

## Research Article

# A Traffic Density-Based Congestion Control Method for VANETs

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This research presents a vehicle ID-based congestion aware message (CAM) for beacon signals on the vehicle environment. At the MAC protocol of the vehicle environment, enhanced vehicle ID-based analysis model is given first. With the automobile ID embedded in their separate CAMs, the model weights the randomized back-off numbers chosen by cars engaging in the back-off procedure. This leads to identifying a car ID-based randomized back-off code, which reduces the likelihood of a collision due to the identical back-off number. A traffic density based-congestion control algorithm (TDCCA) is suggested in this research. The revised mathematical approach surpasses previous work's overall packet latency because just one-fourth of the congestion window is employed during the experiment. The research includes a congestion management method that adjusts the rate of CAM transmitted over the host controller to improve the efficiency of the model parameters. The method considers various circumstances, from nonsaturated to substantially saturated networks (in terms of congestion probability) and sparsely dispersed and teemed networks (in the form of vehicular intensity). The technique is run across various automobile ID-based back-off values for high-standard results analysis. The simulation outcomes in terms of packet delivery ratio, energy consumption, delay, success rate, and collision ensure the effectiveness of the TDCCA method. Even at high traffic densities, the automobile ID-based CAM following information method outperforms the typical fixed CAM frequency IEEE 802.11p, according to simulation findings for all back-off figures.

## 1. Introduction to Vehicular Environment

According to India's Department of Transportation and Highways research, 13 people are killed in road accidents per hour. According to statistics, over 3500 traffic accidents occur every day all through the globe [1]. Furthermore, according to the United Nations, India has the highest road mortality rate globally. The absence of sufficient information offered to the motorists is one of the key factors for this tragic situation [2]. This crucial challenge can be fixed if motorists or trucks are given relevant and complete information about nearby cars (i.e., CAM).

Vehicular ad hoc networks (VANETs) offer the foundation for increasing road security by making cars interact with one another via onboard components [3]. Dedicated relatively recent phenomenon governs this communication. Every vehicle

employs two types of communications for such safe driving implementations: CAMs and emergency-driven messaging (EDMs). These safety signals are sent out over the same control channel (CCH). The most popular message communication on the sole CCH is CAM distribution, which sends data streams about the transmitting vehicle [4]. Because CAM transmits information on the state of participating cars, these messages are transmitted regularly to maintain the network updated. As a result, these CAM statements occupy the majority of CCH. Furthermore, in high vehicle density, the automotive system is likely to become congested due to the large volume of traffic [5].

Congestion refers to a networked situation of message overflow. In other words, sending too much data through a network reduces networked efficiency. When a system is congested, the user's connected resource requirements are greater than the

network's set content [6]. Whenever a user's necessary network load exceeds the network's material and computational power, researchers often anticipate that the network lowers the user's customer service. This results in a higher risk of a datagram being lost and a corresponding rise in latency of datagram transmission, lowering system capacity [7].

The information transmitted between cars mostly includes traffic accidents, road problems, and vehicle reversing, and this data is referred to as network congestion of the vehicular network. The cache capacity of automobiles networks is 100 KB, and that load refers to the information stored in the cache of car nodes [8]. Whenever network traffic is low, the arrival rate of data on the web of cars increases exponentially, while the average amount of time keeps increasing. When the load is between  $a$  and  $b$ , the data arrival rate slowly increases, and the mean waiting for speed increases [9].

The network begins to drop packets when the load hits  $b$  and rises. When the load exceeds  $b$ , the data average throughput drops rapidly, and the average latency rises. As a result, it can observe that when working near point  $b$ , the connection of car load has better network resource use efficiency [10]. When the load exceeds point  $b$ , the internet of vehicles (IoV) experiences a networked bottleneck, resulting in a quick fall in the data exchange proportion and an increase in overall latency of data transfer. Whenever the cache size of a vehicle node exceeds 70 KB, traffic management should be initiated immediately [11].

The IEEE802.11p standard subcommittee is currently formulating certain standards to address the congestion problem in VANETs [12]. Only data with the greatest priority degrees can reach the circuit if the channel utilization percentage in the system is much more than 50%, and many other low-level data will be denied access. This traffic control strategy can help to alleviate congestion issues to some degree, but it comes with several drawbacks.

This paper's achievements can be summarised as follows.

- (i) A traffic path analysis and its road weights are computed to analyze the traffic congestion density
- (ii) After predicting the congestion in the vehicular environment, a congestion control method is suggested
- (iii) The simulation analysis of the proposed system is done by analyzing with different speeds, numbers of vehicles, and traffic densities

The rest of the article is organized as follows: Section 2 indicates the background to the vehicular communication models. The suggested traffic density based-congestion control algorithm (TDCCA) is designed and developed in Section 3. Section 4 illustrates the software outcome analysis and its outcomes. The conclusion and future scope are listed in Section 5.

## 2. Background to the Vehicular Communication Environments

Many scientists provided their proposals for a distribution method that uses appropriate algorithms. Certain algorithm features are dependent on the segmentation covering the

network region, where the cross-section area that makes up the network affects the distribution procedure and its effectiveness [13]. Different research has described these various strategies. Vehicle-to-vehicle situations generate a broadcasting storm in the planned safety data transfer approach, with a high density of cars sharing safety-related data over numerous hops [14]. All vehicles evaluate the digital information before distributing it to eliminate duplicate data transfer. Each vehicle's data should be private, with no knowledge about the driver's identity [15]. The payload overflow is reduced by using this technique of distribution.

The network discovery approach, which uses specially designed hello and synchronization packets to identify the target nodes, establishes the route before delivery. The entities are employed for a streamlined data collecting and modification method during the interaction [16]. Cognitive data are recommended for successful data distribution by attaining management over a few characteristics such as throughput, time, and push understand latency, among others. Vehicle to vehicle (V2V) compatibility across car manufacturers has been accomplished using standardized data protection protocols [17].

Substantial research has been done throughout time to improve the MAC layer efficiency of vehicle networks. Initially, Daneshgaran et al. developed a 2-dimensional Markovian approach to analyze the efficiency of the IEEE 802.11 MAC program's dispersed coordination functional (DCF) [18]. Furthermore, the Bianchi concept was expanded to investigate the performance factor of the IEEE 802.11 DCF in unbalanced conditions by 19. Duffy et al. [19] offer the first 3D Stochastic process models for IEEE 802.11 systems with a finite-length buffer. The Bianchi approach was recently employed for changing and measuring the effectiveness of the broadcasting methods of interaction in IEEE 802.11. Liu et al. present a multimedia architecture-based methodological approach to describe the periodic transmission of the signal transmitted on the CCH [20]. They also provide a CAM scheduling approach, namely, session expiry planning, for controlling CAMs transmitted over the CCH. Luo et al. investigate saturation performance using Doppler spread situations. Campolo et al. investigate the behavior of the broadcast technique in ad hoc wireless systems under saturation conditions [21].

Verma and Singh provide an analytical framework for highway applications considering specialized short-range connectivity communications indices [22]. By incorporating the concepts of steak and contact frequency in VANETs, Luo et al. propose a 2-dimensional mathematical framework for beaconing [23]. Ma and Chen offer a mathematical framework for 1-hop safety-critical signal broadcast via CCH using the access category (ACs) capability of enhanced dispersed channel allocation (EDCA) 802.11p [24]. Ma et al. suggest a computational framework formula built on the queuing system and randomized geometries for a more realistic approximation of actual network behavior [25].

Nevertheless, all of the calculations from Van Eenennaam et al. to Yao et al. imply that messages arrive in a Poisson point process, which is virtually impossible in an actual mobile environment because safety signals are broadcasted regularly over

the CCH system [26, 27]. Yang et al. provide a scientific model for the importance of this issue broadcast, employing the notion of the flexible congestion window (CW) in VANETs. Tong et al. ignore the control method for suspending the back-off time clock in the IEEE 802.11p MAC [28]. Yang et al. have demonstrated that the max CW length is tuned to optimize effectiveness depending on the traffic density [29]. Most of these studies used network throughput, end-to-end latency, and bandwidth as key metrics.

However, because safety signals like CAM permit broadcast connectivity, end-to-end interaction in VANETs is not assured. As a result, these measurements are no longer applicable to vehicle networks. As a result, for safety-related applications on VANETs, designing an effective strategy for frequent broadcasting for CAM is essential.

Various methods for congestion prevention and detection were studied in the past. The technology allows tracking and categorizing cars traveling in a certain direction, paving the door for more intelligent vehicular traffic administration throughout urban regions to help decongest their routes. Scholars developed a data and partly automated decision-based vehicle network to prevent traffic congestion in metro regions.

The suggested algorithm can recognize and localize locations with significant traffic that cause congestion and compute a capacity enhancement strategy at an early stage overcrowding in the kill zone. Balid et al. focused on a vehicle fleet control system that included road incident monitoring [30]. This model is based on data gathered by vehicle sensors, which are also utilized to create an opportunist fleet, a localized automotive mesh (or a half-mesh). The detection method comprises a variety of events like stop and restart to control the motion of following cars in a cluster and assist them in taking the quickest action to prevent traffic risks [31].

Rajput et al. have worked on developing dynamic redirection to escape various risks and roadblocks [32]. The directional-based hazardous routing protocol uses a distributed data network between vehicles driving on a certain route or to a specific destination. Various obstacles and risks are identified as occurrences, like flash floods, tree breaking, land slipping, and collisions. Correct measures are performed for the cars, which are rerouted to escape the current scenario [33]. The current study presents an enhanced automobile ID-based statistical model in light of the preceding. Furthermore, the suggested approach is utilized over the conventional model parameters to correctly pick the CAM rate, based on the program's requirements, to provide increased connection speeds even in saturation.

### 3. Proposed Traffic Density-Based Congestion Control Algorithm

Vehicular ad hoc networks allow cars to interact with one another, providing crucial information such as traffic jams and disasters and assuring rapid reaction. Vehicles are part of the traffic radio system, including OBUs (onboard units), vehicle-to-vehicle connectivity, vehicle to roadside unit (RSU) interaction, and RSU-to-cloud interaction. The suggested model relies on a congestion obstacle avoidance concept to pre-

vent traffic delays caused by accidents, road degradation, avalanches, and other natural disasters.

The work processes of the TDCCA method are depicted in Figure 1. The congestion in the vehicular environment is identified by utilizing the channel condition. The load in the channel is estimated, and the congestion is identified; after that, the condition is sent to the nearby users to alert them about the congestion. If traffic is detected using the vehicle congestion index (VCI), data can be transmitted with other cars and the RSU. A rerouting system checks other routes possible based on the residual number of accessible roadways depending on this constraint. The data is then sent to the other cars, who must reroute per the best course. Vehicles are used to gather traffic data, and VCD is used to locate traffic (a high density of vehicles). Path weight computation (PWC) is used to calculate road levels to get updated values for determining the best path for cars.

*3.1. Methodology.* The mathematical expressions and methods are given in the following subsections. With the numerous phases, the approach is characterized. In step one, the automobile is initialized, establishing the numerous attributes needed to identify the vehicle, such as the car's, departing location, lane id, and highway id. The car's data is acquired in step two, including parameters such as the vehicle's maximum pace, emission statistics, and fuel usage. Step three: road surface parameters and vehicle status, traffic circumstances are examined, including road measurements such as diameter and thickness, the amount of vehicular congestion, or other congestion circumstances. The vehicle traffic index algorithm determines the amount of congestion, which might be low, medium, or extreme. Step four: transportation analysis is described as predicting road congestion. If congestion is detected, step five activates the traffic monitoring system, which informs the vehicle about the best route to take in the event of traffic. To explain mathematics, many concepts have been utilized.

#### (i) Vehicle initialization

Every vehicle is given a unique vehicle identifier ( $V_x$ ) used to locate the truck on the road. In this case, the TDCCA method captures vehicle data such as the car's current location, destination choices, and location data. Originally, the car follows the predetermined course.  $V_x, R_x, D_x$  are vehicle attributes that can be specified as the vehicle id, road id, and data-id. The identity of the highway on which the car travels is defined by the raid. The lanes upon which a car departs and arrives, as well as the location of its arriving and departing, are defined by  $P_1$  and  $P_2$ , while  $S_a$  and  $S_d$  denote arriving and departing speed.

#### (ii) Vehicle data collection

As automobiles travel down the highway, the TDCCA method gathers operational data from sensors installed on the automobiles, such as mean average pace ( $S_m$ ), mean transit times ( $T_m$ ), fuel usage rate ( $F_u$ ), and vehicular exhaust emissions value ( $E_{em}$ ), which includes  $CO_2$ , CO, and  $NO_x$  value systems. The gases emitted by automobiles

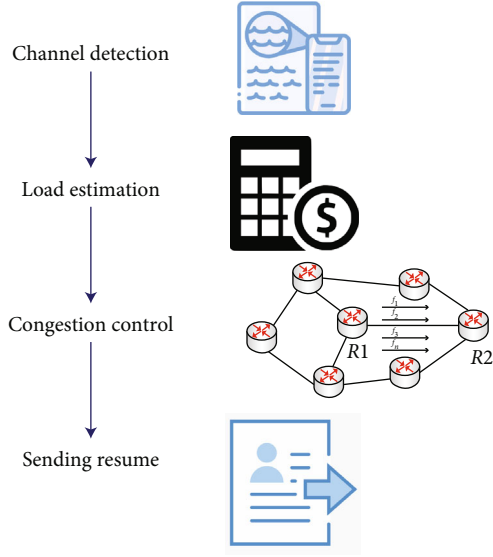


FIGURE 1: The work process of the TDCCA method.

aid in determining the present condition of pollutants on a certain stretch of road.

The communication model of the vehicular environment is shown in Figure 2. The vehicles in the VANET environment are identified as  $V_1, V_2, \dots, V_n$ . The communication range of a vehicle is shown in the figure. The vehicles can communicate with nearby vehicles when they are in the communication range, and they will frequently communicate with RSU.

### (iii) Assessment of traffic conditions

To assess the congestion situation, the TDCCA method employs a multimetric variable system that comprises multiple elements of inclusion such as lane width ( $R_w$ ), road lengths ( $R_l$ ), car width ( $V_w$ ), and vehicle lengths ( $V_l$ ). A report is prepared following categories described as a road traffic analysis for  $n$  amount of vehicles on a certain road section  $R_s$  is the concatenation of all variables. The data from the car traffic reports are communicated with all cars and RSU just on a specific major road.

The average speed of an automobile on a certain road section is computed to establish the road traffic ratio, and it is expressed in the following equation.

$$S_m = \frac{1}{m} \prod_{x=0}^m V_x. \quad (1)$$

The number of cars is denoted  $m$ , and the speed of every vehicle is  $V_x$ .

The vehicle volume was determined using Equations (2) and (3) on a certain road length.

$$\prod_{x=0}^m B_x + D_x, \quad (2)$$

$$\prod_{x=0}^m L_x + \prod_{y=0}^m \frac{1}{D_y}. \quad (3)$$

The gap among the cars is  $D_x$ , and the length among the automobiles is  $D_y$ . The length of the road is denoted  $L_x$ , and the path weight is denoted  $B_x$ .

The congestion situation is computed in 2 directions:

- (i) *Bottleneck Condition*. This situation arises when a section of road (width) is occupied by many cars that wish to pass through it. The bottleneck condition is denoted in the following equation

$$\sigma = \frac{\prod_{x=0}^m B_x + D_x}{B_r + 1}. \quad (4)$$

The path weight is denoted as  $B_x$ , and the road weight is denoted  $B_r$ . The distance between the vehicles is denoted as  $D_x$ .

- (ii) *Accidents or Jam Situation*. A traffic process can be characterized as one that happens as a result of an incident or any form of traffic snarl that can develop on the highway in the past 300 seconds. The accident condition is denoted in the following equation

$$\rho = \frac{\prod_{x=0}^m R_l(x) + D_x}{(V_l + 1) \times m}. \quad (5)$$

Here,  $\sigma$  and  $\rho$  are two activities that determine traffic congestion total width and duration of the highway. The road length is denoted  $R_l(x)$ , the vehicle length is denoted  $V_l$ , the distance between vehicles is expressed as  $D_x$ , and the total number of vehicles is denoted as  $m$ .

The expected time transit of an automobile on a certain section of road is determined using the following equation.

$$D_x = \frac{R_y^l}{V_y^s}. \quad (6)$$

The vehicle traveled path is denoted  $D_x$ .  $R_y^l$  denotes the lengths of a road ( $R$ ) and its highway segment ( $y$ ).  $V_y^s$  is the heavy vehicles speed that is obtained on road network  $y$ . The total time it takes a vehicle to go from point A to point B using various roadways is computed using the following equation.

$$T_{tot} = \sum_{x=0}^n \sum_{y=0}^n T_{\text{path}}(x, y), \quad (7)$$

where  $T_{tot}$  denotes the number of surviving roads, and  $n$  indicates the probability of segments separated on the route cars travel. The path traveled by the vehicle is denoted  $T_{\text{path}}(x, y)$ .  $T_{tot}$  is the total time of the vehicle that is

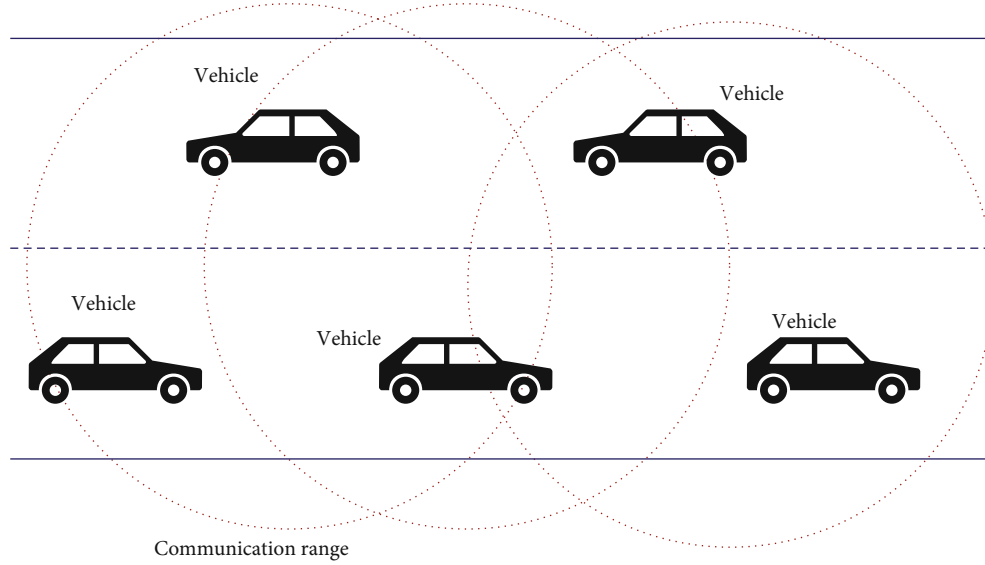


FIGURE 2: The communication model of the vehicular environment.

Gather the inflow and outflow traffic  
 Estimate the number of vehicles  
 Compute mean length and width of vehicles  
 Compute the road dimension  
 Compute congestion if  $R_l < \prod_{x=0}^m V_w + D_x$   
 Compute congestion if  $(V_l + 1) \times m < \prod_{x=0}^m R_l(x) + D_x$   
 Compute congestion if the travel period is greater than the expected period  
 Compute  $T_{path}/T_{tot}$   
 Monitor traffic evaluation area  $S_{TEA}$   
 Compute the vehicle congestion density (VCD)

ALGORITHM 1: Congestion detection

computed using the following equation.

$$T_{tot} = \frac{R_y^l}{V_y^k}. \quad (8)$$

$V_y^k$  denotes the traffic density as measured during transit.  $R_y^l$  denotes the lengths of a road ( $R$ ) and its highway segment ( $y$ ). The transit time is expressed in the following equation.

$$\vartheta = \frac{\sum_{x=0}^n \sum_{y=0}^n T_{path}(x, y)}{\sum_{x=0}^n \sum_{y=0}^n T_{tot}(x, y)}. \quad (9)$$

The path of the vehicle is expressed as  $T_{path}(x, y)$ , and the total available path is expressed as  $T_{tot}(x, y)$ . The total number of vehicles in the vehicular network is denoted as  $n$ . It estimates the projected transit time for an automobile and the real transit times for a specific route. The real trip time is calculated using a stopwatch. Fuel usage on a major

roadway and section is computed using the following equation.

$$G_c = \sum_{x=0}^n \sum_{y=0}^n \frac{Q_y}{U_x}. \quad (10)$$

$G_c$  denotes fuel usage rate,  $Q_y$  denotes motor fuel usage per units hour (kg/h), and  $U_x$  denotes speed limit in kilometres per hour.

#### (iv) Road congestion assessment

The TDCCA method calculates three variables for determining traffic nations:  $\sigma$ ,  $\rho$ , and  $\vartheta$ . The scenarios in the TDCCA method are meant to analyze traffic jams. The gathered data is sent to RSU nodes that analyze the traffic situation in a designated region known as a (transport evaluation area) TEA.

*Case 1.* Network congestion whenever the physical size is equal to which is less than the number of vehicles moving

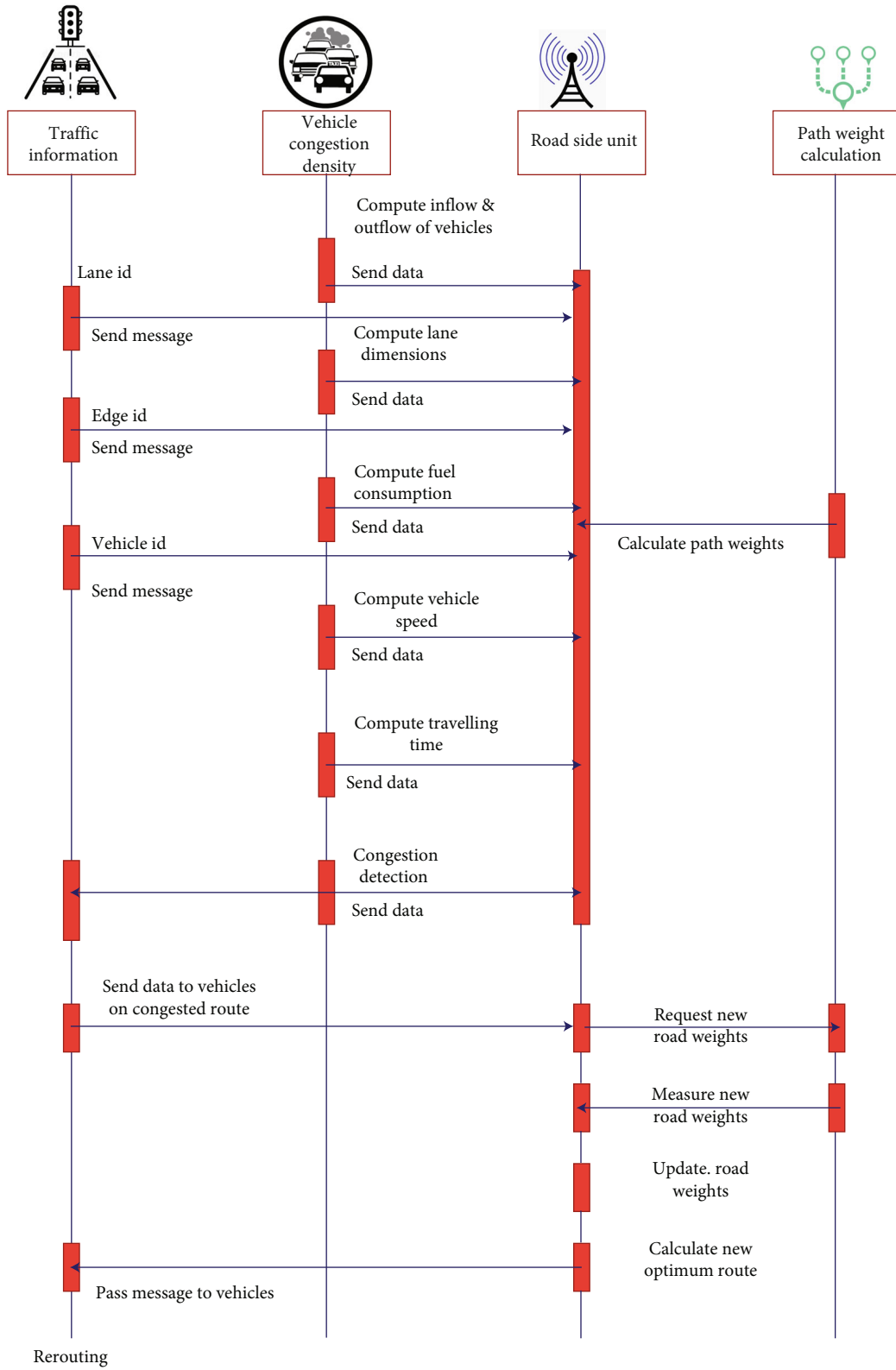


FIGURE 3: The communication model of the TDCCA method.

TABLE 1: Simulation parameters.

Parameter	Value
Number of channels	3
Queue size	1000
Arrival rate	Poisson
Communication distance	600 m
Congestion window	512
Slot period	12 us
Propagation delay	1 us
Simulation time	600 seconds

through the route segment. This situation is expressed in the following equation.

$$S_{TEA} \left( \sigma \leq \frac{\sum_{x=0}^m (V_w + D_x)}{B_r} \right). \quad (11)$$

The vehicle width is indicated as  $V_w$ , the gap between the vehicles is denoted as  $D_x$ , and the weight parameter of the road is denoted  $B_r$ . The bottleneck parameter is indicated as  $\sigma$ .

*Case 2.* Due to a collision or heavy traffic, the whole length of the highway is filled by cars in a single lane. This condition is expressed in the following equation.

$$S_{TEA} \left( \rho \leq \frac{\sum_{y=0}^m (V_l + D_y)}{(V_l + 1) \times m} \right). \quad (12)$$

The length of the vehicle is denoted as  $V_l$ , the gap between the vehicle is expressed as  $D_y$ , and the total number of vehicles is denoted as  $m$ . The CAM parameter is expressed as  $\rho$ .

*Case 3.* When the expected transit time of cars is shorter than the real driving time on the path, traffic is present. This condition is expressed in the following equation.

$$S_{TEA} \left( \vartheta \leq \frac{\sum_{x=0}^n \sum_{y=0}^n T_{path}(x, y)}{\sum_{x=0}^n \sum_{y=0}^n T_{tot}(x, y)} \right). \quad (13)$$

The path of the vehicle is expressed as  $T_{path}(x, y)$ , and the total available path is expressed as  $T_{tot}(x, y)$ . The transit time is expressed as  $\vartheta$ . Algorithm 1 for determining vehicle flow volume and detecting traffic is described.

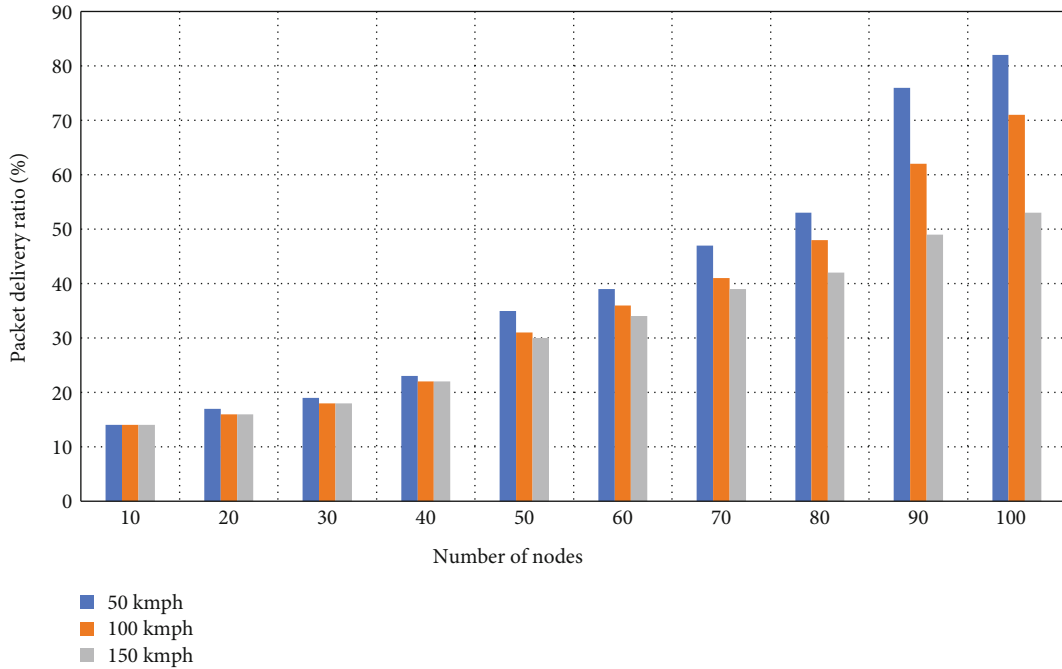
**3.2. Multiagent System.** In this research, almost all network participants, namely, the origin, drain, and connections in a network, are equipped with an embedded platform capable of storing Global Positioning System (GPS) locations and analyzing sensor-generated vehicle design data. Every vehicle has an  $R$ -radius transmission distance. The module includes the stationary agent, the distributed application, and the knowledge bases, which identify dependable far-

end locations at various logical sections as intermediary nodes for the propagation of safety data.

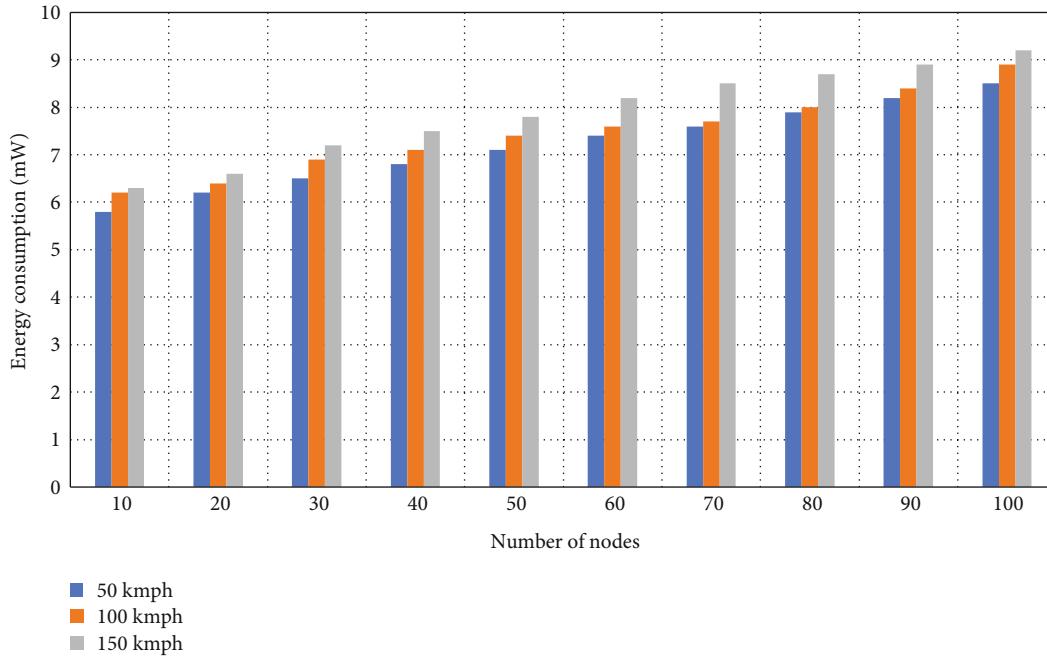
- (i) *Knowledge Base.* This is the state's centralized repository for storing sensor-generated information recorded by multiagents. It stores information such as packets time to live (TTL) number, GPS locations, traffic volume and road surfaces, network power, node identification with sequence digits, continuous movement, and a small number of preencoded security warnings
- (ii) *Vehicle Management Agent.* It creates the information in the skill set, which can then trigger the next phase. It is a stationary agent tasked with locating the appropriate distant far-end nodes in each logical segment. This job is carried out in collaboration with the next phase. If it cannot locate the far endpoint vehicles in the conceptual section within the allotted TTL length; then, the TTL expires, triggering the next phase for the newest plate number. Then, it assists the data signal with channel congestion and seeks intensely for a network in the region of interest that is regarded as a trustworthy indirect route to execute
- (iii) *Far End Node Selection Agents.* This is a mobile representative that travels to all nodes to collect vehicle design data and submit this to the first agent. It is prompted anytime there is a substantial change in the system, and it coordinates to refresh the skill set per each trigger concerning far end node capability

The following is the suggested system's functional sequence. (1) Agent establishes and implements a national database or skill set on the connected path's transmitting data, and agent updates relative differences along the real axis. Agent activates next phase, which travels in or out of linked segments to choose the best far ending node for the given location services of GPS. (2) The region of interest (ROI) vehicle is equipped with time to live, geolocation, and movement characteristics. The node's automobile movement and velocity metrics assist in selecting a relaying option. (3) The agent is a mobility agent that uses the broadcasting network to visually travel about the linked topology, updating the skill set. (4) The resource examines the knowledgebases, which are only responsible for disseminating prepared code words with low network activities to meet a reduced end-to-end latency.

**3.3. Congestion Control Mechanism Optimization System.** The technique used in this work is an active congested means of control to prevent channel congestion by using an acceptable protocol. It depicts the congested control structure, divided into four sections: channel identification, load estimate, congestion management, and sending recovery. Initially, every vehicle senses local channels load  $L$  with a recognizing interval of  $T$ . When the discovering intervals are over, every vehicle calculates target channel loading  $L_{tr}$ , and the interval is based on sensor local broadcast load  $L$  for the next detection. The traffic control approach then



(a)



(b)

FIGURE 4: (a) Packet delivery ratio analysis of the TDCCA method. (b) Energy consumption analysis of the TDCCA method.

ensures that channel load does not exceed the expected total channels load  $L_{tr}$ . Lastly, nodes that defy the congestion control technique must restore transmitting.

The communication model of the TDCCA method is expressed in Figure 3. The traffic information, vehicle congestion density, roadside unit, and path weight computation modules are present in the proposed system, and these modules are interconnected with each other to effectively analyze the congestion in the vehicular environment. Because

unconsumed capacity at a node is specified as locally accessible capacity, every node estimates its local materials frequency band by passively watching network events. The method leverages the percentage of idle channel time previously to indicate a node's local raw capacity. This strategy appears too hopeful since it ignores two factors: because of the back-off technique in 802.11, part of the downtime could be exploited; second, when networks demand grows, the bandwidth spent in conflict arise. Authors proved that when



TABLE 2: Packet delivery ratio evaluation of the TDCCA method.

Number of nodes	50 kmph	100 kmph	150 kmph
10	14	14	14
20	17	16	16
30	19	18	18
40	23	22	22
50	35	31	30
60	39	36	34
70	47	41	39
80	53	48	42
90	76	62	49
100	82	71	53

the channel is overloaded, the quantity of downtime and incident time for 802.11p is insignificant.

As a result, estimating locally available capacity using the proportion of idle channels time may be straightforward and precise. A node's connectivity can be seen as one of four states: sending, getting, noisy, or idle. In the chaotic condition, a node detects a busy transport but cannot decipher the message's contents. The locally accessible capacity for a node is determined by observing the time taken in various states. The total period is expressed in Equation (14), and the available bandwidth is expressed as  $BW_{av}$  and indicated in Equation (15).

$$P = P_{tr} + P_{rc} + P_{no} + P_{id}, \quad (14)$$

$$BW_{av} = \frac{P_{id}}{P} \times C_C. \quad (15)$$

$P$  stands for total time,  $P_{tr}$  for transmission time,  $P_{rc}$  for receiving time,  $P_{no}$  for noise time,  $P_{id}$  for idling time,  $C_C$  for data transmission, and  $BW_{av}$  for available channel capacity. The frequency prediction can be reduced to represent the long-term demand to use a modified time series to remove the influence of transitory fluctuations in bandwidth estimations.

Then, it constructs the congestion level indication, which is represented by the following equation.

$$C_C = \begin{cases} \frac{BW_c}{BW_{av}} & BW_{av} > 0, \\ \text{Maximum} & \text{else.} \end{cases} \quad (16)$$

$BW_{av}$  refers to the road's useable bandwidth. The channel bandwidth is denoted as  $BW_c$ . The lesser the traffic ratio, the lower the congested degree, and the greater the relaxation extent of the route. The greater the traffic degree, the more competition there is, and the greater the congested rate.

**3.3.1. Congestion Control Algorithm.** When there is a low vehicle traffic concentration and a rapid vehicle velocity, the maximum frequency of the signal transmitted sent, the quicker the car's state data is provided. Automobile users

can grasp the local traffic conditions more quickly and precisely. However, when there is a large vehicle flow concentration, and the vehicle velocity is moderate, the car condition happens slowly. A decreased beacon frequency can also provide timely and exact mastery of neighboring vehicle condition data. Thus, in high vehicular traffic density, the free channels welcome new customers by lowering beacon frequencies, so avoiding congestion issues.

When automobile users adjust the rate at which beacons are produced, the slot is allocated again in the temple area. Comparing is hard to do, particularly in distributors that are nearing completion. Because VANET is a dispersed self-organized network with no central planning, every beacon period fluctuates, making the redistribution of channels unfeasible. When the beacon frequency must be decreased, the basic standard frequencies are assured. Each automobile maintains one or more periodicities in a one-second ten periodicity. It results in more car drivers, equivalent to the usual beacon rate.

To ensure people's lives, it regulates the regularity of beacons to alter the number of participants that can be tolerated in the network and the reliability of messaging. The frequencies of transmitting beacon in 1 second are  $fr$ , and the effective reception rates of every signal are  $bc_{ss}$ . The probability of getting  $x$  beacon is denoted in the following equation.

$$\Pr^x = \frac{C_{fr}^x bc_{ss}^x}{(1 - bc_{ss})^{fr-x}}. \quad (17)$$

The channel capacity with frequency is denoted  $C_{fr}^x$ , and successful reception of the signal is indicated as  $bc_{ss}^x$ . The channel frequency is indicated as  $fr$ . The likelihood of receiving at least  $n$  beacons is then denoted in the following equation.

$$\Pr_n = 1 - \sum_{x=0}^{n-1} \Pr^x. \quad (18)$$

The quantity of  $bc_{ss}$  is controlled by the network's congestion state, basic structure, and transmitting distance, among other factors. The probability of getting the  $x$  beacon is indicated as  $\Pr^x$ . The level of cybersecurity is measured by  $\Pr_n$ . When changing  $fr$ ,  $bc_{ss}$ , and  $n$ , it requires a minimum criterion. The probability of securely receiving the beacon is expressed in the following equation.

$$\Pr_n = 1 - \sum_{x=0}^{n-1} \frac{C_{fr}^x bc_{ss}^x}{(1 - bc_{ss})^{fr-x}}. \quad (19)$$

The channel capacity with frequency is denoted  $C_{fr}^x$ , and successful reception of the signal is indicated as  $bc_{ss}^x$ . As a result, the traffic control scheme is divided into four stages:

There is still open channel capacity when the vehicular traffic density is low  $\gamma = 0$ , and the speed limit is rapid.

The amount of channel tools available is insufficient to keep up with the rising vehicle traffic intensity. Set  $\gamma = 1$  and modify the power such that  $bc_{ss}$  meets Equation (19).

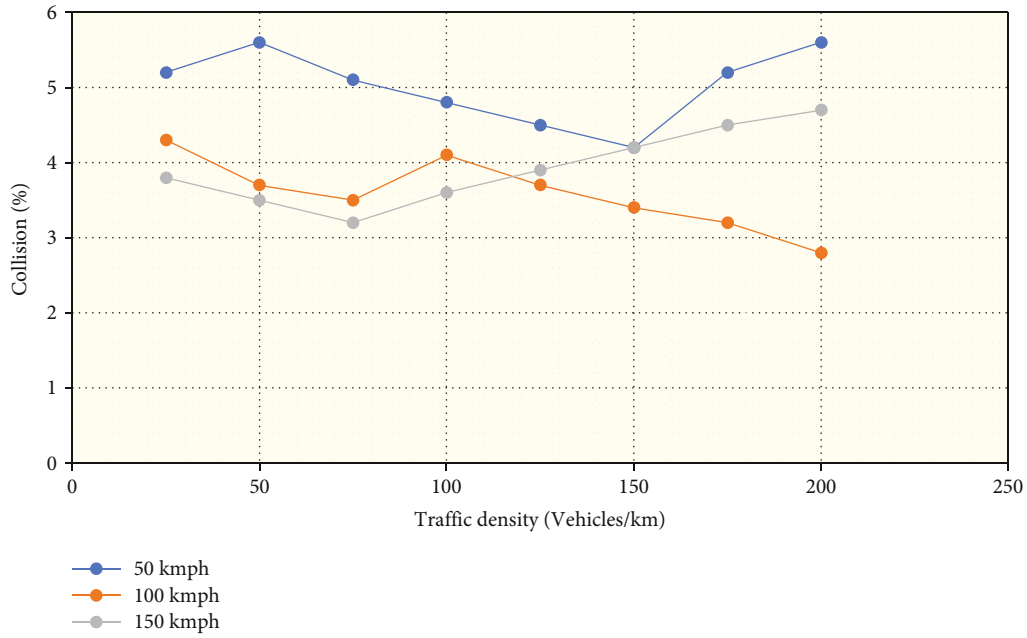


FIGURE 5: Collision analysis of the TDCCA method.

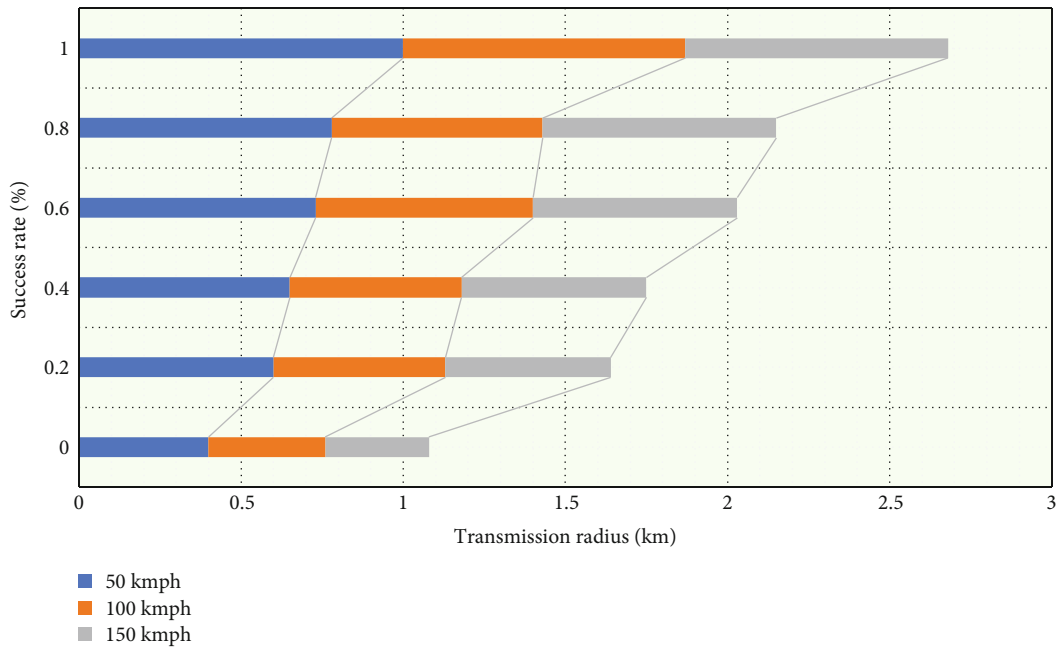


FIGURE 6: Success rate analysis of the TDCCA method.

It becomes more incompatible as vehicle traffic density increases. Adjust the voltage such that  $bc_{ss}$  meets with order  $y=2$ .

Whenever vehicle traffic density rises,  $bc_{ss}$  is unable to cut beacon frequencies anymore and hence it is violated. It must use the power management approach to avoid the communication scope of the automobile and prevent congestion.

3.3.2. *Sending Restoration Messages.* When certain network nodes refuse to understand the strategic congestion plan, they must begin delivering recovery strategies for the system to return to normal. When ensuring the performance of a congestion management system, the transmitting restoration approach is commonly utilized. When certain nodes refuse to understand congestion management mechanisms for various reasons, channels might get congested and encourage

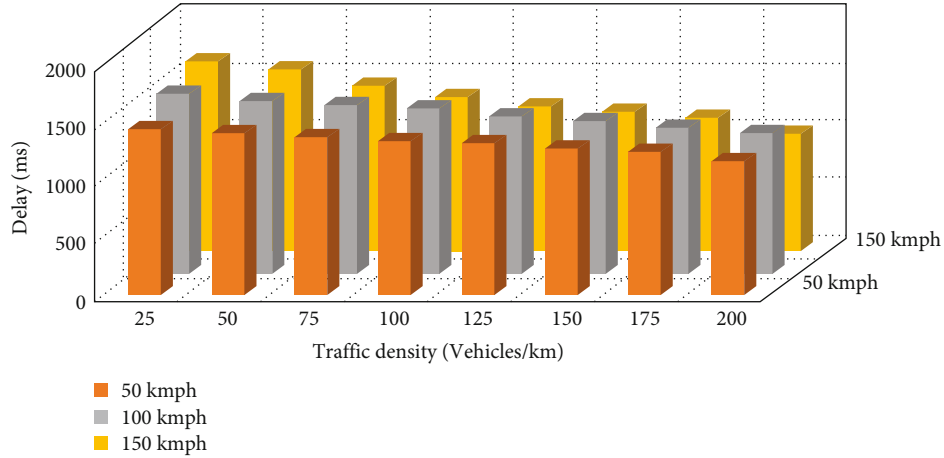


FIGURE 7: Delay evaluation of the TDCCA method.

TABLE 3: Delay analysis of the TDCCA method.

Traffic density (vehicles/km)	50 kmph	100 kmph	150 kmph
25	1432	1543	1653
50	1398	1487	1575
75	1365	1453	1432
100	1323	1421	1343
125	1310	1354	1254
150	1265	1321	1212
175	1232	1254	1154
200	1154	1213	1021

TABLE 4: Simulation analysis of the TDCCA method.

Method	Throughput (kbps)	End-to-end delay (ms)	Packet delivery ratio (%)
Newreno	1452	76.3	85.7
Veno	1864	68.5	78.5
Vegas	2312	45.5	81.4
Westwood	1646	38.6	84.5
Compound	2123	41.3	90.4
Cubic	1985	62.4	89.4
TDCCA	2543	39.5	92.3

secure data collision, resulting in a reduction in traffic surveillance. To avoid the issues above, transmitting restoration following flow control is required to guarantee that the network remains in a resting condition. The goal of sending messages is to compel all cars to adhere to a traffic-control scheme.

TDCCA method is designed and implemented in this section with congestion-aware messages and traffic density-based congestion control methods. The congestion and traffic density are identified based on the number of vehicles and channel capacity of the vehicular environment. The simulation outcomes of the TDCCA method are evaluated and analyzed in the next section.

#### 4. Simulation Analysis and Performance Analysis

This article constructed a movement pattern to replicate car behaviors on the highway to assess our model's effectiveness. The C++ developer program is used to build and test this movement pattern and its related properties. Events are recorded for various node densities and available resources during the messages contained. It uses three tiers of mobility indicators to assess the dissemination technique under varied scenarios. Lastly, every vehicle is outfitted with an organization scheme that allows for creating a database that is used to make decisions at handoff at ROI areas. In this part, the suggested scheme's outcomes are illustrated and described under controlled settings of typical traffic. The efficiency is enhanced by the built-in emergency message and far-end cluster connection. The simulation parameter is denoted in Table 1.

The simulation parameters used for the analysis of the TDCCA method are denoted in Table 1. The number of channels for the vehicular node is used as three. The congestion window size is considered as 512, the propagation delay is denoted 1 $\mu$ s, the total simulation time is considered as 600 seconds. The communication range of a vehicle is considered 600 m, and the arrival rate of the traffic is considered as poisson. These parameters are used in addition to the Nakagami propagation model for the vehicular environment.

The packet delivery ratio and energy consumption analysis of the TDCCA method are shown in Figures 4(a) and 4(b). The simulation analysis of the TDCCA method is done by varying the number of nodes from a minimum of 10 nodes to a maximum of 100 nodes with a step size of 10 nodes. The vehicle speed is varied from 50 kmph to 150 kmph. As the vehicle speed increases, the TDCCA method outcome decreases. Because the highest speed leads to shifting more coverage area in a small time which will result in connection failure. The highest number of nodes in the environment enhances the connectivity between vehicles using vehicle-to-vehicle communication.

Table 2 indicates the packet delivery ratio evaluation of the TDCCA method. The simulation analysis of the TDCCA

method is analyzed by varying the number of nodes and speed from a smaller to a higher size. As the number of nodes increases, the connectivity increases, and when the speed of the vehicle in the vehicular environment increases, the respective connection failure occurs, which leads to poor system performance. The TDCCA method with the proposed congestion control mechanism ensures the higher packet delivery ratio of the system.

The collision analysis of the TDCCA method is shown in Figure 5. The traffic density of the vehicles is varied from 25 to 200 vehicles at the same time with an incremental size of 25 vehicles. As the traffic density increases, the possibility of collision also increases. The increased number of collisions leads to poor performance because of the higher possibility of link failure and higher packet drops. The TDCCA method increases the throughput with a better congestion control mechanism.

The end-to-end delay analysis of the TDCCA method is tabulated in Table 1. The simulation analysis of the TDCCA method is done by considering vehicle speed at different rates and varying the traffic density from 25 vehicles/km to a maximum of 200 vehicles/km. The delay is computed as the difference of receiving time to packet sent time. Due to the higher traffic density, the end-to-end delay increases. The end-to-end delay increases when the vehicle speed increases. The higher traffic density and vehicle speed lead to higher packet drop probability which results in poor performance.

The success rate analysis of the TDCCA method is represented in Figure 6. The transmission radius of the vehicles is varied from a minimum level to a maximum level. The simulation outcomes are measured with different transmission radii and different vehicle speeds. The simulation results indicate that the transmission radius and success rate are directly related, and vehicle speed and success rate are indirectly related to each other. The TDCCA method ensures a higher success rate with the congestion control algorithm.

The delay evaluation of the TDCCA method is displayed in Figure 7. The traffic density and vehicle speed are varied and the respective end-to-end delay of the TDCCA method is computed and plotted. The TDCCA method produces less end-to-end delay with an optimized congestion control algorithm. The traffic density and vehicle speed directly affect the end-to-end delay. As the density and vehicle increases, the possibility of packet drop and route failure occurs which results in lesser performance.

Tables 3 and 4 indicate the simulation analysis of the proposed TDCCA using network simulator 2. The simulation outcomes of the TDCCA are evaluated, and the outcomes in terms of throughput, end-to-end delay, and packet delivery ratio are measured. The proposed TDCCA results are compared with the standard congestion control models like Newreno, Veno, Vegas, Westwood, Compound, and Cubic. The traffic density-based congestion control model reduces the packet drop and thus enhances the overall throughput and packet delivery ratio.

The proposed method has 75%, 36%, 10%, 54%, 20%, and 28% improvement in throughput (kbps) and 7.7%, 17.6%, 13.4%, 9.2%, 2.1%, and 3.2% improvement in packet delivery ratio compared to Newreno, Veno, Vegas, Westwood, Compound, and Cubic, respectively.

The TDCCA method is designed, analyzed, and evaluated in this section. The suggested system with an optimized congestion control algorithm based on traffic density ensures higher simulation outcomes. The simulation outcomes in terms of packet delivery ratio, energy consumption, delay, success rate, and collision ensure the effectiveness of the TDCCA method.

## 5. Conclusion and Future Scope

The research offers a traffic density-based congestion control method based on vehicle ID to enhance a vehicle environment's efficiency. The main idea is to combine every vehicle's randomized back-off number (determined during channel evaluation) with their unique vehicle ID. This guarantees that each car chooses a better pseudorandom back-off value. As a result, the model greatly reduces the likelihood of many cars picking the same back-off value. Furthermore, the suggested model does not use zero as the arbitrary initial back-off value. Simulation findings demonstrate that the designed model requires a fourth of the congestion window length and outperforms previous work on overall packet latency and collision frequency. Furthermore, as previously indicated, 120 milliseconds is the minimum permissible latency for safety-related single-hop communications. The suggested model has an average latency of 0.8 milliseconds, which is 250 times smaller than the allowable latency for safety-related single-hop communications. The research introduces the TDCCA method to increase the effectiveness of the suggested model parameters. The model uses the likelihood of CAM signals colliding as a regulatory element in determining the optimum CAM rate. The simulation outcomes in terms of packet delivery ratio, energy consumption, delay, success rate, and collision ensure the effectiveness of the TDCCA method. Even now, in high-saturation conditions, this greatly reduces traffic. In the VANET system, the suggested CAM speed adaptation-based 1-dimensional mathematical model is optimized to enhance MAC and connection layer efficiency. The proposed system has a higher computation time because the system needs to analyze the traffic every time. The complexity can be reduced by using simplified traffic computation models.

## Data Availability

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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