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Research Article

Adaptive and Optimized Control Channel Utilization in Vehicular Ad Hoc Networks

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Vehicular ad hoc networks (VANETs) are counted as a state-of-art technology which can be considered to provide reliable communication which is increase the safety and convenience of drivers in the road. Due to channel congestion occurrence in both highway and urban scenario, many VANET's safety applications face degradation in their quality of service especially in a high-density environment. To improve the performance, reliability, and safety of VANETs, message overhead on the standard wireless channel dedicated short-range communications (DSRC) should be alleviated to guarantee safety-related applications. To this end, this paper proposes an approach to optimize the utilization of the control channel (CCH) and make the control channel interval (CCHI) adaptive to the emergency cases in the vehicular scenarios. More precisely, when there is an emergency cases, a part of service channel interval (SCHI) is exploited to ensure the guarantee of emergency message delivery. When a vehicle intended to transmit the safety message to the surround vehicles, the proposed method granted that CCH is allocated to meet the traffic safety demands; then, the safety messages disseminate properly to the transmission range. A part of the service channel interval (SCHI) is exploited to ensure the guarantee of emergency message delivery, Then, applying the laying chicken algorithm (LCA) to solve the derived CCH optimized utilization. Finally, extensive simulations are carried out to validate the proposed optimized CCH utilization. To validate the performance of the proposed adaptive congestion control approach (ACCA), we used the network simulator Ns-3 [35] to simulate the vehicle's environment, after generating vehicles' mobility traces of the nodes using the network simulator for urban mobility (SUMO) with OpenStreetMap (OSM). The simulation indicates that our congestion algorithm (ACCA) performs better service quality than other existing algorithms. We got a better network connection regarding safety messages, beacon rate with time, and packet length for different vehicles' densities.

1. Introduction

We have witnessed a fast development of vehicular communication by the public and private sectors in the past decade. This technology has the capability to reduce the number of traffic accidents and associated fatalities. Hence, it paves the way for an efficient intelligent transportation system (ITS) in vehicular communication scenarios. To enable such efficient vehicular communication, two leading radio access technologies, DSRC and cellular V2X (C-V2X), are considered best candidates. Federal Communication Commission (FCC) was designated a specific frequency band in the 5.9 GHz band (viz., 5.850-5.925 GHz) whereas C-V2X has been proposed by 3GPP in release 14 to address vehicular communication problems because of the high mobility and density [1].

In order to guarantee the broadcasting of safety messages in emergency cases in the roads, each vehicle is supported with DSRC which is broadcasting the safety messages in a fixed beaconing rate value to the vehicles in the transmission range. DSRC follows the carrier sense multiple access with collision avoidance (CSMA/CA) at MAC layer [2]. The probability of collision is very high when the number of vehicles in the transmission range is increased; in this case, the channel indicated its full of safety messages and collision growth rapidly. On the other hand, when the density of vehicles is relatively low, the channel is not completely used, to more utilize the channel resource and ensure the dissemination of safety messages with the adaptation of the beaconing rate.

The DSRC gained attention in the vehicular network research community as it is well mature and widely deployed to support vehicle to everything (V2X) communication (as illustrated in Figure 1). It has been proven the effectiveness of the DSRC for safety-related applications. The success of DSRC is due to its standardization in terms of communication technology and allocating dedicated frequency [3]. Governments, academia, and standardization figures have extensively participated in this promising step. Another important point that makes DSRC an enabler for V2X communication is the free subscription and low cost of deployment. Further, the DSRC is supported and compatible with the IEEE 802.11 standards, which could promote the effectiveness of DSRC in the market of vehicular communication. Several automotive companies such as Lexus and Toyota started to lunch DSRC for connected vehicles in the USA in 2021. In the USA, all automakers are encouraged to accelerate the adoption of vehicle-to-vehicle and vehicle-to-infrastructure based on DSRC [4].

In 1999, the Federal Communication Commission (FCC) admitted the importance of transportation safety and allocated 75 MHz of spectrum at 5.850-5.925 GHz—the 5.9 GHz for vehicular communication. Absolutely, keeping the entire 5.9 GHz band for V2X scenarios promotes the innovative on-road applications, including traffic safety and automation. IEEE 802.11p is considered a promising standard to offer short-range wireless access for vehicular environment (WAVE) [5]. WAVE provides service to both on-board unit (OBU) and roadside unit (RSU) (Figure 1). OBU is embedded into intelligent vehicles while RSU is fixed in popular places such as intersections [6]. More particularly, IEEE 802.11p and IEEE 1609.4 standards provide MAC and physical layer protocols for vehicle-to-vehicle (V2V) and vehicle-2-infrastructure (V2I) communication [7].

The MAC of IEEE 802.11p is adopted prioritized enhanced distributed channel access (EDCA) protocol and multichannel operation as discussed in [8, 9]. The DSRC uses one common control channel (CCH) to provide traffic safety-related services while the remaining 6 service channels are used for comfort-related applications. Regular and synchronous switching between CCH and SCH is required in order to serve both safety and nonsafety-related applications. The time interval for disseminating safety-related messages is defined by CCHI while that time for service-related messages is defined as (SCHI). A combined CCHI and SCHI is named the synchronization interval (SI) and is set to 100 ms in the standard IEEE 802.11p.

In IEEE 802.11p, CCH is preserved for safety-related message transmission. Periodic and emergency are an example for safety-related messages and both are competing to access CCH. Periodic messages are transmitted at regular intervals while emergency packets are generated asynchronously when there is an emergency event. This public safety application should be delivered with high reliability and low latency. Further, scheduling and prioritizing safety-related messages over the control channel interval are very significant for efficient V2X environment. Achieving these requirements required high utilization of control channel and dynamic interval of CCH. In [8, 9], the authors have proposed dynamic CCH that would be adaptable to the traffic load.

This work proposes an approach to optimize the utilization of control channel (CCH) and make the control channel interval (CCHI) adaptive to the emergency situation in the vehicular scenarios. More precisely, when there is an emergency situation, a part of service channel interval (SCHI) is exploited to ensure the guarantee of emergency message delivery. Then, we used the laying chicken algorithm to solve the derived CCH optimized utilization. Finally, extensive simulations took place to validate the proposed optimized CCH utilization. Further, the proposed approach can be utilized to meet strict emergency message deadline and hence vehicles can exchange safety-related messages successfully.

Context awareness beacon scheduling (CABS) mechanism is one of the decentralized approaches which is considered in vehicular communication to control and minimize the congestion occurrence. CABS mechanism found a way to reduce the congestion that occurs when network density increased because of the high rate of beacon messages. Through the virtual frame table which has enough acknowledgements about the nodes, for example, velocity, direction, location of vehicles, slot time and delivery rate, this information will share between the available vehicles. Based on the available slot time, the vehicles have to transmit their message; otherwise, they have to wait for a new time slot this mechanism leads to reducing the congestion in VANET [10]. However, the MAC layer has to allocate the proper time slots for each packet transmission.

The rest of this paper is organized as follows. Section 2 shades light on the background of the literature on developed mathematical model for congestion control. This is followed by the system design architecture in Section 3. Section 4 present CCH optimization problem formulation and solution. Then, in Section 5, an analysis of the optimization problem with illustrating performance broadcasting of safety message and beacon rate with different vehicle numbers using Ns-3 simulator with Sum is presented. Finally, Section 6 concludes the paper.

2. Related Work

The problem of congestion control in the vehicular network has been investigated in various aspects. The authors in [11] presented a model based on Markov chain, with an aim to study the proper protocol that is appropriate to the specifications of both emergent and periodic messages while executing the MAC protocol over the network of vehicular, good results were received by following strict EDCA MAC protocol and analyzed it with lower transmission delay. As a result, the simulation shows a significant delivery ratio and optimum delay for both messages in the simulation in accordance with proper parameters. Further, [3] propelled two optimization algorithms for transmissions of the messages based in the length of control channel interval (CCHI), to

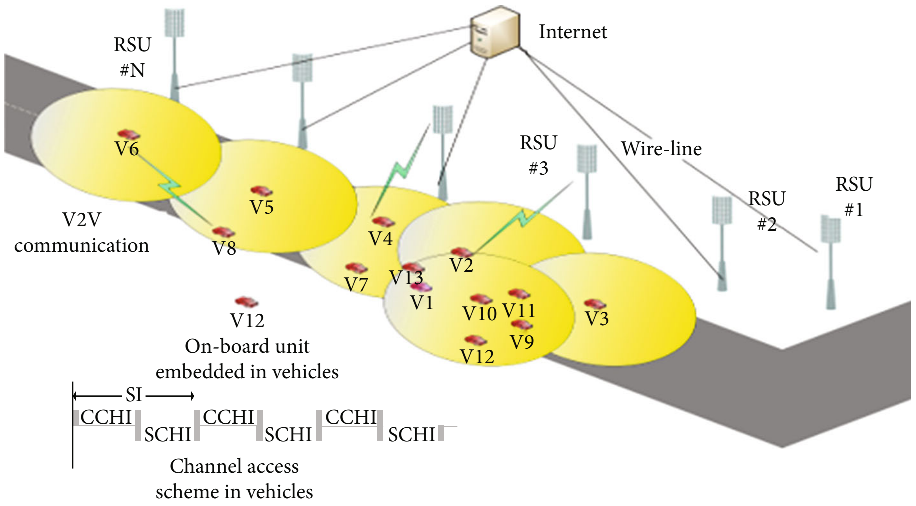

Figure 1: Connected vehicle scenarios.

be fixed or dynamic, which has led to the selection of optimal MAC parameters, when adopting the IEEE 802.11e enhanced distributed channel access (EDCA) protocol during deliberation in the choice of emergency message and network traffic. As a result, the simulation shows the success rate of sending data with minimum delay.

The author [12] suggests an analytical model for the MAC protocol that have an improved distributed channel access (EDCA) to shoulder the control channel (CCH) and optimum method on the service channels (SCHs)in wireless access in vehicular environments for the intelligent transport system, abiding different priority patterns for the safety and not safety packets. By using multidimensional Markov chains for the suggested MAC, the intended significant delivery ratio is also derived, and the delay is distributed on both the safety packet and the RFS packet. The consequences demonstrate that the safety packet can be reached to the destination within 100 ms with a delivery probability higher than 98%, even if the number of vehicles counted to 150.

The authors in [13] aimed to allow the vehicles to switch the classes of two applications, dedicated short-range communication (DSRC). It recommended the vehicles to check the control channel every 100 ms, known as synchronization interval (SI), in order to proliferate their status to their neighbors within a stipulated time for reliability and to make the control channel use the internal more than the nonsafety application; they suggest following the optimal channel access (OCA) improve the transmission rate. It perfectly uses the length of CCH, which had led to the addition of the transmission rate, along with the use of mobility and topology aware algorithm (MTA), adapted to modify the DSRC based on some conditions, such as road and network conditions. It accesses the safety and nonsafety to work on the DSRC, with both algorithms maintaining the reliability, increasing the time delay and the control channel interval to half of the synchronization.

The authors in [14] intended an adaptive multichannel assignment and coordination (AMAC) that projects the channel access to be idle or not, with respect to channel switching between service providers and users for SCH resource reservations, which are degraded of CCH due to network traffic with more than one application running on CCH at fixed intervals in the collision-aware packet transmission mechanisms. These two mechanisms provide an efficient and reliable quality of service along with the modified time diversity among vehicles, by developing an analytical model base on 1-D and 2-D Markov chain model. Finally, the throughput increased, and the errors reduced, in addition to the collision used to compute the delay and packet delivery ratio.

The authors in [15] retaliated the disconnection of VANET due to the high mobility of these nodes, in order to keep the safety packet, cooperative and reliable RSU-assisted IEEE 802.11p-based multichannel MAC protocol for VANET is proposed which is called RAM. It is used to calculate the optimized interval and to keep in track of the safety packet transmission and resend it when it is not delivered successfully. The result shows that the collided safety will be resent in the contention-based interval and the optimized interval will be calculated based on the traffic load and vehicles density.

The authors in [4] recommended three perspectives which are designed to adapt to the changes that happened during the movement of VANET, multichannel MAC protocols are noted because of the instability of data traffic, and also using multidimensional Markov chains (up to three dimensions) in the MAC protocols which finally takes into consideration the Markov models. They are the basis of real-life application requirements to enhance the available analytical models and protocol designs. After the implementation of the current protocol, future work is scrutinized which are related to dynamic interval division MAC protocol.

3. System Design Architecture

Adaptive and optimization channel utilization method is configured in each vehicle, and our proposed laying chicken algorithm optimization is considered to maximize the

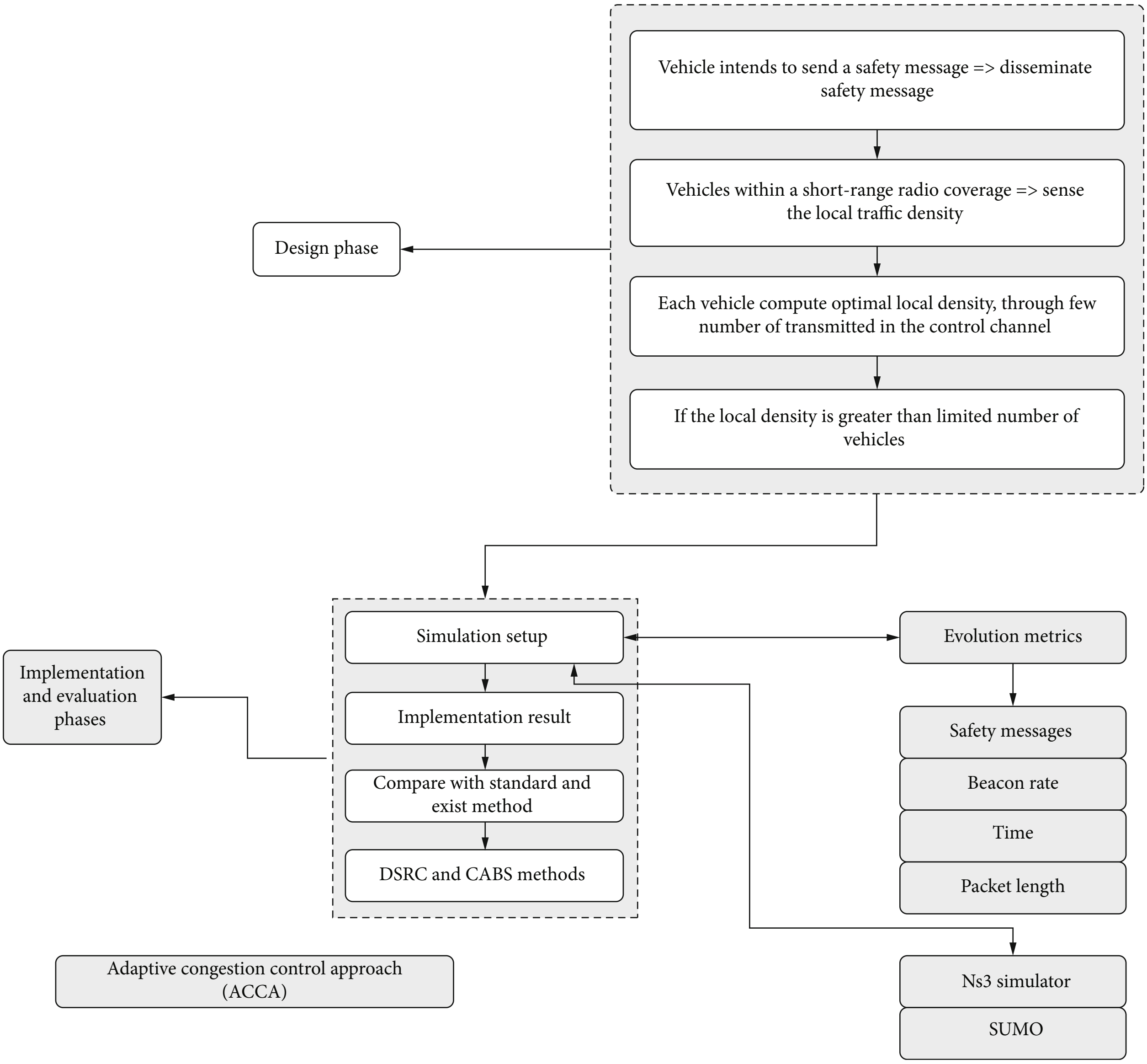

Figure 2: The systematic architecture of research design, implementation, and evaluation phases of the ACCA approach.

control channel CCH utilization. The proposed optimization algorithm is followed to find the optimal solutions for continuous optimization problems in channel unitization in VANET communication. The main idea behind our optimization method is adaptive to the emergency situation in the vehicular environment that occurs on the roads. More precisely, when there is an emergency condition happening on the roads, a part of the service channel interval (SCHI) is exploited by the control channel to ensure the guarantee of emergency message delivery. When the vehicles are intended to send the safety message to disseminate safety message information to the vehicles in the transmission area. Firstly, it computes the local traffic density through a few numbers of transmissions in a control channel. If the local density is greater than a limited number, a part of service channel is allocated to safety-related traffic; otherwise, the control channel is set to the default control channel interval CCHI. To this end, the congestion control ACCA approach is proposed to dynamically adapt channel utilization techniques according to traffic density. More precisely, the proposed ACCA is based on the percentage of vehicular density in the transmission area. Figure 2 shows the system structure of the ACCA approach.

4. Overview of the Proposed CCH Optimization Approach

This section presents the proposed control channel optimization approach. The adaptive and optimization approach is installed in the vehicles and applies the LCA optimizer algorithm to maximize the CCH utilization. LCA is used to find optimal solutions for continuous optimization problems. The formulated problem is modelled as a bilevel optimization algorithm to maximize the utilization of CCH and SCH. Then, the problem is subject to constraints of minimizing the probability of collision for both CCH and SCH

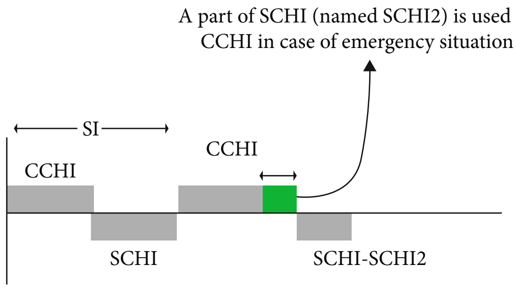

Figure 3: Adaptive control channel interval access.

Table 1: Abbreviations used in the proposed mathematical model.

Abbreviation	Description
UCCH	Utilization of Control Channel
USCH	Utilization of Service Channel
P C1	Probability of collision for CCH
P C2	Probability of collision for SCH
SCHI2	Service channel interval 2
SCHI	Service channel interval time
CCHI	Control channel interval time
SCHI1	Service channel interval 1
Dp	A part of service channel interval
k	Synchronization time interval (100 ms)
UCCHi	Utilization of control channel for vehicle i
n	Number of vehicles within a radio communication Range
RVi	Number of received periodic messages from vehicle i
Sji	Number of periodic messages sent from vehicle j to vehicle i
Remgi	Number of received emergency message
Semgi	Number of emergency messages sent
pji	Number of messages sent from vehicle j to vehicle i
N1, N2, N3	Number of periodic, emergency and service messages within a radio coverage
k1, k2, k3	Chance of collision

channels. Figure 3 illustrates the procedure of optimization of the CCH channel. We used a bilevel optimization model to formulate the mathematical modelling of our proposed approach in which the feasible set is determined by the set of optimal solutions of an optimization problem.

4.1. Maximum CCH Capacity. The amount of data that can be transmitted over the CCH is highly limited by its low transmission time interval named CCHI. The theoretical capacity of CCH considerably depends on the channel utilization and its duration. Here, we analyze the control channel capacity in order to estimate local density within the radio coverage of vehicles. The estimated optimal local density represents the number of channel access within one CCHI and considering a fixed beacon size. The optimal local density ensures all vehicles CCH access within the specific radiocommunication range. We assume that beacon rate is 2 in each CCHI, CCH utilization 100% and 48 ms of CCHI (excluding the guard band). According to the assumptions, the useful CCHI is 24 ms. If the transmission time is 1 ms for beacon size of 256 byte [16], the optimal number of vehicles that could access the CCH within one CCHI is 24. Table 1 shows all abbreviations which is used in the mathematical modelling of the proposed method.

```
$(a0, b0)$: initial feasible solution
$(a$ best, $b$ best$)$: optimal value
$i$: iterations
popu: a set of population
$x = 1$.
while $x < i$ do
populations close to $(a0, b0)$ is generated
$(a0, b0) = (a$ best, $b$ best$)$
for $i = 1$ to popu do
if cost of function > cost of function at $(a0, b0)$ then
$(a$ best, $b$ best$) = (ai, bi)$
end if
end for
$(a0, b0) = (a$ best, $b$ best$)$
$x = x + 1$
end while
```

Algorithm 1: LCA algorithm to maximize CCH utilization.

4.2. System Model Formulation. The proposed CCH optimization is used for V2V communication without the presence of RSU. In this paper, we assume all vehicles are tagged with the global positioning system (GPS) receiver. All vehicles are embedded with OBU to support V2V communication and emergency message dissemination among vehicles. The OBU and in-vehicle navigation technologies enable vehicles to get an accurate position and mobility characteristics. We also assume that all vehicles have the same communication and carrier sensing range in a specific area. Also, the beacon broadcast rate is 50 milliseconds—i.e., every vehicle broadcast 2 beacons in a single CCHI. This paper assumes the maximum channel usage of 85%. The reason for this saturated channel condition is to study the worst-case network overhead [17].

The proposed approach optimizes the utilization of CCH while fulfilling the minimization of collision probability in V2V scenarios. We consider a portion of highway vehicular scenario of length L and vehicles have a constant communication range of R. According to the mentioned assumptions, the objective function of the proposed optimization problem can be formulated as a bilevel programming model:

$$\text{Max} \quad UCCH + USCH \tag{1}$$

subject to

$$\min PC_1 + PC_2 \tag{2}$$

subject to

$$UCCH \leq CCHI + SCHI_2 \tag{3}$$

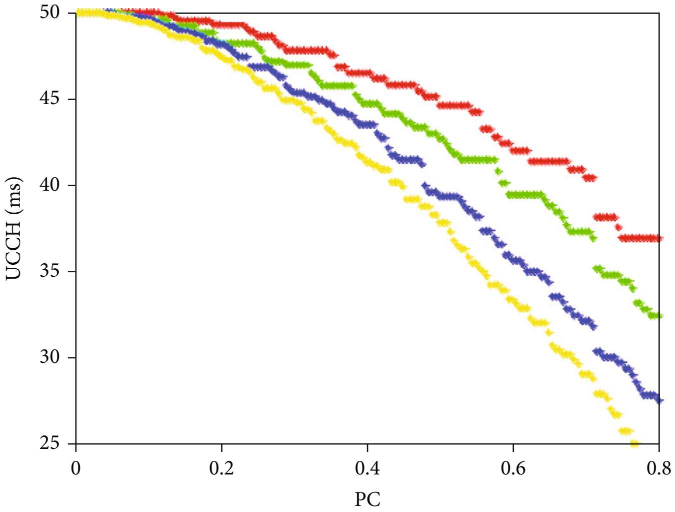

Figure 4: The impact of PC on the utilization of CCH.

$$USCH \leq SCHI_1 + dp - SCHI_2 \tag{4}$$

$$SCHI + CCHI = k \tag{5}$$

$$UCCH, USCH, CCHI, SCHI_1, SCHI_2, dp, k \geq 0 \tag{6}$$

where

$$SCHI_2 = \begin{cases} dp, \text{if} \quad UCCH \geq CCHI \\ 0 \end{cases} \tag{7}$$

$$UCCH_i = \begin{cases} \dfrac{n * RV_i * (CCHI + SCHI_2)}{\sum_{j=1}^{n_{ih}} S_{ji}}, \text{if no } emeg.and \; n < 22 \\ \dfrac{n * RV_i + R_{emgi} * (CCHI + SCHI_2)}{\sum_{j=1}^{n_{ih}} S_{ji} + S_{emgi}}, \text{if no } emeg.event \end{cases} \tag{8}$$

$$UCCH = \frac{\sum_{i=1}^{n} UCCH_i}{n} \tag{9}$$

$$USCH = \frac{RV_i * (SCHI - SCHI_2)}{\sum_{j=1}^{n_{ih}} p_{ji}} \tag{10}$$

$$PC_1 = \binom{N_1}{k_1} * P^{k_1} * (1 - P)^{(N_{1-}K_1)} + \binom{N_2}{k_2} * q^{k_2} * (1 - q)^{(N_2 - k_2)} \tag{11}$$

$$PC_1 = \binom{N_3}{k_3} * r^{k_1} * (1 - r)^{(N_{3-}K_3)} \tag{12}$$

4.3. Proposed Algorithm. This research paper has proposed an optimal CCH utilization method that is embedded in intelligent vehicle in order to maximize CCH utilization. This optimization is formulated as a bilevel discrete optimization problem. In [18], the laying chicken algorithm (LCA) is used to find optimal solutions for continuous optimization problems. Here, we modified LCA to solve the proposed bilevel discrete optimization problem in high mobile vehicular scenarios.

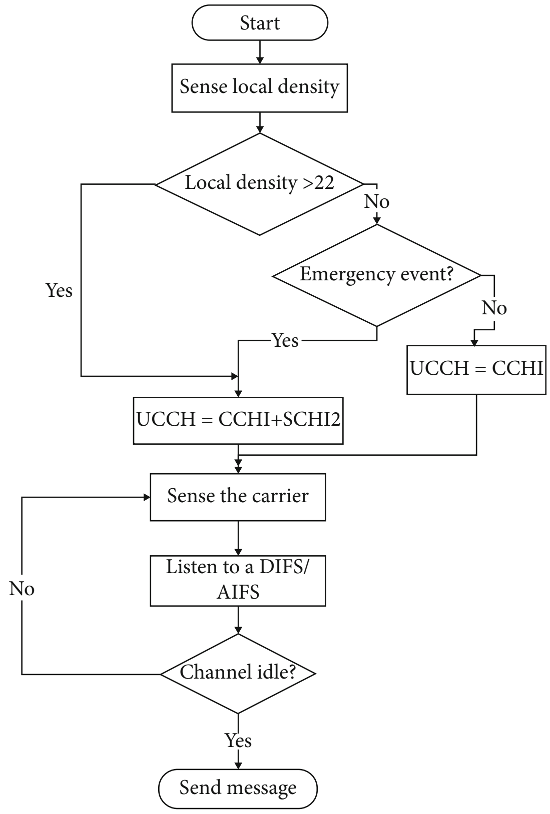

Figure 5: The procedure of CCH congestion avoidance.

As illustrated in Figure 2, when a vehicle intends to send a safety message to nearby vehicles, CCH is granted in order to meet the traffic safety demands. Standard DSRC broadcast the safety message in fixed frequency which causes channel congestions in dense environments. The proposed work suggests to take a part from the service channel when the number of vehicles increased. The basic safety message

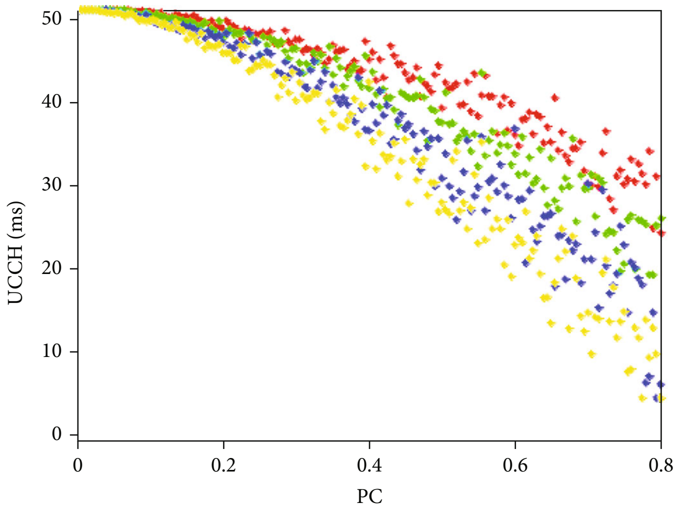

Figure 6: The impact of PC and traffic density on the utilization of CCH.

(BSM) will disseminate safety-related messages within the vehicular network, which will ultimately make all cars to receive the safety messages and fulfil the safety requirements. Vehicles within a short-range radio coverage sense the local traffic density. Each vehicle could compute optimal local density through a few numbers of transmitted beacons in a CCHI. If the local density is greater than 22 vehicles, a part of SCH is allocated to safety-related traffics; otherwise, CCH is set to the default CCHI. In case emergency traffic incident occurs and CCH capacity reaches its maximum level, a part of SCH is used by the CCH in order to promote the level of safety traffic.

In the aforementioned section, we highlighted how to formulate the optimization of CCH in constraint to the probability of collision. This formulation is considered a discrete optimization problem and can be solved using LCA. Likewise, the process of producing chicken from eggs, LCA approaches optimal CCH condition from several feasible solutions, which are generated randomly. Fundamentally, each egg is defined as one feasible CCH solution while a chicken is representing an optimal solution of the defined discrete optimization problem.

Mother hens handle all hatching process of eggs from its warming to egg to turning to chickens. In LCA, similarly, the cost of the objective functions in Equation (1) is the temperature of eggs. In our proposed algorithm, the temperature is the utilization of CCH. In case of higher temperature of an egg (CCH utilization), the higher is the value of an objective function for specific CCH utilization condition. Algorithm 1 shows the mechanism of selecting optimal CCH utilization in a set of feasible solutions. The LCA explores the optimal solution from the initial feasible population. This solution ($(a0, b0)$) is randomly selected among candidate CCH utilization. Thereafter, initial population is selected near the initial solution. In case of objective function value is bigger than this value at ($(a0, b0)$), then new value is replaced in the (a best, b best). Eventually, the process of maximizing CCH utilization will continue until optimal CCH with highest objective function is found.

Figure 4 demonstrates the CCH utilization versus safety messages probability of collision on the control channel, according to different numbers of vehicular density (50 is red color, 80 green color, 100 blue color, and 150 is yellow color). It is straightforward that a larger safety packet collision among vehicles causes a lower UCCH. Similarly, higher traffic density is more sensitive to an increase of packet collision probability. This is exactly happening in Figure 5 and illustrating the principle of the proposed mathematical formulation in Equation (1).

Figure 6 shows the performance of CCH according to the rate of safety message collisions, according to different numbers of vehicular density (50 in red color, 80 green color, 100 blue color, and 150 is yellow color) vehicles. Commonly, larger collision probability results in lower utilization of the wireless channel. We also observe the more sparse distribution of the UCCH according to the collision probability with varied message transmission in a specified interval of time. From this, one can infer that in case of emergency situations the CCH is more likely to be congested. Hence, a part of SCH should be granted to guarantee reliable dissemination of emergency-related messages.

5. Performance Evaluation

The evaluation and the analysis of the mathematical formulation developed will be carried out in this section. We consider a highway vehicular scenario, where vehicles are distributed in the Poisson movement pattern. Such mobility model has an efficient vehicle following movement and location service. Cars are entering the vehicular scenarios according to constant distance among vehicles and emergency situation is randomly generated. Furthermore, there is no roadside.

Infrastructure as the proposed mathematical model is applied in a V2V environment. Also, vehicles are embedded with IEEE802.11p and this capability creates full coverage of street segments. The experiments are carried out using MATLAB R2019a is a programming tool to analyze the

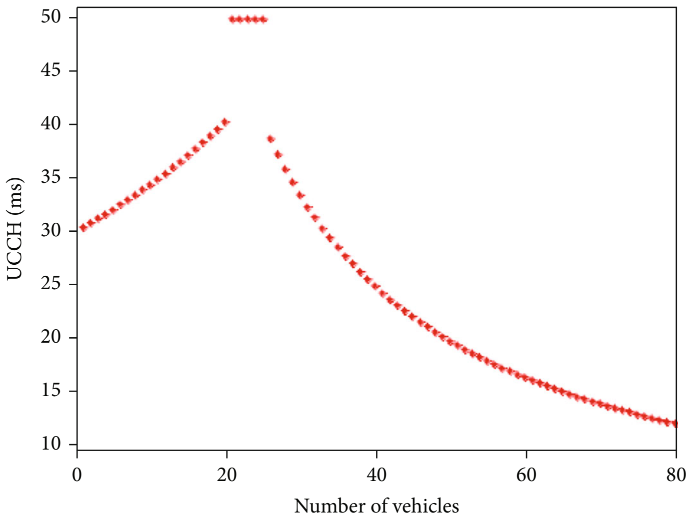

Figure 7: Effect of varying traffic densities on the performance of CCH.

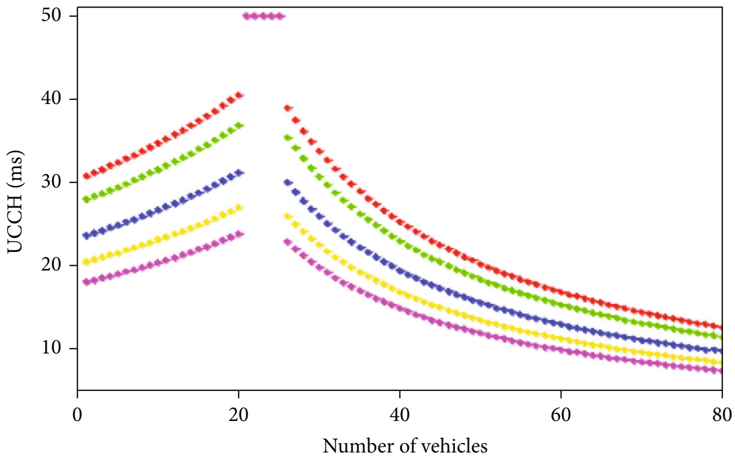

Figure 8: Effect of varying emergency rates on the performance of CCH.

mathematical formulation, then implemented using network simulator Ns-3.

At the physical layer, we assume the vehicular network is modelled in an open environment with an ideal wireless channel; no fading is considered among vehicles. The transmission range is set on 200 meters for vehicles. In the highway scenario, we will change the traffic density from 50 to 150 nodes, and they move with constant speed. Further, the IEEE 802.11p [19] standard protocol is used to model the MAC layer. At the MAC layer, the beacon size is set on the 256 bytes. The value of dp is set to zero.

This section also presents the experiments of analyzing the performance of CCH utilization according to the traffic density. In Figure 6, CCH capacity is illustrated with an increase of in traffic density. As illustrated in Figure 7, when traffic density is increasing within a radiocommunication range, the utilization of the CCH is increasing as well. However, this behavior is correct until the traffic density reaches 22. After this value, the CCH capacity is deteriorated, and hence, the UCCH is acutely decreasing. This is because an increase on the number of vehicles in the vicinity results in

Table 2: Shows the parameters used in the simulation of highway and urban scenarios.

Parameters	Value
Total road length	652 m×752 m
Number of lanes	4 (2 in each direction)
Vehicles speed	0-40 km/h
Transmission range	15 – 1000 m
Transmission rate	3-27 Mbps
Contention window size	15-1023
Bandwidth	10MHz
Safety messages generation rate	10 packet/s
MAC type	802.11p
Propagation model	TwoRayGround
Simulation time	100 s

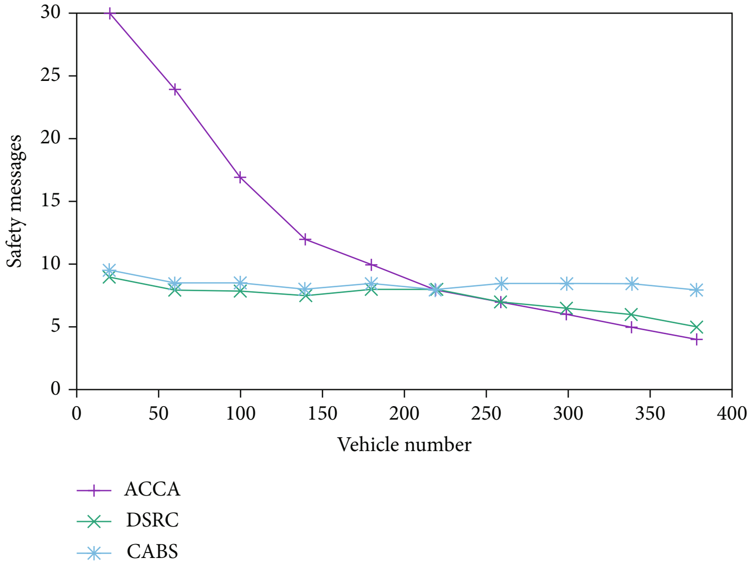

Figure 9: Safety messages on vehicle numbers.

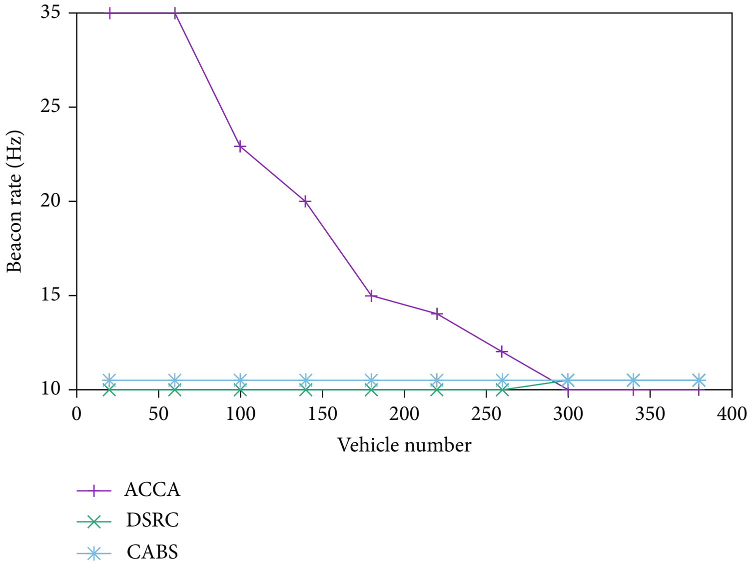

Figure 10: Beacon rate with respect to the variation of vehicular density.

higher beacon transmission. Such volume of transmission will lead to higher overhead and packet collision.

Another experiment took place to illustrate the effects of a few numbers of emergency events on the performance of CCH utilization. As simulation analysis is shown in Figure 8, we observe that the CCH utilization is increasing with an increase in traffic density till reaches 22 neighbors' vehicles. However, when an emergency event rate is increasing, the UCCH is glaringly decreasing.

This is not surprising as the higher number of emergency events results in a higher number of safety message broadcast. This will certainly create huge load on the CCH and hence it negatively affects its performance.

5.1. Simulation Results. To validate the performance of ACCA, we used the Ns-3 [35] to simulate the vehicle's environment with different mobility directions. After generating vehicles' mobility traces of the nodes using network simulator for urban mobility (SUMO). ACCA is compared with the dedicated short-range communication DSRC and unfair control method in terms of safety messages, beacon rate with time, and packet length for different vehicles' densities. Urban scenario was considered, according to VANET's standards, communications between vehicles, and also between vehicles are established by IEEE 802.11p protocol. Moreover, data transmissions in the MAC layer are carried out based on the CSMA/CA strategy. TwoRayGround propagation

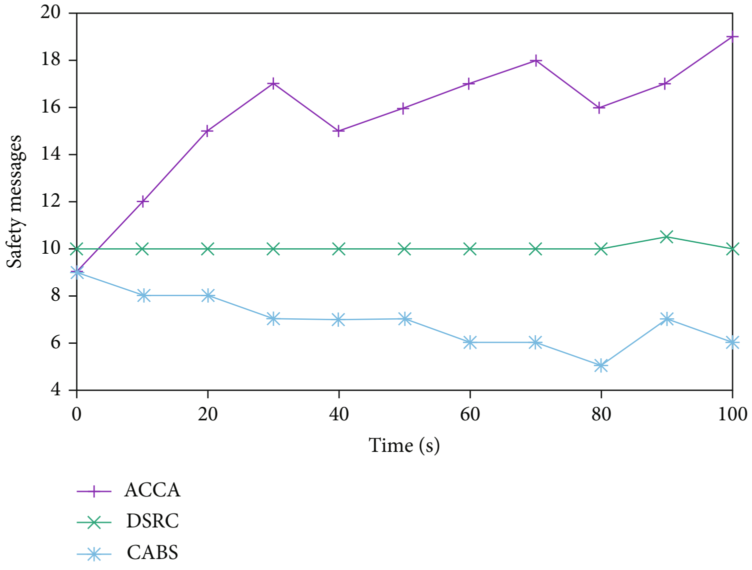

Figure 11: Time of safety message.

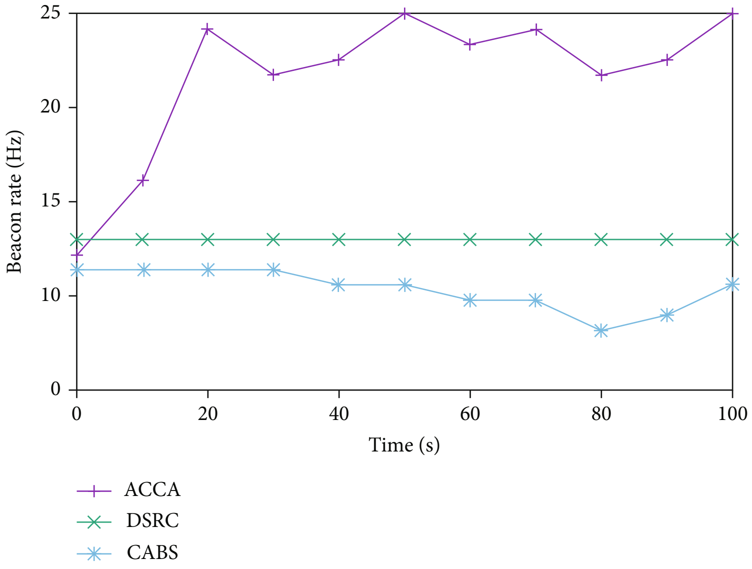

Figure 12: Time of beacon rate.

models used for traffic propagation in urban scenarios, respectively. The simulation time was set 100 seconds because the preliminary results showed that after 100 s second the results become nearly steady as shown in Table 2.

We set the simulation time on 100 s for different numbers of vehicles. The data rate is set to 3 Mbps, which is the default data rate of DSRC. Performance of ACCA was tested using different numbers of vehicles up to 400. At the beginning, we test the average of safety messages received by each vehicle. Figure 9 shows that ACCA is performed better than standard DSRC and CABS congestion control methods in term of receiving safety messages.

Figure 10 illustrates the variation of beacon rate with different vehicle densities. The ACCA beacon rate is decreased with increasing number of vehicle density while standard DSRC and CABS congestion control remain stable. The first two points of ACCA are at rate upper bound 30 Hz because the channel is not completely utilized at that time.

In Figure 11, we evaluate the performance variation of ACCA over time, then compared the result with standard DSRC and CABS congestion control methods. As can be seen, we set time up to 100 s and then evaluate the changes in received safety messages over time. The result indicates that received safety messages of ACCA increase with the time.

In Figure 12, we evaluate the average beacon rate according to the simulation time. We can also find that average of beacon rate of ACCA converges to the optimal state in 20s.

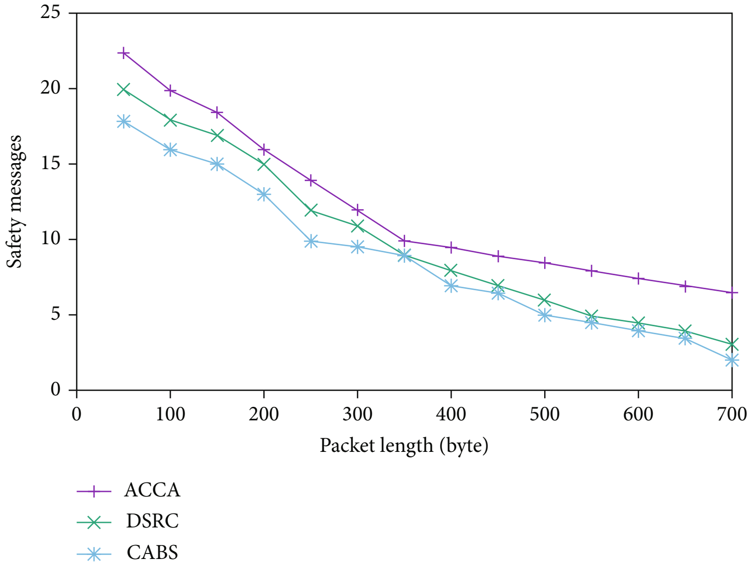

Figure 13: Safety messages on different packet lengths.

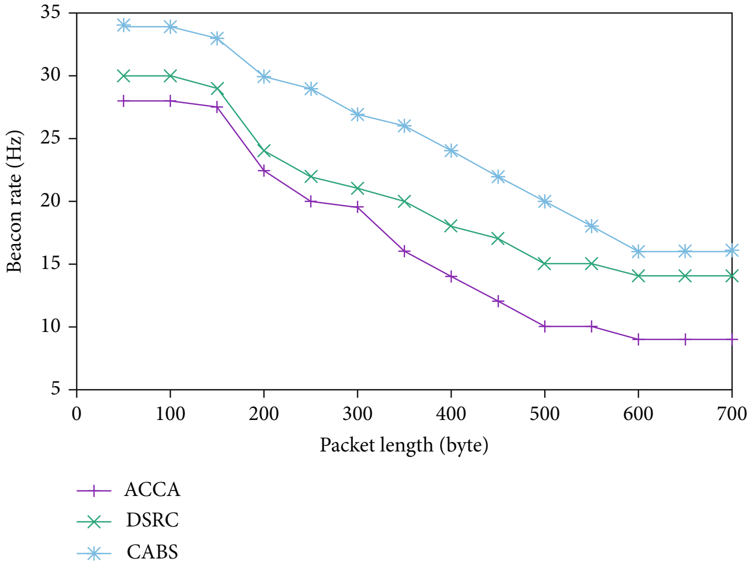

Figure 14: Beacon rate on different packet lengths.

From previous results, we know that ACCA is able to adapt to a changing environment and quickly converge to the optimal state.

Figure 13 shows the performance of ACCA with congestion control methods through different packet lengths. In this performance evaluation, vehicles are moved and the packet length changes from 50 bytes to 700 bytes. The result is shown as in Figures 13 and 14, when the packet length increased the number of safety messages that are received by the vehicles also decreased.

When the packet length increased as in Figure 14, it costs the channel more time to broadcast the beacon, for this reason the beacon rate also decreased.

6. Conclusion

The vehicle congestion, dynamic mobility, communication links, different traffic conditions, and regulations are the main challenges in VANET's. In this paper, ACCA was proposed to control the congestion in VANET, and the proposed optimized channel utilization (ACCA) to ensure the transmission of broadcasting safety message to vehicles when number of vehicles increased. Optimization algorithms LCA was used to maximize the CCH utilization in emergency situations and to achieve this contribution, and we developed a mathematical model and hence prevent the congestion for CCH. LCA, as a metaheuristic algorithm, has been used to explore the best solution of the CCH utilization. This will certainly fulfil the requirements of traffic safety applications. Considering a highway and urban scenario, the performance of ACCA was compared with two existing congestion control strategies including DSRC and CABS. A thorough performance evaluations have been carried out, and results show the superiority of our proposed algorithm as compared with other related algorithms. The proposed approach can be utilized to meet strict emergency message deadline, and hence, vehicles can exchange safety-related messages successfully. This will assure the significance of the proposed algorithm in vehicle-to-vehicle scenarios.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] E. A. Feukeu and T. Zuva, "Dynamic broadcast storm mitigation approach for VANETs," *Future Generation Computer Systems*, vol. 107, pp. 1097–1104, 2020.

[2] B. K. Pattanayak, O. Pattinaik, and S. Pani, "A novel approach to detection of and protection from Sybil attack in VANET," *Advances in Intelligent Computing and Communication*, vol. 109, pp. 240–247, 2020.

[3] A. A. Almohammedi, N. K. Noordin, A. Sali, F. Hashim, and M. Balfaqih, "An adaptive multi-channel assignment and coordination scheme for IEEE 802.11 p/1609.4 in vehicular ad-hoc networks," *IEEE Access*, vol. 6, pp. 2781–2802, 2018.

[4] C. Ameixieira, J. Matos, R. Moreira, A. Cardote, A. Oliveira, and S. Sargento, "An IEEE802.11 p/WAVE implementation with synchronous channel switching for seamless dual- channel access (poster)," in *2011 IEEE vehicular networking conference (VNC)*, pp. 214–221, Amsterdam, Netherlands, 2011.

[5] H. Qin, B. Cao, W. Chen, X. Xiao, and P. Yang, "WiFi-Assisted control traffic offloading in vehicular environments," *IEEE Transactions on Vehicular Technology*, vol. 69, pp. 4542–4547, 2020.

[6] J. Choi and Y. Yi, "Joint optimization of emergency and periodic message transmissions in vehicular networks," in *MILCOM 2017-2017 IEEE Military Communications Conference (MILCOM)*, pp. 846–851, Baltimore, MD, USA, 2017.

[7] J. Choi and Y. Yi, "Joint optimization of message transmissions with adaptive selection of CCH interval in VANETs," *IEEE Access*, vol. 7, pp. 72090–72104, 2019.

[8] K. Z. Ghafoor, M. Guizani, L. Kong, H. S. Maghdid, and K. F. Jasim, "Enabling efficient coexistence of DSRC and C-V2X in vehicular networks," *IEEE Wireless Communications*, vol. 27, no. 2, pp. 134–140, 2020.

[9] K. Z. Ghafoor, L. Kong, S. Zeadally et al., "Millimeter-wave communication for internet of vehicles: status, challenges and perspectives," *IEEE Internet of Things Journal*, vol. 7, no. 9, pp. 8525–8546, 2020.

[10] S. Bai, J. Oh, and J. I. Jung, "Context awareness beacon scheduling scheme for congestion control in vehicle to vehicle safety communication," *Ad Hoc Networks*, vol. 11, no. 7, pp. 2049–2058, 2013.

[11] K. A. Hafeez, A. Anpalagan, and L. Zhao, "Optimizing the control channel interval of the DSRC for vehicular safety applications," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 5, pp. 3377–3388, 2016.

[12] E. Hosseini, "Laying chicken algorithm: a new meta-heuristic approach to solve continuous programming problems," *Journal of Computational and Applied Mathematics*, vol. 6, no. 1, p. 2, 2017.

[13] Y. Kim, Y. H. Bae, D. S. Eom, and B. D. Choi, "Performance analysis of a mac protocol consisting of EDCA on the CCH and a reservation on the SCHS for the IEEE 802.11 p/1609.4 wave," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 6, pp. 5160–5175, 2017.

[14] V. Nguyen, T. T. Khanh, T. Z. Oo, N. H. Tran, E. N. Huh, and C. S. Hong, "A cooperative and reliable RSU-assisted IEEE 802.11p-based multi-channel mac protocol for VANETs," *IEEE Access*, vol. 7, pp. 107576–107590, 2019.

[15] V. Nguyen, O. T. T. Kim, C. Pham et al., "A survey on adaptive multi-channel MAC protocols in VANETs using Markov models," *IEEE Access*, vol. 6, pp. 16493–16514, 2018.

[16] P. K. Singh, R. Singh, S. K. Nandi, K. Z. Ghafoor, D. B. Rawat, and S. Nandi, "Blockchain- based adaptive trust management in internet of vehicles using smart contract," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 6, pp. 3616–3630, 2021.

[17] S. Son and K. J. Park, "BEAT: beacon inter-reception time ensured adaptive transmission for vehicle-to-vehicle safety communication," *Sensors*, vol. 19, no. 14, p. 3061, 2019.

[18] Q. Wang, S. Leng, H. Fu, and Y. Zhang, "An IEEE 802.11p-based multichannel MAC scheme with channel coordination for vehicular ad hoc networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 13, no. 2, pp. 449–458, 2012.

[19] S. Zemouri, S. Djahel, and J. Murphy, "An altruistic prediction-based congestion control for strict beaconing requirements in urban VANETs," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 49, no. 12, pp. 2582–2597, 2019.