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RESEARCH ARTICLE

Optimized Controller Scheme for Autonomous Navigation in Infotainment on Internet-of-Vehicles

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Abstract – The infotainment system curves an innovative mechanism of essential information dissemination for ensuring driving safety and improved driving experiences. However, there are significant challenges in developing an infotainment system to fit into the operational design of advanced technology, e.g., Internet-of-Vehicle (IoV). A review of existing studies has witnessed advantages and shortcomings, especially from the perspective of navigational services. Therefore, the proposed scheme introduces a novel autonomous signal control system that can realize the navigational demands of each vehicle meeting at the intersection to offer a faster clearance in the traffic management system. Analytically designed with a collaborative cloud environment, the proposed scheme implements a novel optimized controller scheme that can operate in a decentralized manner using a Fuzzy controller system for efficient traffic management in IoV applications.

Index Terms – Infotainment, Internet of Vehicle, Navigation, Signal, Traffic Management, Clearance.

1. INTRODUCTION

With the progressive inflow of innovative technologies, automotive industries have incorporated smart mechanisms to ensure higher safety standards, enhanced driving experience, and improved connectivity [1][2]. An infotainment system is one such way to ensure this fact by integrating entertainment and information access with management [3][4]. The prime components of the infotainment system are integrated head units, display, Graphical Processing Unit (GPU), operating system, enhanced connection supportability with network protocol, integration with automotive sensors, and digital instrument cluster [5][6]. With the advancement of the Internet-of-Things (IoT), there is a current evolution towards Internet-of-Vehicles (IoV), which calls for a higher set of connected vehicles using the internet for performing exchanging of information [7][8]. There is a higher degree of the scope of such applications, and it has inherent challenges, too, especially concerning Vehicular Ad hoc Networks (VANET) [9]. One of the base operations of the infotainment system is towards assisting in the navigational system. With increasing demand, the future of IoV calls for unmanned vehicle systems which can take an autonomous decisions towards this navigation process [10].

Apart from this, there is a discrete difference between VANET and IoT based VANET system. All the vehicular nodes in VANET is represented as a mobile node in the form of a wirelss access point. Hence, these vehicular nodes acts as a wireless connectivity to other vehicular nodes residing in its proximal sensing range. On the other hand, IoT-based VANET represents the extensive version of conventional VANET where all the vehicular node is represented as a smart node on the highways which is capable of performing extensive networking, storage, and computation.

Table 1 Distinction between VANET and IoT based VANET

VANET	IoT based VANET
Smaller Coverage	Exponentially Large Coverage
Each Node Offers Mobile Wireless Access Point	Each Node Offers Smart Operation
Less Computation	Maximal Computation
Limited to few Services	Open for Integration with Varied Services

The concept of VANET is more inclined towards offering a robust infrastructure of network while IoT-based VANET is towards offering a complete stack operation. Further, Table 1

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highlights the prime distinctive difference between VANET and IoT based VANET.

Basically, the conventional research in VANET is classied as rural and urban type. However, proposed research work is focused on IoT based VANET system for its more likelihood of supporting extensive traffic relation operation in future. Therefore, there is a need to evolve into a novel infotainment system that fits this futuristic vehicular communication aim. According to the concept of navigation, it is to be noted that information regarding the decision of the direction of travel and path of travel, specifically reliable and trustworthy, must be computed and shared with the infotainment system. This highly challenging task requires installing expensive infrastructures or networking devices on each road to facilitate this navigational relaying service. Fortunately, there are various research-based initiatives towards the such direction where infotainment systems can be cost-effectively run for navigational services by addressing various associated challenges. The evolution of such an infotainment system will facilitate challenging traffic management and offer discrete dissemination of information that is computed cost-effectively.

This paper contributes to developing an optimization model for facilitating an efficient infotainment system in VANET. The following is the contribution of the proposed scheme:

- A computational scheme is developed to integrate VANET with a collaborative cloud environment for faster access to traffic information by the controller units.
- Traffic signal systems are designed to compute the best route using probability based on traffic density.
- A fuzzy-based controller is proposed for identifying the best path and time for vehicles at intersections.
- The proposed scheme ensures the least waiting time and less computationally burden-based computational method to build an intelligence of traffic information.

2. RELATED WORK

Various work is currently being carried out on the vehicle-to-vehicle communication system considering the infotainment system's specific workability. The recent work by Gholamhosseinian and Seitz [11] has studied various forms of communication management, specifically considering the intersection point of the road. According to this study, the development of various intersection management schemes is highly dependent on information sharing depending upon the various communication anomalies and external factors associated with it. The work carried out by Wu et al. [12] discussed a unique caching system that could offer energy efficiency for all vehicular communication systems using an infotainment system. The study performs the selection of the cache node to carry out transmission content relaying services. A similar study towards improving caching technique has been implemented by Xue et al. [13], where the resources of cache memory from the roadside unit and vehicles have been used by adopting a dynamic programming scheme. The technique has also deployed a greedy approach based on cooperation to assess the cooperative scheme of the vehicular communication system.

A study towards accomplishing a better form of throughput is carried out by Nguyen et al. [14], where a dynamic cooperative scheme has been introduced based on the willingness of the forwarders. The work implemented by Andreica et al. [15] has developed a security model which can assess performance over controller area network deployment over vehicular communication. According to the study, it is stated that the incorporation of a cloud-based environment could assist in controlling the computational cost associated with security processing over a bus traffic system. Ni et al. [16] have deployed the Internet of Vehicles concept, where the work aims to assess resource utilization and performance evaluation. The study considers infrastructure and non-infrastructure to carry out the communication system in the presence of congested traffic. Deployment of machine learning has been implemented in the work of Sharma and Liu [17], where the idea of the work is to identify the security threat in the form of vehicular node misbehavior for the internet of vehicles. The study has used a supervised learning algorithm to assess the performance accuracy towards identifying the threat. A unique methodology for the car infotainment system is reported in Quintal and Lima [18], where the hovering method and haptic technique have been used to evaluate the feedback system. Unique modeling of discrete architecture has been designed by Wang et al. [19], where parallel vehicular communication has been developed to predict different driving techniques for ensuring safer driving skills.

Dimitrakopoulos et al. [20] have used a Bayesian network to perform autonomous music selection in an infotainment system. The prediction is based on the driver profile, external environment, current situation, etc. The work carried out by Vasudev et al. [21] have presented a secured mechanism of authentication between two vehicular communication system by using an encryption operation. The study is implemented over the Raspberry Pi module, acting as a trusted authority and cloud server. A study toward gains of load balancing is carried out by Kassir et al. [22] using stochastic geometric modeling to ensure cluster-based communication systems in a vehicular network. Sonmez et al. [23] have developed a machine-learning approach to manage the traffic load over vehicular communication systems, considering the associated edge computing. The study model develops a cloud simulation environment where a learning method is implemented in two layers considering node mobility. The work carried out by Leonardi et al. [24] have presented a unique form of networking flow using partitioning of channel capacity specifically for time-sensitive networking associated with infotainment application. The study addresses the problems of reconfiguration towards the allocation of bandwidth by the vehicular node to offer seamless communication. The work carried out by Maffiola et al. [25] has developed a decentralized model for the aggregation of traffic data in a vehicular communication system using blockchain. The core idea of this work is to facilitate data exchange among the vehicles in a decentralized manner.

The adoption of machine learning has also been carried out by Tan et al. [26] to ensure communication systems among vehicles especially focusing on addressing handover problems. The author has used the Q-learning algorithm for this purpose and experimented with a real network setup considering the mobility model. Fu et al. [27] have used a transcoding scheme over a vehicular network implemented over a fog environment. Using time-varying characteristics, the author has used Markov's decision-making to ensure better video quality during the streaming process in the infotainment system. Qureshi et al. [28] analyze traffic conditions to evaluate the data dissemination process, where an election mechanism is implemented to select the cluster head for forwarding data. Choi et al. [29] have implemented a mechanism to identify the driver in an intelligent vehicle system using a convolution neural network. The study collects brain signals based on the driver's motion and models the driver's behavior. Gagliardi et al. conducted a study on road classification [30], which uses artificial intelligence using a convolution neural network. Apart from this, their various studies carried out on communication systems of short-range by Zaeri [31], the identification and forwarding of obstacles by Kristiana et al. [32], the analysis of distance-based schemes by Ahed et al. [33], and the impact of big data in traffic management by Mouad et al. [34].

2.1. Research Problem

After reviewing the existing approaches towards different techniques for improving vehicular communication systems, it has been noted that both beneficial perspectives and limiting factors feature them. Such limiting factors are identified in the form of a research problem as follows:

- Some of the dominant proportion of the methodological trend in the existing system is based on machine learning-based concepts. Although such concepts offer better predictive outcomes; however, such modeling is never carried out considering the constraint-based perspective of vehicular mobility or in simplified form.
- Derivation of valuable computed information, intelligence, is less seen in adopted methodologies in literature; iii) identifying the vehicular nodes based on time-based prioritization over intersection is less emphasized in the existing system.
- Less preference is given to topology construction, especially when a cloud-based VANET system is modeled toward targeting scalable performance.
- No work is being carried out towards identifying the specific navigational demands of specific vehicles to be catered up uniquely by traffic signal decisions; in the existing system, the outcome of a traffic signal is unanimously accepted and followed by all vehicles uniformly, irrespective of their dynamic demands.
- Computation towards traffic density and offering solutions towards reduced wait time in an intersection point is less emphasized in the existing scheme.
- Studies towards a navigational system in VANET mainly emphasize using a map-based scheme. No smart/intelligent navigational system has been witnessed in its simplest form in the infotainment system in existing study models.
- Available analytical streams of methodologies carry out mining operations over the traffic data to generate more valuable information; however, such information is used for discretely channelizing each vehicle in VANET.

2.2. Research Motivation

After concluding the research problems, as discussed above, an insight towards some of the notable contributory models has been carried out towards planning the proposed design process as a part of the motivation. The study by Ahn and Choi [35] developed a traffic signal control system that can not only facilitate the betterment of the communication system but also emphasizes considering the reduction of vehicle queue length on specific roads. This idea is simplistic in the design process and is also considered in the proposed model implementation; however, the model also suffers from scalability problems owing to the non-inclusion of any collaborative network. Gomez et al. also conducted a similar study on traffic signal control systems [36], where a learning-based algorithm was implemented using a reinforcement learning scheme. This work also uses computer vision to reduce vehicle queue length at intersection points. The prime pitfall of the study is that computer vision can be replaced with conventional sensory-based roadside units that offer more coverage than computer vision.

Apart from this, adopting a learning scheme offers better accuracy but is computationally extensive and hence is a prime shortcoming of this study. However, the idea of reduction of queue length is considered in the proposed study by reducing the wait time and understanding the different demands of navigation of every vehicular node. The adoption

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of the roadside unit for this purpose was noted in the work of Lee and Chiu [37], where a control system is designed to offer faster deployment of signal information over a smart transportation system. Finally, a case study of the Columbian traffic system is studied by Alarcon et al. [38], which is capable of fine-tuning the user interface of the infotainment system based on driver distraction. By reviewing this work, a motivating factor is that it is feasible to develop a unique infotainment system customized for the driver where a smart traffic light system can disseminate specific navigational information different from another vehicle for a faster clearance system. All these studies mentioned above act as a motivation for designing the proposed scheme.

3. PROPOSED MODELLING

The proposed model presents a comprehensive analytical framework to optimize the infotainment system's performance over a vehicular network. Optimization refers to adopting the most simplified approaches with lower dependencies towards extensive computational and hardware resources and achieving a higher scalability performance in the navigation system. The proposed study extends the prior work [39]-[41]. In contrast, the similar use case of the urban VANET system is adopted to be integrated with cloud computing for a better form of navigational relaying services. Figure 1 highlights the typical architecture of the proposed model.

3.1. System Design

According to the proposed architecture in Figure 1, the proposed system adopts a graph theory to construct a topology of the VANET cloud system, considering the essential elements of the position of vehicular nodes, their respective direction, and speed. A use case of an urban VANET system is considered, consisting of a smart traffic light system at every intersection of the road to offer faster clearance to vehicles. Each road is also characterized by one roadside unit capable enough to cover all the transmission ranges of vehicular nodes traveling in that specific path. Apart from this, all roadside units on different roads are synchronized with cloud-based collaborative modules that execute the proposed algorithm. In contrast, the outcome of that algorithm is transmitted to all smart traffic light systems present over the junction. The study also assumes a specific form of the infotainment system in the form of onboard units, which take input as an outcome from the traffic light system and apply it to the infotainment system. As a result of the input received from specific infotainment systems, the system can autonomously decide which routes have the fastest clearance based on the input received from the infotainment systems. The optimization process is carried out as follows:

- The proposed scheme uses distance computation among the vehicular nodes to evaluate the effective position as well as the effective path.
- A fuzzy logic-based concept is used considering the traffic density on each road to construct an objective function towards choosing a better probability of road.
- The study constructs a controller system to evaluate the selection of roads with faster clearance and evaluation of the time clock for a reduced wait period at the intersection point of the road.
- The study uses a similar tree mechanism to construct a collaborative network of Internet of Vehicles IoV on the prior model [40].

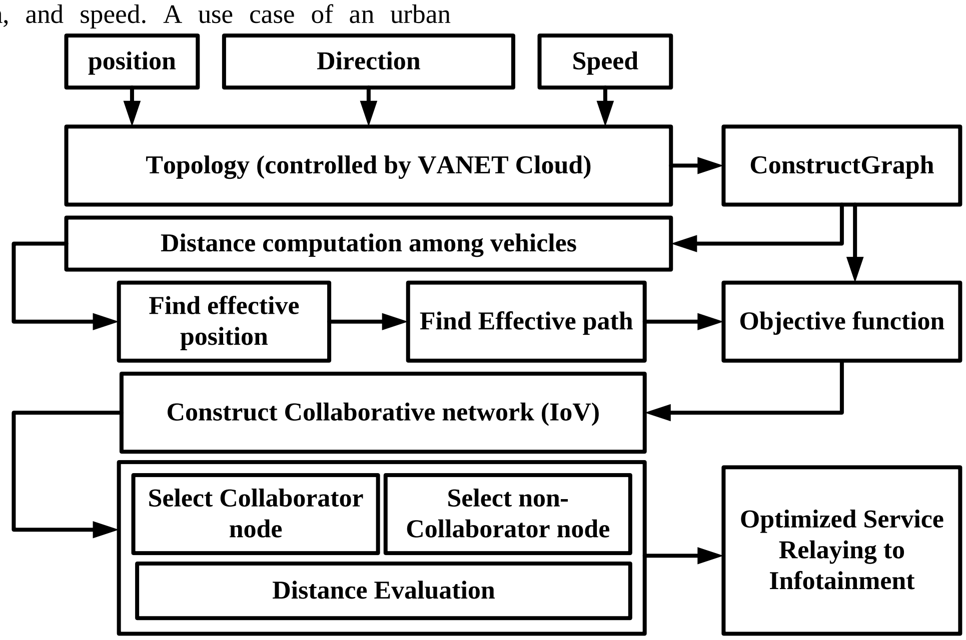

Figure 1 Overall Architecture Diagram of Proposed Scheme

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The prime aim of the optimization modeling is also to reduce the computational burden for creating an environment of IoV with larger connectivity to enable a reliable and seamless communication environment. The proposed scheme utilizes the concept in [40] to distinguish collaborator nodes from non-collaborator nodes. A collaborator node can be considered a relay node that would assist in relaying computed information between a vehicle and another vehicle to a device placed at the roadside or to a smart traffic light system allowing navigation in an ad-hoc manner. In our previous work, we have already emphasized the importance of building functionality for relay nodes, and in this work, we will mainly focus on functionality for non-collaborator nodes. This transmission concept refers to offering better forms of seamless relaying of navigational services to infotainment systems in a simplified manner to ensure better data quality and reduce resource dependence during transmission.

3.2. System Methodology

The prime purpose of the proposed implementation is basically to incorporate the concept of optimization, where a faster and more reliable decision can be made towards clearing the vehicles in an intersection point. Some problems require a system of computing that takes multiple independent variables on which the decision logic is built to arrive at a probabilistic output. Figure 2 illustrates an example of the Fuzzy Computing System (FCS) that takes all the input from the set of {Cloud(C), Temperature(T), Wind(W)}, and yields the degree of rainfall probability (σ) such that $0 \leq \sigma \leq 1$.

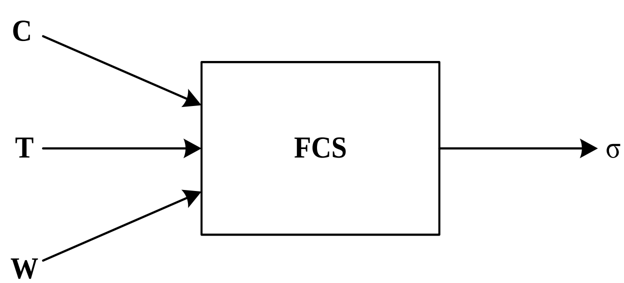

Figure 2 Fuzzy Computing System for Computing Rainfall Prediction

The proposed design framework for the signal light controller in the infotainment dashboard (SLCID) has two fuzzy computing models: i) FCM for Road Selection and ii) FCM for the time clock.

3.2.1. FCM for Road Selection

The prime purpose of this module is to consider the complete graph of topology control for the VANET system where an effective position, as well as route, is being explored using an objective function. The outcome of this operation leads to a finalized decision on the route information, which is being discretely forwarded to specific vehicles. The FCM for Road Selection design framework considers the intersection of the four roadways, as in Figure 3.

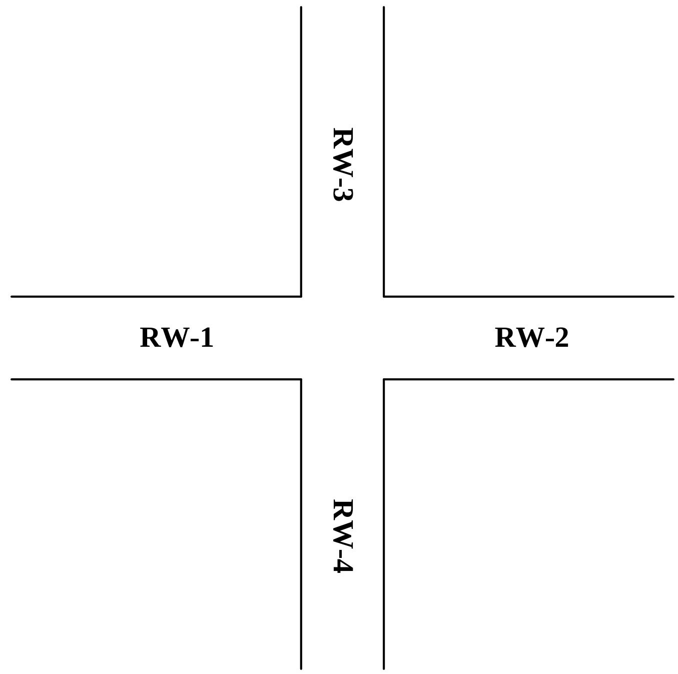

Figure 3 Intersection of the Four Roadways

The decision towards clearance of the vehicular node over each road meeting at the intersection points completely depends upon calculating the density of vehicular nodes over each system. The proposed system uses a fuzzy logic system to create a ruleset. The condition of the Vehicle Traffic Density (VTD) is defined into three different categories as VTD ={Low traffic Density (LTD), Moderate traffic Density(MTD), High traffic Density(HTD)}. These conditions may occur on any of the road's R ∈ {RW1, RW2, RW3, RW4}, which raises various possibilities of the combinations as mentioned in Table 2.

Table 2 Sample Table for Ruleset Construction

Road/Conditions	RW1	RW2	RW3	RW4
1	LTD	LTD	LTD	LTD
2	LTD	LTD	LTD	MTD
3	LTD	LTD	MTD	LTD
4	LTD	MTD	LTD	LTD
5	MTD	LTD	LTD	LTD
6	MTD	MTD	MTD	MTD

7	MTD	MTD	MTD	LTD
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
81				

The ruleset (RS) formulates several Rules (R_n) based on the conditions of the VTD, and the R_n is computed using expression (1):

$$R_n = (C_n)^{nR} \quad (1)$$

As shown in Eq. (1), the variable C_n is the number of conditions, and nR is the number of roads. In this case C_n =3 and nR = 4, therefore the value of the Rn = 81. There will be '3' in the list of conditions, ∀ R ∈ {RW1, RW2, RW3, RW4} having similar conditions of VTD either belongs to {(LTD), (MTD), (HTD)}. In all three conditions, the output of the probability of road section (Pr) will be R ={}as a null set. In the rest of the combinations, the probability of road selected Pr will be any of the elements of R ∈ {RW1, RW2, RW3, RW4}, depending upon the weight of the randomness of the VTD ={(LTD), (MTD), (HTD)}. Figure 4 illustrates the FCM for Road Selection.

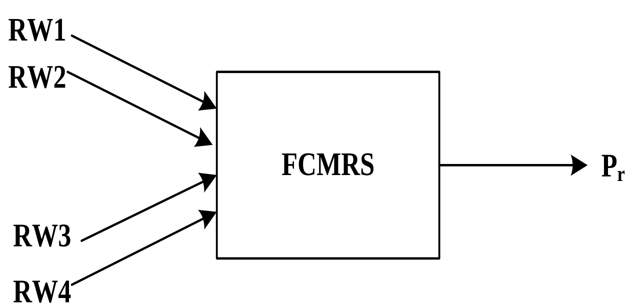

Figure 4 FCM for Road Selection

3.2.2. FCM for Road Selection

The proposed system also uses a similar ruleset of fuzzy logic to control the time clock associated with waiting and clearance of the vehicular node in an intersection point. This part of the implementation is mainly responsible for controlling the duration of the signal light, which differs from every road meeting the intersection point. The mechanism calls for the vehicular nodes with a high wait time as an essential priority, which must be cleared to maintain a similar wait time for all the vehicular nodes. Initially, this operation module's prime role is to monitor and keep track of all the vehicular nodes recently transmitted with clearance signals only. The module assesses the position and direction while it computes the traffic density associated with the vehicular node to keep a spontaneous assess the faster clearance route while communicating with other roadside units via a collaborative cloud network. One of the significant contributions of this module is that one roadside unit is completely free from any form of dependencies with other roadside units to assess the traffic density. As a collaborative cloud network connects all the roadside units as a supermatrix, all the information obtained from each roadside unit is updated instantly. The Algorithm-1 for FCM for road selection is as follows:

Input: RW (road)

Output: R_n (selected road)

Start

1. For RW=:1:4

2. If (j= VTD||LTD||MTD||HTD)

3. $R_n=(C_n)^{nR}$

4. End

5. End

End

Algorithm 1 Selection of Road

Therefore, when the infotainment system within the vehicular node is only required to communicate with one roadside unit, which greatly reduces the computational burden, unlike in any existing systems, this matrix of collaborative network retains updated information of computed decision of signal, step count, and selected road. The proposed system uses probability-based computation using a fuzzy ruleset to determine this time clock duration based on traffic density. Another novel contribution of the proposed module is that it offers distributed operation without affecting the scalable performance of relaying the services in the VANET system, which is capable of sustaining the dynamicity of the traffic load on the different roads towards or away from smart traffic lights system without being sensitive towards relaying information. Further, the number of rulesets doesn't affect the computational burden or memory as the more the ruleset is executed, the more its outcome is stored in the hop table of each vehicle, which can further assist as a relay node to assist the communication system of infotainment. As the information is faster and lightweight, it doesn't overburden the memory capacity of the infotainment system mounted within the vehicle. Hence, the modules mentioned above-combined work to accomplish the proposed study goal. Further elaboration of the fuzzy implementation is stated in the next section in the form of an algorithm.

3.3. Simulation Design

The implementation of the proposed algorithm is based on the concept of optimization towards the communication system among various elements of the infotainment system presented in a typical environment of VANET. The complete optimization process has considered the vehicles' deployment in the IoV environment, where the explicitly computed navigation information is the core information being disseminated discretely to each vehicular node. Deploying a fuzzy logic, the proposed system deploys two essential modules, i.e., selecting road and selecting time. Algorithm 1 illustrates the procedure of road selection using the proposed fuzzy logic scheme.

The proposed algorithm-2 considers the input of n (number of vehicular nodes) shown in Line-1, which yields an outcome of Sr (Selected Road) after processing. Before the start of this algorithm, various attributes are initialized, viz. aw (active wait signal duration), *sc* (step count), β (simulation round), γ (route decision), etc. A new function, g1(x), is constructed to create an intersection point on the urban traffic environment while considering the input arguments of nc current vehicular road and cds computed signal decision (Line-2). There are multiple intersection points in the given scenario using the abovementioned function g1(x), while the number of vehicles passing through each such point is arbitrarily computed.

Input: n (number of vehicular nodes)

Output: S_r (Selected Road)

Start:

1. For i=1: n
2. Int=$g_1(n_c, c_{ds})$
3. If Int<[j]
4. α=g_2(Int, d_{cent})
5. For k=1: h_{max}
6. If α≤h
7. S_r=l
8. End
9. End
10. End

End

Algorithm 2 Selection of Road

The next part of the implementation is associated with creating an entity [*j*], which is compared with the scenario of vehicular node density present in intersection *Int* (Line-3). If this logical condition in Line-3 is valid, then the proposed scheme considers that a positive decision toward clearing the vehicular nodes from one intersection point is relayed. Practically it is done by arriving at a green signal from red/yellow signal) in this process (Line-3). The algorithm constructs a secondary function g_2(x) responsible for controlling vehicular movement decisions, i.e., d_{cent} decision controller signal (Line-4) based on input arguments of *Int* intersection of road and d_{cent} variable. The proposed scheme constructs an objective function toward selecting a road; however, multiple objective functions are constructed based on multiple numbers of the fuzzy-based ruleset to determine the practical condition of a road for a given length of intersection. The proposed scheme constructs such ruleset α compared with a variable h where the value of h is equivalent to 3 (red, green, yellow), i.e., S_r. Depending upon the value of h, the proposed scheme allocates the value of h to S_r as the computed probability of the route to be traveled for a positive decision. The proposed study considers an entity l as all connected neighboring streets from the intersection point *Int*. On a different condition, the highest value of n_c is considered while allocated to selected road S_r (Line-7). A closer look into the complete algorithmic operation shows that the proposed algorithm contributes towards yielding a specific direction to different vehicles at a specific duration.

The next part of the algorithm is responsible for controlling the time clock of the signal that considers the presence of 4 number of intersection points, i.e., Int=4 (Line-1); the study also assumes that the initial condition for all the decisions for clearance via green right sc is set to allow clearance (i.e., green) which is more than the assigned value of π, i.e., the value of clearance (Line-2). The proposed scheme also constructs an attribute attr which consists of elements complete decision of signal c_{ds}, step count s_c, and selected road S_r (Line-3). This logical condition is constructed to perform reconfiguration of the varied decision in the form of the signal light, S_r, and s_c. After this operational step, the algorithm increases the steps concerning c_{ds}.

The subsequent steps of the algorithm evaluate a logical condition to check if the value of the S_r corresponding to the β iteration is equivalent to the S_r condition found at the (β-1) iteration. In contrast, the value of β is not similar to 2 (Line-4 and Line-5). In such conditions, the algorithm sets the value of c_{ds} corresponding to (β-1) value as a (=0.5) while the value of the c_{ds} corresponding to β iteration is allocated with b (=0) (Line-6). This functional operation's prime motive is updating the state of c_{ds} (or lights) at the intersection point (Line-7). Hence, upon successful execution of the above mention algorithmic procedure, the algorithm returns an output of S_r (Selected Road). Afterward, the proposed system initiates a procedure for controlling the time clock of the signal, as discussed in Algorithm 3.

Input: π (value of clearance), Int (intersection)

Output: c_{ds} (computed decision of signal)

Start

1. For *i*=1: *Int*
2. If $s_{c(i)} \geq \pi$
3. [attr(i)]=mat[(*Int*)] attr=[c_{ds}, s_c, S_r]
4. If ($S_r(\beta) \neq S_r(Int\text{-}1)$)
5. If $\beta \neq 2$
6. $c_{ds}(S_r(\beta\text{-}1), S_r(Int))$=(a, b)
7. pt(a_w)
8. $c_{ds}(S_r(i\text{-}1), S_r(i))$=(a, b)
9. End
10. End
11. End
12. End

End

Algorithm 3 Controlling the Time Clock of the Signal

The algorithm considers a pause time a_w, the proposed algorithm alters the value of c_{ds} to zero (a=0) when it corresponds to S_r value concerning (β-1) iteration while the value of c_{ds} is considered as one (b=1) when it corresponds to S_r value for β iteration rounds (Line-8). The proposed system considers an equivalent operation for decision towards clearance (i.e., green) as,

$$C_T(\beta) = \frac{\eta}{\delta} \quad (2)$$

As shown in Eq. (2), the variable C_T represents the clock time of clearance corresponding to β iteration and is computed using two dependable variables, i.e., η and δ. The computation of primary variable η is carried out by-product of time t and summation of n_c concerning S_r and incoming vehicular node n_{in}. i.e.,

$$\eta = (n_c(S_r) + n_{in}) \times t \quad (3)$$

As shown in Eq. (3), it can be seen that the computed value of η attribute will respect the favorable duration associated with the clearance of all the incoming vehicular nodes for all the considered lanes towards the intersection point. Similarly, the variable δ will represent all the outgoing vehicular nodes. Hence, the empirical expression of CT in Eq. (2) represents a probability toward clock time of clearance. It should be noted that time clock is related to exact duration of time when the traffic signal hold on any specific active traffic command. For an exactly, specific duration of green light, red light, or yellow light. Let us consider that one lane system chooses to yield higher duration of green signal for a long time. In such case, this could be an optimal outcome for that specific lane; however, it could potentially impact the level of congestion to all connected lanes by growing the number of cleared vehicles from prior lane. Apart from this, time clock varies with the density of node specifically at the intersection point. Hence, no two lane system could have possible same time clock for its traffic signal and now the challenge is to maintain the time clock in such a way that it justifies the clearance of vehicles from other lane system too. Hence, time clock plays an essential role in minimizing waiting time and offering optimal clearance of vehicles. Therefore, the proposed algorithm contributes towards computation of the computed decision of signal in order to ensure that generated time clock of one lane doesn’t affect the other lane system while offering navigational information in infotainment system.

4. RESULTS AND DISCUSSIONS

This section elaborates on the accomplished result of implementing the proposed scheme and algorithm discussed in the prior section. The scripting of the proposed scheme is carried out by considering a normal windows environment of the 64-bit machine with 16 GB RAM. From the prior section of implementation and discussion of existing studies, it has been noted that the proposed scheme implements a novel scheme of disseminating navigational information in a very discrete method to each vehicle, understanding their navigation demands.

Unlike any conventional method, the proposed scheme doesn't use any map-based method for traveling, nor it uses any form of iterative methodologies with a dependency on the dataset. Instead, the proposed scheme can perform live computation based on traffic density on the specific road and performs a computation towards the faster clearance of each vehicle from their intersection points. The study develops an analytical simulation model considering multiple intersection points with adjoining four roads to formulate the intersection. The capacity of each road is 50 vehicles, while each vehicle is equipped with the standard of IEEE 802.11n, capable of offering a throughput of around 300 Mbps. The assessment is carried out based on multiple performance metrics.

As shown in Table 3, the evaluation of the proposed scheme is carried out considering mutliple performance metric i.e., consistency, decision of clearance, time clock, clearance, and passed vehicle. The idea of adopting this performance metric to evaluate the responsiveness of proposed scheme towards clearing the vehicles waiting at the point of intersection. In order to understand the state of traffic over each lane, the proposed scheme uses the fuzzy rules exhibted in Table 2. This table makes a decision of traffic considering the actual scenario of node density of traffic associated with all the lanes connecting to the intersection point under observation. The first metric is the consistency factor, computed as the rate of traffic being handled by the roadside unit in both the incoming and outgoing direction of its placement. The second metric is the duration of the decision for clearance, which is understood as the time the green light is switched on to allow the vehicle to pass. As each vehicle has its navigational demands, accuracy in this performance metric is essential. The third metric is the time clock, which evaluates the signal assignment for clearing the vehicles from the intersection point and reducing the queue length. The final metric is to assess the balance between clearance and the number of vehicles to assess the score of the effectiveness of the fuzzy controller to decide on clearance based on current traffic density. The entire outcome analysis is graphically shown, and the findings are quantified accordingly.

Table 3 Numerical Outcomes of Proposed Study

Evaluation for Consistency				
Rounds	**I1**	**I2**	**I3**	**I4**
0	10	12	13	14
50	10	13	12	13
100	11	10	12	13
150	10	14	12	12
Evaluation for Decision of Clearance				
Rounds	**I1**	**I2**	**I3**	**I4**
0	7	8	6	7
50	8	6	8	7
100	8	7	8	7
150	9	**8**	**6**	8
Evaluation of Time Clock				
Rounds	**I1**	**I2**	**I3**	**I4**
0	0.7	1.7	1.9	1.5
50	1	1.6	1.8	1.7
100	1	1.8	1.7	1.6
150	1	1.7	1.5	1.8

Evaluation of Clearance			
I1	**I2**	**I3**	**I4**
34	44	34	39
Evaluation of Passed Vehicle			
I1	**I2**	**I3**	**I4**
450	700	500	750

The significance of this outcome is that it offers a simplified and direct understanding of the performance score of each intersection points in order to formulate better navigational information to be generated in infotainment system. Table 3 highlights numerical computation of various performance attributes under observation with respect to number of test rounds and four intersection points of a road i.e., I1, I2, I3, and I4.

A closer look into the numerical outcome of above Table 3 shows that there is a good balance being noted in managing traffic density of all the 4 sample intersection point. Apart from this, it can be also noted that proposed scheme facilitates towards clearing a higher number of vehicles at an efficient management of time clock associated with the traffic signal along with faster propagation of signal to the vehicular nodes in the form of infotainment data.

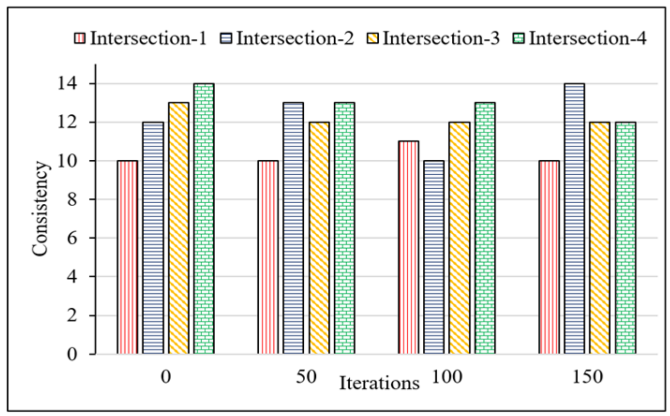

Figure 5 Evaluation of Consistency Factor

Figure 5 shows that the proposed system's consistency factor is quite high individually for all four specific intersection points for a given number of iterations. Several vehicles are randomly assigned with each increasing iteration. However, it should be noted that the number of sensed information by roadside units increases with an increased iteration. The figure identifies bottleneck condition in case of nearing to 50th iteration and approach of the 150th iteration for the 4th junction. However, the duration of that bottleneck condition is evaluated to be less than 1.976 minutes only. The bottleneck condition is stated when the traffic density increases more than the capacity of each road (i.e., 50 vehicles). The significance of this outcome is that the proposed scheme can offer better consistency while disseminating navigational information in fluctuating traffic conditions.

Although the proposed system consumes a few minutes for decision-making for the first time in the initial iteration (which is just one time), a closer look at Figure 6 will showcase that the proposed duration of decision for clearance ranges with a difference of 1 minute approximately for all the intersection points. The outcome exhibits lesser fluctuating values for the clearance signal to arrive in the infotainment system irrespective of traffic density. One important fact is that there is no uniform duration for the clearance associated with all four roads concurrently owing to the dynamic demands of navigation of all individual drivers, which agrees with the practical scenario. The higher priority is always offered to the first existing route in the intersection offered by the fuzzy controller system, which indirectly opens the clearance for other connected intersection points. Further, it is also noted that the proposed scheme maintains a higher degree of uniformity in reducing bottleneck conditions for each road discretely. However, the entire scheme operates over a collaborative network.

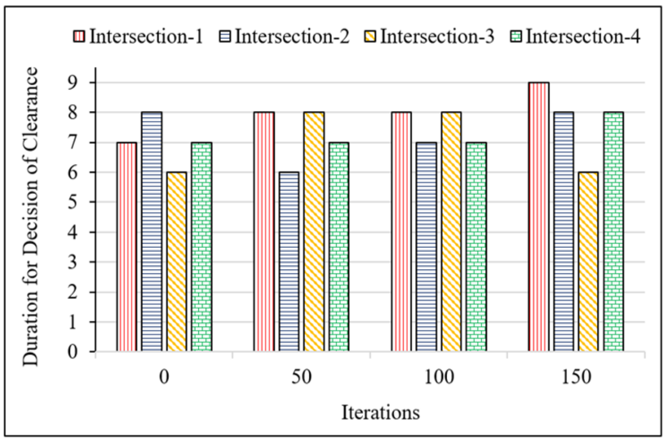

Figure 6 Evaluation of Duration of Decision for Clearance

Figure 7 Evaluation of Time Clock

Figure 7 shows that there is quite a fluctuating value of the time clock information over increasing iterations corresponding to all four intersecting points. The higher fluctuation only results from a lesser extent of traffic data. However, a deeper insight into this graphical outcome shows a higher uniformity of the time clock for the first intersection point compared to others, compensating for other road traffic. It will mean that the proposed system will always find one of the alternative routes for a faster traffic system, which will always positively impact the other roads meeting at the intersection for a faster clearance system.

Further evaluations are carried out to analyze the performance concerning the balance between the clearance of vehicular nodes and vehicle counts. The analysis of clearance of vehicular nodes (vehicles) is shown in Figure 8. At the same time, an analysis regarding the number of vehicular nodes corresponding to clearance is shown in Figure 9. A closer graph trend analysis exhibits that the proposed system maintains a good balance.

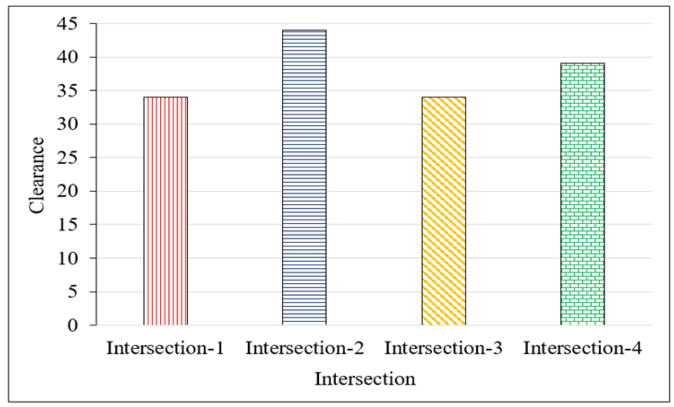

Figure 8 Evaluation of Clearance

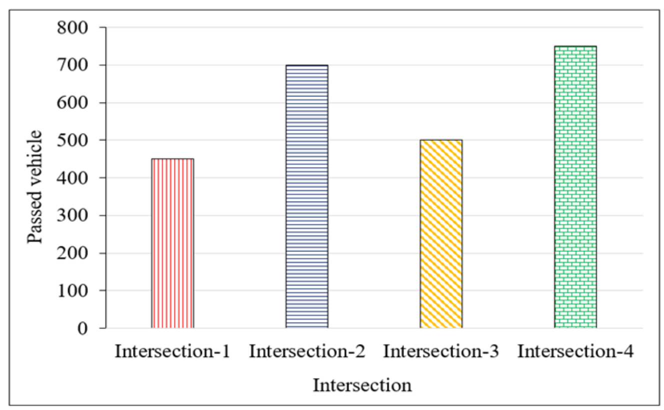

Figure 9 Evaluation of the Number of vehicles

This will mean that each junction and its related information are highly synchronized among the roadside unit, where the controller captures information and takes decisions in a decentralized manner. A closer look into the graphical outcome shows that the 2nd and 4th intersection point has witnessed a higher number of clearances, which agrees with the higher number of vehicles being passed by these two junction points.

Therefore, the significance of this outcome is that the proposed scheme can perform cross-validation of clearance, and several vehicles are passed in a highly reliable manner without using any sophisticated algorithm, as noted in the existing scheme. Therefore, a better form of optimization toward controller design is noted in the proposed scheme.

RESEARCH ARTICLE

5. CONCLUSION

The proposed paper has presented a comprehensive yet simplified optimization scheme for developing a controller system in an infotainment system of VANET. The contribution, as well as novelty of the proposed scheme, are as follows: i) A simplified probability-based decision technique has been presented in the proposed scheme towards assisting in catering up navigational demands in the urban VANET system, ii) Adoption of the cloud-based collaborative model further contributes towards faster dissemination and updating of decision towards clearance system in a decentralized manner despite being highly connected and synchronized roadside units, iii) the proposed scheme not only offers a better scheme of connectivity among the vehicular nodes but also reduces the waiting period in intersection points thereby facilitating dynamic infotainment services for IoV.

REFERENCES

[1] J. Zhang, G. Lu, H. Yu, Y. Wang, and C. Yang, "Effect of the Uncertainty Level of Vehicle-Position Information on the Stability and Safety of the Car-Following Process," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 6, pp. 4944-4958, June 2022, doi: 10.1109/TITS.2020.3044623.

[2] E. de Gelder et al., "Towards an Ontology for Scenario Definition for the Assessment of Automated Vehicles: An Object-Oriented Framework," in IEEE Transactions on Intelligent Vehicles, vol. 7, no. 2, pp. 300-314, June 2022, doi: 10.1109/TIV.2022.3144803.

[3] B. Vinoth Kumar, P. Sivakumar, R. S. Sandhya Devi, Software Engineering for Automotive Systems-Principles and Applications, CRC Press, ISBN: 9781000548006, 1000548007, 2022

[4] Z. Mahmood, Connected Vehicles in the Internet of Things-Concepts, Technologies, and Frameworks for the IoV, Springer International Publishing, ISBN: 9783030361679, 3030361675, 2020

[5] K. P. Srinivasan and T. Muthuramalingam, "Design, Fabrication, and Crack Analysis of Silver Track Printed Flexible Sensor for Automobile Infotainment Application," in IEEE Sensors Journal, vol. 21, no. 12, pp. 13910-13915, 15 June 15, 2021, doi: 10.1109/JSEN.2021.3071582.

[6] B. L. Nguyen, D. T. Ngo, N. H. Tran, M. N. Dao, and H. L. Vu, "Dynamic V2I/V2V Cooperative Scheme for Connectivity and Throughput Enhancement," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 2, pp. 1236-1246, Feb. 2022, doi: 10.1109/TITS.2020.3023708.

[7] P. Agbaje, A. Anjum, A. Mitra, E. Oseghale, G. Bloom and H. Olufowobi, "Survey of Interoperability Challenges in the Internet of Vehicles," in IEEE Transactions on Intelligent Transportation Systems, 2022, doi: 10.1109/TITS.2022.3194413.

[8] X. Xu, H. Li, W. Xu, Z. Liu, L. Yao, and F. Dai, "Artificial intelligence for edge service optimization in the Internet of Vehicles: A survey," in Tsinghua Science and Technology, vol. 27, no. 2, pp. 270-287, April 2022, doi: 10.26599/TST.2020.9010025.

[9] O. S. Al-Heety, Z. Zakaria, M. Ismail, M. M. Shakir, S. Alani, and H. Alsariera, "A Comprehensive Survey: Benefits, Services, Recent Works, Challenges, Security, and Use Cases for SDN-VANET," in IEEE Access, vol. 8, pp. 91028-91047, 2020, doi: 10.1109/ACCESS.2020.2992580.

[10] R. Han, Y. Wen, L. Bai, J. Liu, and J. Choi, "Age of Information Aware UAV Deployment for Intelligent Transportation Systems," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 3, pp. 2705-2715, March 2022, doi: 10.1109/TITS.2021.3117974.

[11] A. Gholamhosseinian and J. Seitz, "A Comprehensive Survey on Cooperative Intersection Management for Heterogeneous Connected Vehicles," in IEEE Access, vol. 10, pp. 7937-7972, 2022, doi: 10.1109/ACCESS.2022.3142450.

[12] H. Wu, J. Zhang, Z. Cai, F. Liu, Y. Li, and A. Liu, "Toward Energy-Aware Caching for Intelligent Connected Vehicles," in IEEE Internet of Things Journal, vol. 7, no. 9, pp. 8157-8166, Sept. 2020, doi: 10.1109/JIOT.2020.2980954.

[13] Z. Xue, Y. Liu, G. Han, F. Ayaz, Z. Sheng and Y. Wang, "Two-Layer Distributed Content Caching for Infotainment Applications in VANETs," in IEEE Internet of Things Journal, vol. 9, no. 3, pp. 1696-1711, 1 February 1, 2022, doi 10.1109/JIOT.2021.3089280.

[14] B. L. Nguyen, D. T. Ngo, N. H. Tran, M. N. Dao, and H. L. Vu, "Dynamic V2I/V2V Cooperative Scheme for Connectivity and Throughput Enhancement," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 2, pp. 1236-1246, Feb. 2022, doi: 10.1109/TITS.2020.3023708.

[15] T. Andreica, C. -D. Curiac, C. Jichici and B. Groza, "Android Head Units vs. In-Vehicle ECUs: Performance Assessment for Deploying In-Vehicle Intrusion Detection Systems for the CAN Bus," in IEEE Access, vol. 10, pp. 95161-95178, 2022, doi: 10.1109/ACCESS.2022.3204746.

[16] Y. Ni et al., "Toward Reliable and Scalable Internet of Vehicles: Performance Analysis and Resource Management," in Proceedings of the IEEE, vol. 108, no. 2, pp. 324-340, Feb. 2020, doi: 10.1109/JPROC.2019.2950349.

[17] P. Sharma and H. Liu, "A Machine-Learning-Based Data-Centric Misbehavior Detection Model for Internet of Vehicles," in IEEE Internet of Things Journal, vol. 8, no. 6, pp. 4991-4999, 15 March 15, 2021, doi: 10.1109/JIOT.2020.3035035.

[18] F. Quintal and M. Lima, "HapWheel: In-Car Infotainment System Feedback Using Haptic and Hovering Techniques," in IEEE Transactions on Haptics, vol. 15, no. 1, pp. 121-130, 1 Jan.-March 2022, doi: 10.1109/TOH.2021.3095763.

[19] X. Wang, S. Han, L. Yang, T. Yao, and L. Li, "Parallel Internet of Vehicles: ACP-Based System Architecture and Behavioral Modeling," in IEEE Internet of Things Journal, vol. 7, no. 5, pp. 3735-3746, May 2020, doi: 10.1109/JIOT.2020.2969693.

[20] G. J. Dimitrakopoulos and I. E. Panagiotopoulos, "In-Vehicle Infotainment Systems: Using Bayesian Networks to Model Cognitive Selection of Music Genres," in IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 11, pp. 6900-6909, Nov. 2021, doi: 10.1109/TITS.2020.2997003.

[21] H. Vasudev, V. Deshpande, D. Das and S. K. Das, "A Lightweight Mutual Authentication Protocol for V2V Communication in Internet of Vehicles," in IEEE Transactions on Vehicular Technology, vol. 69, no. 6, pp. 6709-6717, June 2020, doi: 10.1109/TVT.2020.2986585.

[22] S. Kassir, G. de Veciana, N. Wang, X. Wang, and P. Palacharla, "Analysis of Opportunistic Relaying and Load Balancing Gains Through V2V Clustering," in IEEE Transactions on Vehicular Technology, vol. 71, no. 9, pp. 9896-9911, Sept. 2022, doi: 10.1109/TVT.2022.3178129.

[23] C. Sonmez, C. Tunca, A. Ozgovde, and C. Ersoy, "Machine Learning-Based Workload Orchestrator for Vehicular Edge Computing," in IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 4, pp. 2239-2251, April 2021, doi: 10.1109/TITS.2020.3024233.

[24] L. Leonardi, L. L. Bello, and G. Patti, "Bandwidth Partitioning for Time-Sensitive Networking Flows in Automotive Communications," in IEEE Communications Letters, vol. 25, no. 10, pp. 3258-3261, Oct. 2021, doi: 10.1109/LCOMM.2021.3103004.

[25] D. Maffiola, S. Longari, M. Carminati, M. Tanelli, and S. Zanero, "GOLIATH: A Decentralized Framework for Data Collection in Intelligent Transportation Systems," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 8, pp. 13372-13385, Aug. 2022, doi: 10.1109/TITS.2021.3123824.

[26] K. Tan, D. Bremner, J. Le Kernec, Y. Sambo, L. Zhang, and M. A. Imran, "Intelligent Handover Algorithm for Vehicle-to-Network Communications With Double-Deep Q-Learning," in IEEE

Transactions on Vehicular Technology, vol. 71, no. 7, pp. 7848-7862, July 2022, doi: 10.1109/TVT.2022.3169804.
[27] F. Fu, Y. Kang, Z. Zhang, F. R. Yu and T. Wu, "Soft Actor–Critic DRL for Live Transcoding and Streaming in Vehicular Fog-Computing-Enabled IoV," in IEEE Internet of Things Journal, vol. 8, no. 3, pp. 1308-1321, 1 February 1, 2021, doi: 10.1109/JIOT.2020.3003398.
[28] K. N. Qureshi, M. M. Idrees, J. Lloret, and I. Bosch, "Self-Assessment Based Clustering Data Dissemination for Sparse and Dense Traffic Conditions for Internet of Vehicles," in IEEE Access, vol. 8, pp. 10363-10372, 2020, doi: 10.1109/ACCESS.2020.2964530.
[29] G. Choi, K. Lim and S. B. Pan, "Driver Identification System Using 2D ECG and EMG Based on Multistream CNN for Intelligent Vehicle," in IEEE Sensors Letters, vol. 6, no. 6, pp. 1-4, June 2022, Art no. 6001904, doi: 10.1109/LSENS.2022.3175787.
[30] A. Gagliardi, V. Staderini and S. Saponara, "An Embedded System for Acoustic Data Processing and AI-Based Real-Time Classification for Road Surface Analysis," in IEEE Access, vol. 10, pp. 63073-63084, 2022, doi: 10.1109/ACCESS.2022.3183116.
[31] N. Zaeri, "A heterogeneous short-range communication platform for the Internet of Vehicles," International Journal of Electrical and Computer Engineering, Vol.11, No.3, June-2021, pp. 2165~2177.DOI: 10.11591/ijece.v11i3.pp2165-2177
[32] L. Kristiana, A. R. Darlis, I. A. Dewi, "The feasibility of obstacle awareness forwarding scheme in a visible light communication vehicular network," International Journal of Electrical and Computer Engineering, Vol.10, No.6, December-2020, pp. 6453~6460, DOI: 10.11591/ijece.v10i6.pp6453-6460
[33] K. Ahed, M. Benamar, R. El Ouazzan, "The impact of channel model on the performance of distance-based schemes in vehicular named data networks," International Journal of Electrical and Computer Engineering, Vol. 12, No. 5, October 2022, pp. 5279~5290, DOI:10.11591/ijece.v12i5.pp5279-5290
[34] T. Mouad, L. M. Driss, K. Mustapha, "Big data traffic management in a vehicular ad-hoc network," International Journal of Electrical and Computer Engineering, Vol.11, No.4, August 2021, pp. 3483~3491, DOI: 10.11591/ijece.v11i4.pp3483-3491
[35] S. Ahn, J. Choi, "Internet of Vehicles and Cost-Effective Traffic Signal Control," MDPI-Sensors, vol.19, No.6, 2019, DOI: https://doi.org/10.3390/s19061275
[36] J.H. Gomez, J. D. Romo, R.S. Cebrera, A.P. de la Cruz, J.M. M. Molina, "Traffic Signal Control System Based on Intelligent Transportation System and Reinforcement Learning," MDPI-Electronics, vol.10, no.19, 2021, DOI: ttps://doi.org/10.3390/electronics10192363
[37] W-H Lee, C-Y Chiu, "Design and Implementation of a Smart Traffic Signal Control System for Smart City Applications," MDPI-Sensors, Vol.20, No.2, 2020, DOI: https://doi.org/10.3390/s20020508
[38] J. Alarcon, I. Balcazar, C.A. Collazos, H. Luna, F. Moreira, "User Interface Design Patterns for Infotainment Systems Based on Driver Distraction: A Colombian Case Study," MDPI-sustainability, vol.14, no.13, 2022, DOI: https://doi.org/10.3390/su14138186
[39] S. Reshma, C. Chetanaprakash, "Advancement in infotainment system in the automotive sector with vehicular cloud network and current state of the art," International Journal of Electrical and Computer Engineering, vol.10, No.2, pp.2077-2087, 2020, DOI: http://doi.org/10.11591/ijece.v10i2.pp2077-2087
[40] S. Reshma, C. Chetanaprakash, "Framework of Infotainment using Predictive Scheme for Traffic Management in Internet-of-Vehicle" International Journal of Advanced Computer Science and Applications (IJACSA), 13(4), 2022. http://dx.doi.org/10.14569/IJACSA.2022.0130473.
[41] S. Reshma, C. Chetanaprakash, "Novel Hybrid Architecture of Infotainment for Streaming Signals in Vehicular Network," Research Square, 16 March 2021, DOI: 10.21203/rs.3.rs-273846/v1.

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