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Performance Analysis of Sensing-based Semi-Persistent Scheduling (SB-SPS) MAC Protocol for C-V2X

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Abstract—Sensing-based Semi-Persistent Scheduling (SB-SPS) MAC protocol is proposed as part of the latest cellular vehicle to everything (C-V2X) standard for medium access between vehicles. As C-V2X uses LTE based frame structure, mode 4 of the C-V2X standard uses SB-SPS to allocate resource blocks effectively. C-V2X shows great potential for the future as it brings many improvements such as enhanced range, reliability, and the ability to support and evolve with emerging technologies such as 5G. In this article, the SB-SPS protocol's performance was analyzed in different scenarios using OMNET++, SUMO, and Veins simulator. Different vehicle speeds and densities were used to observe the effect on packet loss and throughput. It was found that as packet loss decreased, throughput increased when the mobility of vehicles decreased. The effects of changing some important parameters of SB-SPS were also observed. The results showed that while parameters such as increasing the number of subchannels increased the packet delivery ratio (PDR), the change in the probability of resource reselection parameter did not affect the PDR.

Keywords- C-V2X, SB-SPS, LTE, MAC, Vehicular Networks.

I. INTRODUCTION

Ever since the inception of intelligent transportation systems (ITS), it has always aimed for delivering people with smart, safe, and well-managed transport facilities. Dedicated short-range communication (DSRC) as shown in Fig. 1 [1] based standard for vehicular communication was proposed by the US Department of Transportation named Wireless Access in Vehicular Environments (WAVE) [2]. It proposed improvements to IEEE 802.11 and the enhanced version was called 802.11p for ITS applications. IEEE 802.11p uses physical and MAC layers for Vehicle to everything (V2X) communication. The communication standard proposed in Europe for vehicular communication is also based on IEEE 802.11p known as ETSI ITS-G5.

Vehicle to everything (V2X) means vehicles communicate with vehicles and infrastructure and implement this system by being aware of their environment [3]. Based on 802.11p, IEEE issued DSRC technology that allowed the vehicles to communicate with infrastructure and other vehicles directly. DSRC operated in a short range with low latency and was a perfect fit for direct vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, but security and safety were major concerns. The broadening horizon of LTE provided a chance to look for much more suitable options in vehicular communications to overcome the shortcomings of DSRC.

In 2016, the third generation partnership project (3GPP) release 14 put forth the evolved standard of LTE known as C-V2X with four modes defined for communication. Release 12 already introduced us to mode-1 and mode-2 also mentioned as device-to-device (D2D) communication equipped with sidelink or PC5 interface. PC5 interface [4] facilitated direct communication between user equipment (UE) without navigating to the base station. The nature of D2D communication paved the path for many applications to take advantage i.e. sending data by using proximity services, making communication possible in a dynamic environment. However, D2D communication is not dependable for complying with the latency demands and prerequisites of safer vehicular communication [5].

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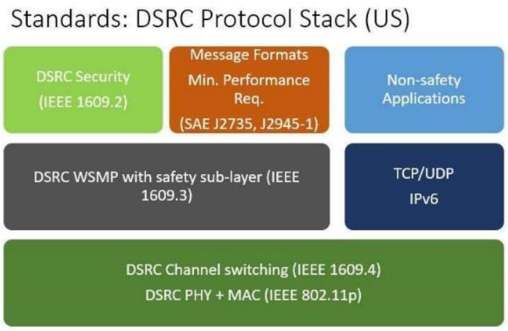

Figure 1. DSRC Protocol Stack

Cellular vehicle to everything (C-V2X) was introduced with additional two modes [6], mode-3 and mode-4 to subdue the underlying issues with earlier modes. C-V2X includes connectivity across the vehicle-to-infrastructure (V2I), vehicle-to-vehicle (V2V), vehicle-to-network (V2N), and vehicle-to-pedestrian (V2P). Mode-3 employs eNB (in-coverage mode) scheduler to perform network-assisted scheduling. Uu interface helps to establish communication between vehicular UE and eNB. UE scheduling is done by mode-4 [7] in an ad hoc manner with the help of the PC5 interface. This interface provides an immediate LTE sidelink in the middle of two UEs (vehicular). For C-V2X, mode-3 and mode-4 have been aimed to redeem the latency requisites and adapt to the increased density of vehicles and escalated Doppler spread.

Release 14 detailed improvements in various dimensions of features to upgrade performance for desired scenarios. The strategy used in mode-2 for allocating resources arbitrarily experienced problems like packet collisions and scalability. However, mode-4 has improved the packet collision avoidance procedure in which it keeps the history of channel occupancy to lower the collision chance.

This research is focused on the analysis of C-V2X Mode 4. The aim is to explore the various new features and develop an understanding of their working in different vehicular scenarios. Since DSRC is existing already for several years, this analysis is important to observe if C-V2X can be an alternative to DSRC. Earlier there was no need for ad hoc MAC and vehicular communication relied only on MAC infrastructure. But C-V2X introduced sensing-based semi-persistent scheduling (SBSPS) MAC protocol which aims for ad hoc communication.

Section II provides an overview of existing MAC protocols and recent research conducted on SB-SPS. Section III explains the C-V2X Mode 4 and its working. Section IV describes the simulation setup in detail. Section V provides the results and some discussion explaining the results. Finally, the paper is concluded by providing possible future research directions and a summary of the research.

II. RELATED WORKS

Carrier-sense multiple access with collision avoidance (CSMA/CA) is a MAC protocol in which carrier sensing is employed to avoid collisions. Nodes sense the carrier before transmission and only transmit if the sensed channel is found to be idle. Packet data is sent in its entirety when the nodes transmit. CSMA/CA is used in the Data Link Layer also known as Layer 2. IEEE 802.11e quality of service enhancement is supported by enhanced distributed channel access (EDCA) [2] in wireless networks. Traffic having a high priority is much more likely to be sent before traffic having low priority because the node with high priority traffic has to wait less as compared to the node with low priority traffic. High-priority traffic accomplishes this task by using shorter arbitration inter-frame space (AIFS). In EDCA, the level of priorities is known as access categories (ACs). The size of the contention window can be adjusted across each category according to the expected traffic.

Networks having shared medium uses time-division multiple access (TDMA) as a channel access method. Many researchers have considered it in their work [8-14] and many protocols are based on it. The frequency channel is divided into different time slots which allows many users to share the same frequency channel. Each user transmits in their time slot successively. In this way without using the whole channel, the same transmission medium is shared. TDMA has multiple transmitters in place of one transmitter with one receiver.

A reliable single-hop broadcast channel is implemented across all neighboring terminals by a distributed MAC layer architecture known as reliable R-ALOHA (RR-ALOHA). R-ALOHA protocol is extended by RR-ALOHA [8] to provide a safe environment in case of hidden-node problems. Nodes are provided by bandwidths that can be varied according to the requirements of QoS procedures. One-hop and multi-hop broadcasts are provided by VeMAC by overcoming hidden node issues [9]. Collisions caused by mobile nodes are reduced by the protocol as vehicles moving in different directions are assigned separate sets of time slots.

Code-division multiple access (CDMA) [17,18] is a channel access method in which multiple access is provided as a single channel can have many transmitters sending information at the same time. In this way, a band of frequencies is shared by many users. To accomplish this task without interference between users, a coding scheme in which transmitters are assigned with codes is employed. Self-organized time-division multiple access (STDMA) [11] as the name suggests have time slots “self-organized”. As compared to CSMA, where a random access-based technique is implemented, a reservation-based scheme is implemented by STDMA. For single packet transmission,

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frames are obtained by dividing time and then further dividing into transmission slots that are equal in size.

As described in [7], the essential evaluation for the introduction of SB-SPS in logically reasonable driving conditions for the New York City system using simulation platforms like OMNeT++, SUMO, and Veins. Their outcomes demonstrated that the sensing-based SPS performs better than the case where resources are allocated randomly in short to intermediate separations regarding packet delivery ratio (PDR), therefore the gains of the SB-SPS decline with separations. Additionally, it was suggested about hybrid automatic repeat request (HARQ) usefulness invalidates the increases of sensing-based SPS over-allocation that are done randomly. At last, they found that the impact of the collisions produced a lot of errors at short to medium separation, however, if the distances were increased, errors from propagation were there.

The authors from the publication mentioned above later produced another paper [15] that examines various arrangements utilizing similar traffic conditions as above and simulation platforms, by changing the sensing window, probability of resource reselection P, and the power that is being transmitted and afterward evaluation of Packet Delivery Ratio across the distance between the transmitter and receiver. They concluded that: expanding P diminishes the PDR in circumstances with channel load, even though the contrasts between various estimations of P are not that prominent to the channel load; adjusting the normal 1s window size for sensing to incremental range (so that later detecting estimations are given higher loads in the determination procedure) delivers some improvement, even though the additions are practically nothing; channels that have lesser load will have a negligible effect on changing the force edge, however, PDR is increased by a lower force limit on a channel having high priority; if the channel has lesser load, the transmitting capacity reduces PDR and seems to have an immaterial impact on channels with more load; lastly, the list to select resources from (that is twenty percent of the total resources, as indicated in Release 14) shows no noteworthy effect too.

The researchers in [16] performed the analysis using a modified test system for allotment of resources based on MATLAB known as LTE-V2V simulator [17], in two metropolitan scenarios (moderate density as well as blocked), the other being a parkway (increased density) case. Provided the packet reception ratio and delay in updating (for example distinction between the moment a packet is effectively received to the moment when the previous packet was accurately received) the reason is differing boundaries appeared to be immaterial in situations with low and medium vehicle load, even though they may get critical in blocked situations. Therefore, a greater probability of keeping a resource P increases delays but enhances Packet Reception Ratio.

Summarizing the discoveries of the papers that have been examined for this research, the general accord is by all accounts that upgrades are required to improve the performance, accordingly convincing a few researchers to begin researching potential upgrades. Huge numbers of the other sensing-based SPS parameters, for the most part, appear to effectively affect the performance, however, a portion of the examination presents conflicting outcomes, for example, [20] guaranteeing that keep likelihood significantly affects the Packet Delivery Ratio/Packet Reception Ratio execution, however the findings in [6][19].

III. SENSING-BASED SEMI-PERSISTENT SCHEDULING (SB-SPS)

A. Methods for Communications

F Mode 4 has 2 methods for communication; one allows communication between evolved UMTS terrestrial radio access network (E-UTRAN) and the vehicle via the sidelink or PC5 interface and the other uses the LTE-Uu interface. The former is referred to as direct communication between vehicles because it doesn't require any cellular network in between. However, the latter is regarded as indirect communication because of the required network assistance. Both of these options can be used independently for transmission [22].

B. Physical Layer

Frames are the small segments in which the LTE physical channel is divided as depicted in Fig. 2. The length of each LTE frame is equivalent to system bandwidth and the width of each LTE frame is equal to 10 ms. Further division of frames takes place in the time domain as subframes and in the frequency domain as subchannels. There are 10 subframes each having two time slots and 1 ms width. Subchannels when subdivided have resource blocks and the number of resource blocks differs in each subchannel. A resource block (RB) has 12 subcarriers of 15 kHz and would be the lowest frequency resource that can be assigned. Data transmission is done by subchannels in transport blocks (TB). QPSK or 16-QAM can be used to transmit transport blocks. Each transport block is followed by sidelink control information (SCI) which holds important information needed for its TB to be correctly received and demodulated. Two resource blocks per subframe are occupied by SCI. TB and its corresponding SCI must be transmitted in the same subframe.

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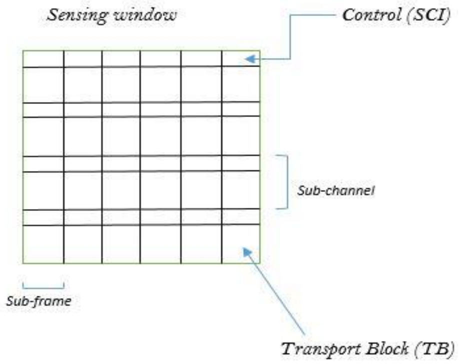

Figure 2. Breakdown of the Physical Layer

C. *Resource Allocation*

LTE provides the option to schedule resources either dynamically or by using semi-persistent scheduling (SPS). In dynamic scheduling, the vehicle has every subframe with scheduled data, this manner gives the system a lot of adaptability in this task, particularly in changing channel conditions. Control signaling provides an extra overhead since it would be required to relay data about the allocation of resources to the physical downlink control channel (PDCCH) within each subframe. Once again, SPS allows pre-distribution of a given resource for a certain time and eliminates the need to distribute resources for a change made earlier at any time. For administrations needing continuous allocations of radio services at typical intervals, SPS is appropriate, for example, voice over LTE (VoLTE), which delivers one package per 20 ms from the robust multi-rate (AMR) disc codec. SPS can thus bolster countless concurrent VoLTE customers without overpowering E-UTRAN with flagging energy. Mode 4 makes use of an improved SPS rendering called sensing-based SPS. SB-SPS follows these steps to perform the resource allocation procedure:

1) *Sesning*

- In sensing, each vehicle monitors the resources used by other vehicles before selecting the resource for its transmission.
- The last 1000 subframes from the sensing window are monitored.
- To determine whether a given resource is currently in use, the sidelink received signal strength indicator (RSSI) is a threshold above which the resource is said to be busy. There is no specified value of this threshold in the standard.
- Creates a list of available resources in a set SA and defines power threshold.

2) *Exemption*

- Performs exemption process to remove resources having more chances of collisions.
- Exclude all resources if any of the following condition is met:
- The vehicle has not monitored that resource in the sensing window.
- If the physical sidelink shared channel-reference signal received power (PSSCHRSRP) is higher than the threshold.
- The remaining resources from the set are checked if they are 20% of the initial resources. If they are less than 20% of total resources, the process is repeated with a 3 dB increase in the threshold.
- A set of candidate resources is created as set SB which includes the resources from set SA that have the lowest average received signal strength indicator (RSSI). Set SB should be 20% of the initial resources of SA.

This set is reported to higher layers for the reservation process. MAC layer randomly selects one of the resources for the first transmission and along with that reserve some resources as transmission opportunities.

3) *Reservation*

The reselection counter is decremented by one after each packet is transmitted in a long band. The length of the band is named as reselection counter and its value is randomly set to a number within a range. Resource reservation interval (RRI) defines that range. For example, if RRI is 20 ms, the range would be in [25, 75], if RRI is 50 ms, the range would be in [10, 30] and if RRI is 100 ms or above, the range would be in [5, 15]. These ranges are opportunities for the transmission of a resource. The reselection process starts when the counter reaches zero. It must be decided if the sensing process will be repeated to select new resources with probability (1-p) or if the previous resources will be kept with probability p. Same RRI will be maintained in the case of previous resources. Upper layers set probability p that can be any value between 0 and 0.8. To make the decision, a random number is generated from the range [0, 1] and if the number turns out to be greater than the probability value p, new resources must be selected for upcoming transmission. Reselection of resources is important because there is no collision-avoiding mechanism, transmission of multiple packets in one band, not having many possibilities of RRI, leads to more collision between vehicles without knowing. So, the band lasts for one second normally to separate the colliding vehicles.

IV. SIMULATION SETUP

The main C-V2X model was developed by [21]. The required modifications were then made in Mode-4 integration for this research. The module had LTE channel control at the top of the hierarchy. This module takes as input different mobility values of the vehicles and the communication-related parameters

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and supplies this information to the transmitter's radio interface. The maximum sending power used for this network was 20 mW. The signal attenuation threshold was set to -110 dBm. Rayleigh fading was used as a path loss model. The value of the alpha parameter was chosen randomly to be 2. The base carrier frequency of all the channels was set to 2.4 GHz.

A straight bidirectional highway was used for simulations. The straight highway's width was 4 m and its length was 2 km. A region at the central 1000 m was defined so that the results were recorded from this region. The basic idea of having this region was to minimize the effect caused by fewer vehicles at the end of the highway.

To simulate, a fast, congested, medium, and slow scenario where the maximum number of vehicles was 174, 156, 173, 246 and the speed of vehicles was 38.89 m/s, 9.50 m/s, 27.78 m/s, 19.44 m/s was defined. The performance of the sensing-based SPS was assessed through different performance metrics like packet loss, throughput, delay, and packet delivery ratio. The subchannel size was varied in some cases.

V. RESULTS AND DISCUSSION

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A. Authors and Affiliations

A fast, congested, and medium scenario was defined to see the effect on packet loss and throughput. Every scenario had a different speed and number of vehicles. The probability of resource keep was set to 0.1 and the number of subchannels was set to 2. When simulations were executed, it was noticed as shown in Fig. 3, as the speed and density of vehicles changed, packet loss decreased. It can be explained as mobility decreased, vehicles became closer and thus packet loss decreased. This can be observed from each scenario since the distance between vehicles was reduced from the fast scenario having the largest gap to the slow scenario with the smallest gap, hence a visible decrease in packet loss.

In the same way, fig. 4 shows that when the packet loss decreased, throughput increased as more packets were received successfully.

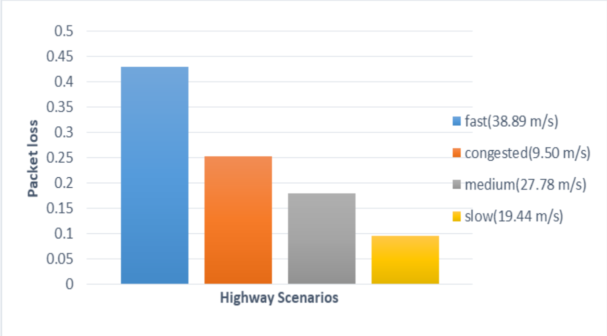

Figure 3. Effect of mobility and different densities on packet loss

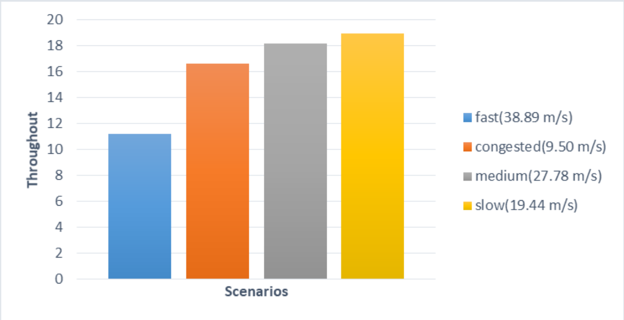

Figure 4. Effect of mobility and different densities on throughput

B. Effect of SPS resource reservation interval

The resource reservation interval was initially set to 100 ms. The values considered were in the range of 100 to 1000 ms. The values for resource reservation interval were changed from 1 to 10 correspondingly. Fig. 5 shows that as the RRI was increased, PDR also increased. The PDR is defined as the ratio between the packets that are decoded successfully to the total number of packets that are transmitted. Successful reception of the packet is determined by the fact that the subchannels carrying transmission packets do not overlap with each other. When resource reservation interval increased, the resources that were being utilized by a vehicle in a given time decreased. So, altogether PDR was increased as the chances of the same resource being reserved by several vehicles were decreased.

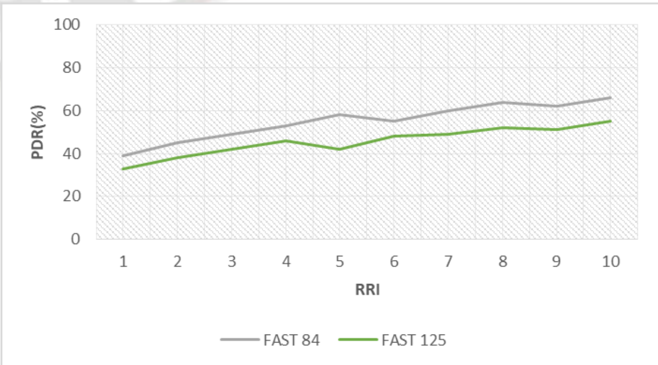

Figure 5. Effect of mobility and different densities on throughput

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C. Effect of the Probability of resource reselection

The 3GPP release 14 defined resource reselection probability as 1-P. When the resource counter (RC) approaches zero, new resources are selected through the SPS process. The effect of changing the probability of resource reselection was analyzed through Packet Delivery Ratio (PDR). The RRI was set to 1 and the number of subchannels was set to 4. From Fig. 6, it can be seen that there was not any considerable change in PDR while the value of P was changed from 0 to 0.8. This explains that vehicle U1 using the sensing-based SPS selects its resources at the start. However, other vehicles will not choose the same resources reserved by vehicle U1. So most of the available resources in the selection window will end up being reserved by other vehicles. Now the available resources are limited. When RC expires and the SPS algorithm is executed again, vehicle U1 will likely select the same resources again. This is equal to maintaining resources without going through the SPS algorithm again.

Figure 6. Effect of changing probability of resource reselection parameter on PDR

D. Effect of SPS resource reservation interval

The effect on the PDR that was brought by changing the number of subchannels was observed. A fast scenario with three different densities was used for this purpose. It can be seen in Fig. 7 that the PDR value increased as the number of subchannels increased from 3 to 5. But it can also be seen that the PDR value was always less for our high vehicle density like in the case of 125 vehicles as compared to 60 vehicles. The reason is that higher vehicle density can lead to higher collisions. The packets collide at the destined receiver if the subchannels reserved by two or more transmitting vehicles become overlapped. So if vehicles have more subchannels to select their resources from, there is a lesser chance that the same resource will be selected by more than one vehicle. As a result, more packets will be received successfully and PDR will also increase.

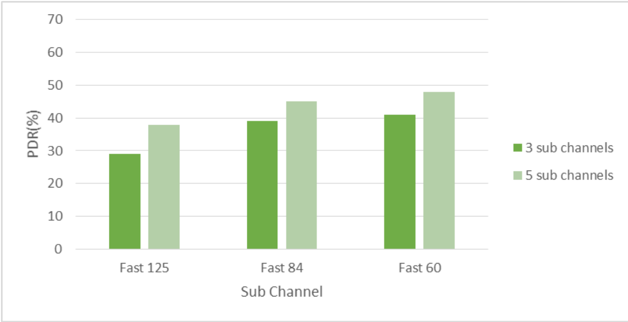

Figure 7. Effect of changing the number of sub-channels on PDR

VI. CONCLUSION

In this paper, we present a performance analysis of the SB-SPS C-V2X protocol. As can be seen from the results that packet loss and throughput had an inverse relation from fast to slow scenarios. Throughput increased as packet loss decreased. A parameter of SB-SPS that is the probability of resource reselection was observed while its value was changed to 0.4 and 0.8 and results showed that there was not any significant change in PDR. In the end, the effect of increasing subchannels was observed, and concluded that PDR increased by this change.

The world is heading towards a new and revolutionary phase of communication with 5G technology, there are going to be many opportunities as well as challenges at the same time. In the same way, C-V2X is also going to evolve with 5G, bringing new solutions for intelligent transportation systems. This will provide a chance for the researchers to examine and analyze this protocol's compatibility and performance with 5G.

REFERENCES

[1] Mohammad Zubair Khan, Muhammad Awais Javed, Hamza Ghandorh, Omar H. Alhazmi, Khalid S. Aloufi, Interference-Aware Transmission Scheduling for Internet of Vehicles, Intelligent Automation & Soft Computing, vol. 33, no. 1, pp. 305-315, 2022.

[2] Mohammad Zubair Khan, Muhammad Awais Javed, Hamza Ghandorh, Omar H. Alhazmi, Khalid S. Aloufi, NA-SMT: A Network-Assisted Service Message Transmission Protocol for reliable IoV communications, IEEE Access, vol. 9, pp. 149542-149551, 2021.

[3] E. Uhlemann, "Introducing connected vehicles [Connected vehicles]," IEEE Vehicular Technology Magazine, vol. 10, no. 1, 1 3 2015.

[4] M. Gonzalez-Martin, M. Sepulcre, R. Molina-Masegosa, and J. Gozalvez, "Analytical Models of the Performance of C-V2X Mode 4 Vehicular Communications," IEEE Transactions on Vehicular Technology, vol. 68, no. 2, pp. 1155-1166, 2019.

[5] B. Toghi, M. Saifuddin, H. N. Mahjoub, M. O. Mughal, Y. P. Fallah, J. Rao and S. Das, "Multiple Access in Cellular V2X: Performance Analysis in Highly Congested Vehicular Networks," in IEEE Vehicular Networking Conference, VNC, 2019.

[6] A. Nabil, K. Kaur, C. DIetrich and V. Marojevic, "Performance Analysis of Sensing-Based Semi-Persistent Scheduling in C-V2X Networks," in IEEE Vehicular Technology Conference, 2019.
[7] R. Molina-Masegosa and J. Gozalvez, "System Level Evaluation of LTE-V2V Mode 4 Communications and Its Distributed Scheduling," in IEEE Vehicular Technology Conference, 2017.
[8] F. Borgonovo, F. Borgonovo, A. Capone, M. Cesana and L. Fratta, "RR-ALOHA, a Reliable R-ALOHA broadcast channel for ad-hoc inter-vehicle communication networks," IN: PROCEEDINGS OF MED-HOC-NET 2002, 2002.
[9] F. Borgonovo, A. Capone, M. Cesana and L. Fratta, "ADHOC MAC: New MAC architecture for ad hoc networks providing efficient and reliable point-to-point and broadcast services," in Wireless Networks, 2004.
[10] Assef Raad Hmeed, Jamal A. Hammad, Ahmed J. Obaid. (2023). Enhanced Quality of Service (QoS) for MANET Routing Protocol Using a Distance Routing Effect Algorithm for Mobility (DREAM). International Journal of Intelligent Systems and Applications in Engineering, 11(4s), 409–417. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2687.
[11] H. A. Omar, W. Zhuang and L. Li, "VeMAC: A TDMA-based MAC protocol for reliable broadcast in VANETs," IEEE Transactions on Mobile Computing, vol. 12, no. 9, pp. 1724-1736, 2013.
[12] L. Gallo and J. Harri, "Analytical study of Self Organizing TDMA for V2X communications," in 2015 IEEE International Conference on Communication Workshop, ICCW 2015, 2015.
[13] S. Bharati and W. Zhuang, "CAH-MAC: Cooperative ADHOC MAC for vehicular networks," IEEE Journal on Selected Areas in Communications, vol. 31, no. 9, pp. 470-479, 2013.
[14] J. Huang, Q. Li, S. Zhong, L. Liu, P. Zhong, J. Wang and J. Ye, "Synthesizing existing CSMA and TDMA based MAC protocols for VANETs," Sensors (Switzerland), vol. 17, no. 2, 10 2 2017.
[15] M. Hadded, P. Muhlethaler, A. Laouiti, R. Zagrouba and L. A. Saidane, "TDMA-Based MAC Protocols for Vehicular Ad Hoc Networks: A Survey, Qualitative Analysis, and Open Research Issues," IEEE Communications Surveys and Tutorials, vol. 17, no. 4, pp. 2461-2492, 1 10 2015.
[16] Mr. Rahul Sharma. (2018). Monitoring of Drainage System in Urban Using Device Free Localization Neural Networks and Cloud computing. International Journal of New Practices in Management and Engineering, 7(04), 08 - 14. https://doi.org/10.17762/ijnpme.v7i04.69.
[17] X. Fan, C. Wang, J. Yu, K. Xing, Y. Chen and J. Liang, "A Reliable broadcast protocol in vehicular Ad Hoc Networks," International Journal of Distributed Sensor Networks, vol. 2015, 2015.
[18] J. J. Blum and A. Eskandarian, "A reliable link-layer protocol for robust and scalable intervehicle communications," in IEEE Transactions on Intelligent Transportation Systems, 2007.
[19] F. Watanabe, M. Fujii, M. Itami and K. Itoh, "An analysis of incident information transmission performance using MCS/CDMA scheme," in IEEE Intelligent Vehicles Symposium, Proceedings, 2005.
[20] H. Nakata, T. Inoue, M. Itami and K. Itoh, "A study of inter vehicle communication scheme allocating PN codes to the location on the road," in IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, 2003.
[21] R. Molina-Masegosa, J. Gozalvez and M. Sepulcre, "Configuration of the C-V2X Mode 4 Sidelink PC5 Interface for Vehicular Communication," in Proceedings - 14th International Conference on Mobile Ad-Hoc and Sensor Networks, MSN 2018, 2018.
[22] Mondal, D., & Patil, S. S. (2022). EEG Signal Classification with Machine Learning model using PCA feature selection with Modified Hilbert transformation for Brain-Computer Interface Application. Machine Learning Applications in Engineering Education and Management, 2(1), 11–19. Retrieved from http://yashikajournals.com/index.php/mlaeem/article/view/20.
[23] A. Bazzi, G. Cecchini, B. M. Masini and A. Zanella, "Study of the Impact of PHY and MAC Parameters in 3GPP C-V2V Mode 4," IEEE Access, vol. 6, pp. 71685-71698, 27 7 2018.
[24] B. McCarthy, A. Burbano-Abril, V. Rangel-Licea and A. O'Driscoll, “OpenCV2X: Modelling of the V2X Cellular Sidelink and Performance Evaluation for Aperiodic Traffic.” *ArXiv* abs/2103.13212 (2021): n. pag.
[25] G. Cecchini, A. Bazzi, B. M. Masini and A. Zanella, "LTEV2Vsim: An LTE-V2V simulator for the investigation of resource allocation for cooperative awareness," in 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems, MT-ITS 2017 - Proceedings, 2017.