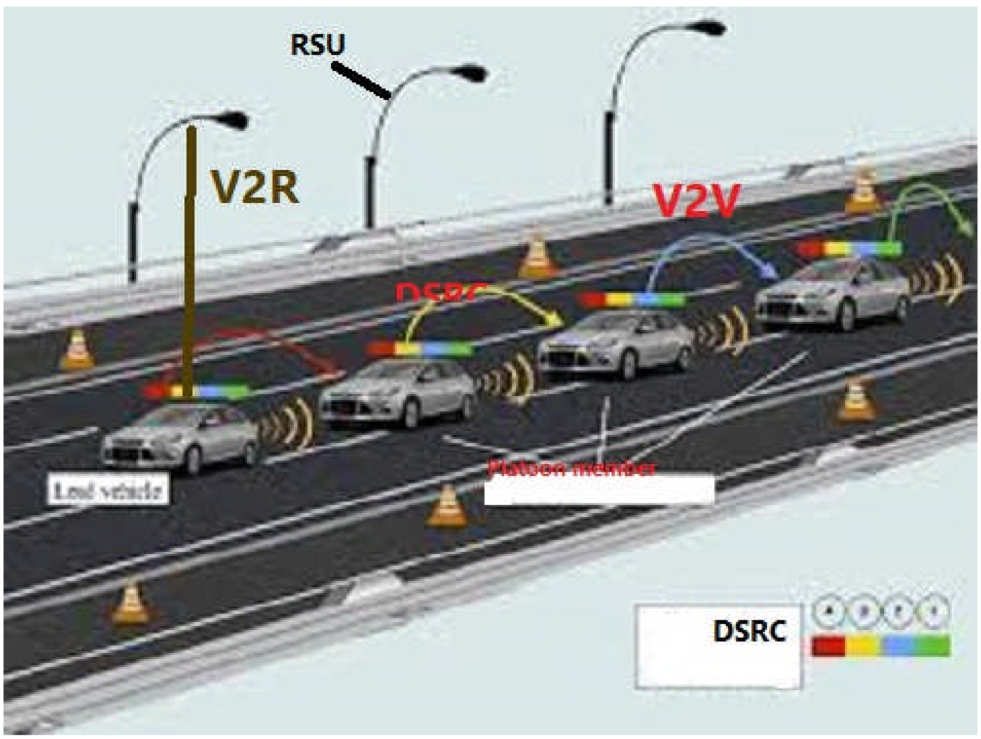

FIGURE 1: THE PLATOON COMMUNICATION SCHEMA

SYSTEM DESIGN

Our scenario includes two-step to execute suitable communication technology in the platoon

V2V Communication in Platoon

The Vehicle To Vehicle V2V technology or intra-platoon communication: used for exchange information from the leader to followers and among Autonomous Vehicles (AVs) in the same platoon, the safety message transmitted from leader-to-member or (member-to-member) for sharing information between the leader vehicle and one of the member vehicles. Simple safety message communication protocol can be used to send periodic messages from the leader Vehicle. This message will contain its present location and direction of movement and speed. So for that, to support platooning, Platoon Id and Platoon depth fields are added to the safety messages. Platoon Id is unique string that is used to distinguish between the different platoons, [10] the simulation repeated by changing some parameters such as channel modulation scheme, network density etc.. So, we can compare the response time, E2E delay and difference in overhead with change the number of vehicle and modulation schema in the environment and test that parameter and its effect to the platoon .

The V2I Communication In Platoon

We can improve the communication of platoon by using one or more services of cloud in a platoon. The most important service needed is to keep the stability of platoon by sensitive the environments and monitoring road safety. This service can be obtained by connecting the vehicle of a leader with RSU when the platoon entered into the transmission coverage of RSU and from RSU to cloud.
The proposal assumed that one RSU deployed in the center of the road. When the platoon vehicles entering to the RSU range, the leader begins to receive the warning message (forward collisions, road works, traffic conditions, and weather conditions). According to this warning message the vehicles in the platoon recognize the surrounding environment and respond on time. Then when a particular accident occurs the leader will take a particular action, for example, to change the direction of the platoon and notify the other vehicles by V2V to the following the leader. The communication of platoon explain in this algorthim

ALG 1: THE COMMUNICATION OF PLATOON

The communication algorithm
Goal : communication of platoon

Begin
For all vehicles do
While broadcasting safety message DO
If V2V communication then
begin
If L id =AV id then
Vehicle *AV* receives the acceleration and speed from the leader
Vehicle *AV* receives the acceleration from its precedent vehicle
end
Else if V2I communication then
Exchange the safety message with RSU
Configure the vehicle cloud
If the headway of *AV* with front vehicle = 2 then
Update the safety message
Update the velocity with CACC
If velocity = 0 then the platoon stop
End.

L id=id of the Leader vehicle

AV id= id of Autonomous vehicle

CACC =The Cooperative Adaptive Cruise Control

THE RSU CLOUD

The RSU cloud consists of three internal layers: application, cloud infrastructure, and cloud platform. In the application layer, various applications and services are considered such as real-time services or cloud primary services, which are accessible remotely by drivers. In our proposed scenario, we exploit the cooperation as a service (CoasS) which provides a variety of new services, such as driver safety, traffic information, warnings of traffic jams and accidents, weather or road conditions, parking availability and monitoring the roads to keep the platoon stability. According to this service, our proposed system keep the platoon driving in a safe manner. Furthermore, we exploit from the RSU cloud the storage service, While the following vehicles in platoon exchange huge amount of data which require additional storage to run their applications, Hence, the cloud provides storage like a service (StasS). Both of the services are used to augment the safety level of vehicles in a platoon on roads by reducing the percentage of crashes, delays and congestion improve mobility. Figure 2shows the RSU cloud infrastructure and its components.

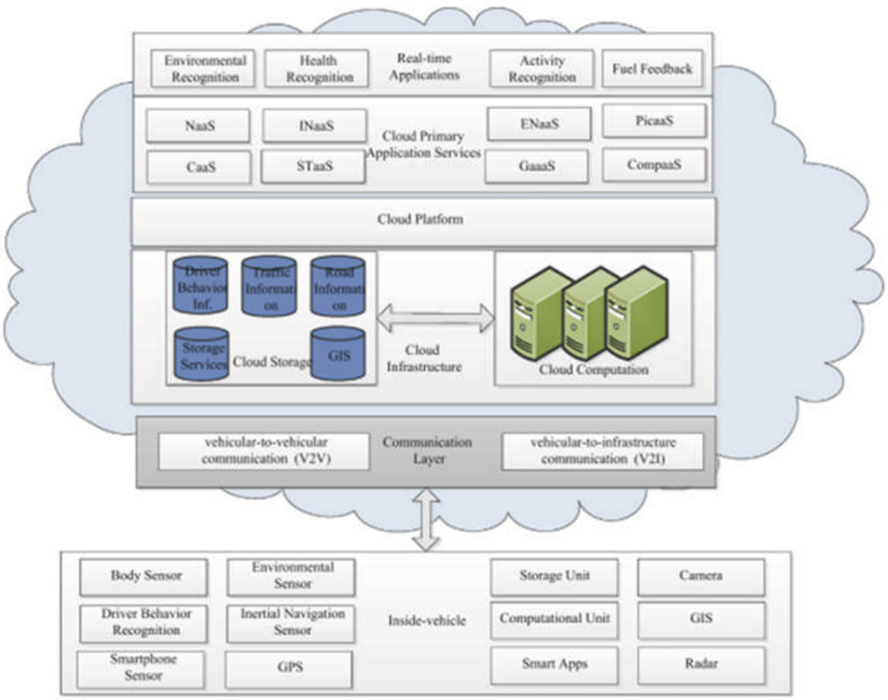

FIGURE 2: THE COMMUNICATION OF VEHICLE WITH CLOUD[11]

DSRC interacts with VANET to promote and development of ITS that enables the impact effect on the peloton's communication. The combination of IEEE802.11P with IEEE 1609 standard formed what is known as WAVE (Wireless Access for Vehicular Environment) or DSRC communication technology[12]. In our communication system, we choose the latest version from the IEEE802.11p standard Where DSRC define in PHY and MAC layers and divided into seven channels one to control and six for service channel. The 75 MHz of bandwidth allocated in the 5.9-GHz band for Dedicated Short Range Communications (DSRC and this bandwidth is divided into seven 10-MHz channels with one control channel (CCH) and six service channels (SCHs (our safety message are transmitted on control channel CCH (e.g., speed of vehicle, velocity, acceleration and road warning) [13]. In our simulation, we depend on an orthogonal frequency-division multiple access (OFDMA) scheme, to enable the synchronized V2V communication of the followers and prevent vehicle interference in the platoon with each member of the follower vehicle in a platoon. Also, we assume the space between the vehicles in the platoon depends on the constant-spacing policy(two-meter) which showed in experimental results that traffic throughput increased when used in V2V communication [14]. The major important issues for simulation the DSRC of a VANET environment is Nakagami propagation signal modelling, which is extremely specified to radio propagation model[15], therefore is Nakagami propagation used in this paper. The signal strength connected with each packet compared to the receiving threshold when a packet is obtained. In addition, if the signal power exceeds the receiving limit, the packet is regarded to be right; otherwise, it is discarded at the MAC layer.

NS-2 Simulation Environment

The system schema implemented in the simulation environment which is used the computer with the Linux (Ubuntu 14.4) operating system. The mobility model used in this simulation environment is VANET

MOBISIM model to generate traffic which supports the movement of platoon[16]. The VANET MOBISIM is integrating with NS2 to product traffic. The mobility model used in this paper is the Manhattan Urban Model used to create a mobility and traffic scenario for vehicles in easily and flexible manner. In the Manhattan model, nodes move only on predefined paths. In Table 1: the parameter of the simulation are shown.

TABLE 1: THE PARAMETER OF THE SIMULATION

Parameter	Value
Network Simulator	NS2.35
Traffic Simulator	Vanet MOBISIM
Channel type	Wireless channel
Layer used	Physical +mac layer
MAC Protocol	IEEE802.11p
Propagation model	Nakagami propagation
Antenna model	Omni antenna
Network interface type	Wireless Phy
Interface queue type	Droptail
Simulation area	700 *700 m
The velocity	10
Simulation time	200sec
max packet interface	20
Transmission range	250 meter

PERFORMANCE MEASUREMENT

The performance of platoon is measured in two scenarios, the first one according to change the number of the vehicle in the environment of platoon, and the second when the modulation of DSRC is changed. Delay and response time of platoon tested when we change the number of the vehicle, the number of the normal vehicles changed from 1,5,10,15,20,25 normal vehicles to measure the effect of density of vehicle in the road to the performance of platoon communication. And for all case, we have one RSU in the middle of the road. We use the default modulation of IEEE802.11P protocol: BSPK (zero-index modulation).The performance with respect to different network densities shown in table 2

TABLE (2) THE RESULT OF OUR SIMULATION WHEN INCREASING THE NUMBER OF VEHICLES

No. Normal Vehicles (Nos)	Send Messages (Nos)	Received Messages (Nos)	Total Received Packet Size (KB)	Consumed Network Bandwidth (kbps)	E2E Delay of 1 Hop DSRC Messages (ms)	Response Time (ms)
5	8800	48765	4762.21	390.32	8.77	11.27
10	12800	83363	8140.92	667.24	8.66	11.29
15	16800	130244	12719.14	1042.47	8.51	11.31
20	20800	184882	18054.88	1479.80	8.61	11.37
25	24800	276547	27006.54	2213.48	8.10	11.42

Impact of Network Density on E2E Delay:

The communication in platoon must be in real-time and this fulfilled by the low latency or delay. Accordingly, it is clear that the efficiency and safety of a DSRC based V2V and V2R communication system in platoon are closely associated with E2E delay. Any data send would reach the receiver with a certain delay. The high latency leads to the performance of platoon is affected negatively. The Effect of an increasing number of vehicle on E2E and response time of platoon shown in the figure 3

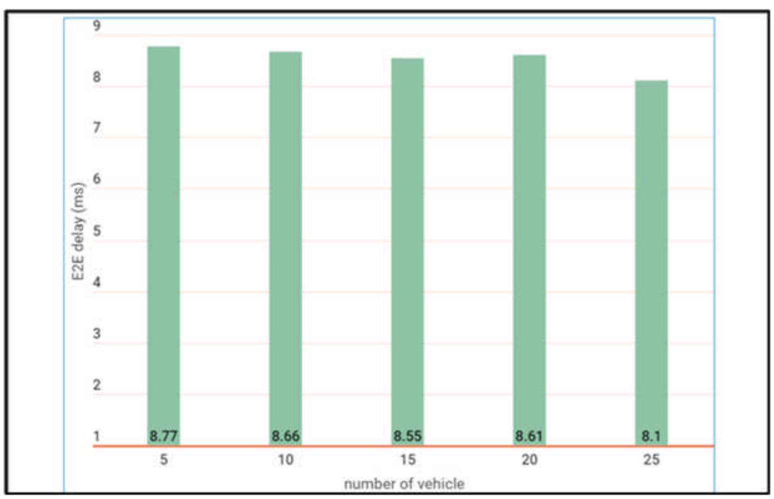

FIGURE 3: END TO END DELAY

Number Of Messages

Another factor is computed is a number of the received messages. When the density of the network is increased received messages should be checked. as we can see, from the table 2and figure 4 we notice that the amount of packets or message obtained and received is significantly greater than the number of packets sending. This happens because of all the members of platoon sharing in broadcasting the same message when they have received warning messages in one hop fashion. All the neighbour vehicles received the broadcast message which means that the messages are doubled in several times. Figure 4 and 5 explain the relationship between the network density and receiving and sending messages respectively.

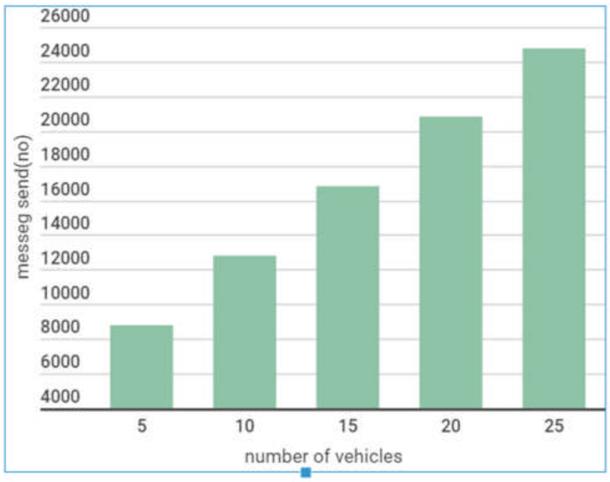

FIGURE 4: TOTAL SAFETY MESSAGE SENT

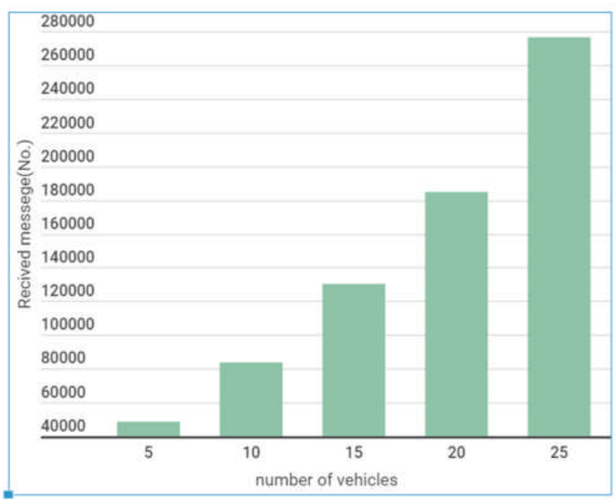

FIGURE 5: TOTAL SAFETY MESSAGE RECEIVED

The Throughput

We test the throughput of platoon by calculating the message delivered successfully and the result of the increased number of the vehicle to the throughput of the platoon. As we notice the effect is not noticeable when the number of vehicles increased and in total that is not hazard the stability of platoon. The effect of an increasing number of vehicles to the throughput of platoon shown in figure 6

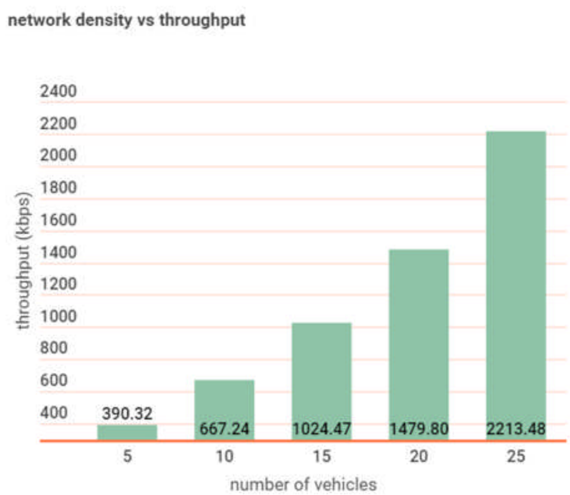

FIGURE 6: NETWORK DENSITY VS THROUGHPUT

THE CHANGE OF MODULATION OF DSRC

The modulation of DSRC is switching in the PHY layer to control the data flow rate.

In this section, study the effect of the throughput communication vehicle and the control overhead of the network with another modulation scheme (64-QAM) is analysed and focused.

In the previous simulation and result, we use the default modulation of IEEE802.11P protocol: BSPK (zero-index modulation) and then repeat the simulation with 64-QAM (three index modulation) and analysis the results we get minimum delay as shown in table 3 to indicate the relation between the received and sent messages in one side with number of vehicles in another side.

TABLE 3: THE RESULT OF SIMULATION WITH 64-QAM

No. Normal Vehicles (Nos)	Send Messages (Nos)	Received Messages (Nos)	Total Received Packet Size (KB)	Consumed Network Bandwidth (kbps)	E2E Delay of DSRC Messages (ms)	Response Time (ms)
5	8800	1549	151.27	12.40	3.32	1.10
10	12800	3128	305.47	25.04	3.41	1.00
15	16800	4313	421.19	34.52	3.35	3.10
25	24800	18607	1817.09	148.93	3.33	1.07

DISCUSSION

In this simulation the number of nodes increased and change the modulation of DSRC concerning E2E delay, the density of the network with total sent packets, total received packets and throughput. Concerning E2E delay when the number of vehicles increased in the environment of a platoon with default modulation of DSRC zero in the BPSK case, the result of E2E delay is with range (7.8 to 9.27) it is in the normal range of DSRC delay. Where the average message delivery delay of 0.1 s is accepted in most critical vehicle safety apps such as V2V collision prevention, lane altering warning, curve velocity warning, warning of a crash and intersection collision, etc. It shows the system's real-time characteristics, permitting the driver to react in-time if the accident does occur, and the E2Edelay never exceeds a threshold. It is very attractive that the delay stays consistent and stable platoon. On the other side when we change the modulation of DSRC to three In 64-QAM case we get E2E delay in the range (1.99ms to 3.98ms), when we compare the delay of 64-QAM with the above result We conclude that the delay is much lower than the previous result, that is mean the 64-QAM give improved outcome in concerning of delay and can be used when transmitted valuable and critical information. When we compared our results with the paper published by Yu, Chong et al [2] the paper discussed the effect of increasing the number of followers in a platoon which expands to 10 followers.The main drawback of this studying is excluding the neighboring vehicle in the surrounding from sharing in the scenario and ignored their effect on the traffic flow. Besides, the study used a back-off mechanism which is could not take the benefit of shared learning when the number of nodes is increasing. Finally, the studying used high modulation indexed which was adopted by our studying and proved that inappropriate because it caused dropping in packet delivery with low delay. On another side, our studying adopts further actual sharing members like RSU and supported the V2I communication which is accomplished by the stable and steady flowing of the platoon.

CONCLUSIONS

In our paper, we analyzed the proposed communication system of platoon .to evaluate the performance of the IEEE802.11P protocol with V2V and V2I technology by broadcast the safety message in the control channel deployed VANET. The V2V communication mode mainly helps in preventing accidents by using Basic Safety Message BSM, whereas V2I provides for a range of utility kinds of non-safety services from the roadside un its. we estimate how the DSRC can support the requirement of the platoon especially concerning safety and stability. Therefore we estimate the communication system of a platoon with many critical issues such as E2E delay and the response time of autonomous vehicle (followers), throughput, and network density when we have many vehicles access to 25 vehicles in the nearby surrounding environment of a platoon. We choose the Manhattan grid and VANET MOBISIM to evaluate our traffic system. We implemented some modifications in DSRC safety messages to broadcasting in V2V and V2I to increase the monitoring of the road and give more stability to the platoon. And the communication system occurs without increasing any additional message overhead, with a low index modulation scheme such as the BPSK modulation. While in 64QAM modulation we get low end to end delay but give a poor performance with packet delivery and throughput. The analysis of the performance assessment Indicates that BPSK has a data transfer rate for the low index modulation scheme. The most appropriate one for short messaging applications is 3 Mbps, also if the number of vehicles is increased and the distance between them is increased, For longer. It is also noteworthy that the throughput of vehicles increases with the BSM efficiency improves proportionally.

REFERENCES

[1] B. Ahmed, A. W. Malik, T. Hafeez, N. J. E. J. o. W. C. Ahmed, and Networking, "Services and simulation frameworks for vehicular cloud computing: a contemporary survey," journal article vol. 2019, no. 1, p. 4, January 07 2019.

[2] S. Ucar, S. C. Ergen, and O. J. I. T. o. V. T. Ozkasap, "IEEE 802.11 p and visible light hybrid communication based secure autonomous platoon," vol. 67, no. 9, pp. 8667-8681, 2018.

[3] C. Yu, S. Si, H. Guo, and H. J. S. Zhao, "Modeling and Performance of the IEEE 802.11 p Broadcasting for Intra-Platoon Communication," vol. 18, no. 9, p. 2971, 2018.

[4] M. Amoozadeh, H. Deng, C.-N. Chuah, H. M. Zhang, and D. Ghosal, "Platoon management with cooperative adaptive cruise control enabled by VANET," *Vehicular communications,* vol. 2, no. 2, pp. 110-123, 2015.

[5] T. Zeng, O. Semiari, W. Saad, and M. Bennis, "Joint communication and control for wireless autonomous vehicular platoon systems," *arXiv preprint arXiv:1804.05290,* 2018.

[6] W. Zhao, D. Ngoduy, S. Shepherd, R. Liu, and M. Papageorgiou, "A platoon based cooperative eco-driving model for mixed automated and human-driven vehicles at a signalised intersection," *Transportation Research Part C: Emerging Technologies,* vol. 95, pp. 802-821, 2018.

[7] P. Fernandes and U. Nunes, "Platooning with IVC-enabled autonomous vehicles: Strategies to mitigate communication delays, improve safety and traffic flow," *IEEE Transactions on Intelligent Transportation Systems,* vol. 13, no. 1, pp. 91-106, 2012.

[8] S. Rezaei, R. Sengupta, H. Krishnan, X. Guan, and P. Student, "Adaptive communication scheme for cooperative active safety system," *NewsBITS (December 2008),* vol. 4, 2008.

[9] L. F. Tulaib, W. M. Jasim, and F. S. Mubarek, "Autonomous Vehicle based-on Vehicular Cloud Networks."

[10] M. Amoozadeh, H. Deng, C.-N. Chuah, H. M. Zhang, and D. J. V. c. Ghosal, "Platoon management with cooperative adaptive cruise control enabled by VANET," vol. 2, no. 2, pp. 110-123, 2015.

[11] M. Whaiduzzaman, M. Sookhak, A. Gani, R. J. J. o. N. Buyya, and C. applications, "A survey on vehicular cloud computing," vol. 40, pp. 325-344, 2014.

[12] D. Su and S. Ahn, "Autonomous platoon formation for VANET-enabled vehicles," in *2016 International Conference on Information and Communication Technology Convergence (ICTC)*, 2016, pp. 247-250: IEEE.

[13] A. J. e. Festag and i. E. u. Informationstechnik, "Standards for vehicular communication—from IEEE 802.11 p to 5G," vol. 132, no. 7, pp. 409-416, 2015.

[14] P. Fernandes and U. J. I. T. o. I. T. S. Nunes, "Platooning with IVC-enabled autonomous vehicles: Strategies to mitigate communication delays, improve safety and traffic flow," vol. 13, no. 1, pp. 91-106, 2012.
[15] M. S. Anwer, "Improving TCP behaviour to non-invasively share spectrum with safety messages in VANET," University of Reading, 2017.
[16] T. Issariyakul and E. Hossain, "Introduction to Network Simulator 2 (NS2)," in *Introduction to network simulator NS2*: Springer, 2009, pp. 1-18.