IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received February 16, 2021, accepted March 24, 2021, date of publication April 6, 2021, date of current version April 16, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3071349

Cellular V2X With D2D Communications for Emergency Message Dissemination and QoS Assured Routing in 5G Environment

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ABSTRACT Cellular Vehicle to Everything (C-V2X) in 5G communications has attracted researchers' attention due to advantages such as higher throughput, data rate and lower delay, etc. However, achieving Quality of Service (QoS) in disseminating emergency messages is a challenging task due to frequent topology changes and concurrent link losses between vehicles. To address this issue, we propose the QoS guaranteed Routing and Emergency message Dissemination in Device-to-Device(D2D) communication (Q-REDD) assisted C-V2X. Primarily, we perform Stable Matching based Routing that assures low end-to-end delay via selecting the best forwarder. The Q-REDD method adopts the Enhanced Sphere Decoder Like (ESDL) algorithm to select the best device for establishing effective D2D communication in the C-V2X environment. If the requested content is not present in the nearby device, the discoverer device requests a 5G base station through a nearby pedestrian. To reduce broadcast storms, Q-REDD performs Chaotic Crow Search Algorithm (CCSA). To validate the performance of Q-REDD, we perform simulations on Omnet++ 4.6 and SUMO 0.21.0 simulator in terms of Packet Delivery Ratio (PDR), End to End delay, Throughput, and Emergency Information Coverage. The obtained results demonstrate that our method enhances the Throughput and PDR up to 30%, reduces End to End delay by 30%, and enhances Emergency Information Coverage by 23%, compared to the existing methods; GTLQR, GPSR, MIR, ETD^2, ALQ and TBED.

INDEX TERMS Cellular V2X, stable matching-based routing, sphere oriented D2D communication, enhanced sphere decoder like algorithm, optimization-based emergency dissemination.

I. INTRODUCTION

Vehicular Adhoc NETwork (VANET) is a growing field of research owing to the increase in the number of vehicles and demand for effective communication [1]. There are two types of vehicle communication in VANET, Vehicle to Vehicle (V2V), and Vehicle to Infrastructure (V2I) communication [2]. V2I communication is a feasible solution in the absence of V2V communication; however, its performance depends on wireless technology [3].

To mitigate this limitation, V2X communication is developed as a complete solution to capture the scalability, connectivity, and efficiency of the vehicular network [4]. V2X communication supports various vehicular applications. It facilitates diverse vehicular communication modes, including V2V, V2I, Vehicle to Pedestrian (V2P), and Vehicle to Network (V2N) [5].

The associate editor coordinating the review of this manuscript and approving it for publication was Guangjie Han.

With respect to road safety, high data transmission and network communications, C-V2X has evolved as a new paradigm [6]. C-V2X in 5G communication enables efficient data delivery, high reliability, and low latency for various C-V2X services and applications [7]. The dynamic nature of vehicular nodes, and the unstable communication link between vehicles, induces a high risk in routing, leading to a reduction in the QoS [8].

Various routing schemes are introduced in vehicular networks, including Bio-Inspired Routing [9], Ad-hoc On-demand Distance Vector AODV based routing [10], and Greedy Perimeter Stateless Routing (GPSR) [11]. These are all traditional routing protocols with issues such as being time-consuming and having a concurrent loss of the link. To reduce the delay during a vehicular conversation, D2D communication is introduced in the V2X environment [12].

Sphere Decoder Like (SDL) algorithm is used to establish D2D communication in a cellular network [13]. Here, the sphere is formed around the discovered device for D2D communication. Adaptive link ability-based D2D communication is established in the C-V2X environment [7], [49].

Emergency message dissemination is significant in a vehicular network to preserve the vehicle's safety in a C-V2X environment [14]. A coordination-free, emergency message dissemination protocol is used to disseminate an emergency message to neighboring vehicles [15]. The Adaptive Probability Dissemination Protocol (APDP) is used to disseminate emergency messages to neighboring vehicles based on the probability value [16], [50], [51].

Considering the studies mentioned above, the C-V2X environment still has several issues regarding the performance of routing, D2D communication, and Emergency dissemination. These issues are listed as follows:

- High mobility is a major problem in incorporating D2D communication in the C-V2X environment.
- Achieving high QoS in urban-based C-V2X is difficult due to the high density of the vehicle.
- Routing in C-V2X leads to high packet losses, high delays, and frequent link losses due to a lack of optimum parameter consideration while selecting the path.
- Best disseminator selection is necessary to avoid broadcast storms while disseminating the emergency message.

Based on the above-listed issues in D2D assisted C-V2X, this paper's contributions are presented in the following sections.

A. MOTIVATION

V2X exhibits poor QoS performance in high-density scenarios with packet collision. For example, video transmission can be predisposed by rains, fog, illumination variations, and moving shadows. Similarly, Inductive Loop Detectors have a high failure rate, the wires often break due to dilatation as a result of the varying climate conditions, and they hinder traffic in installations and maintenances. In the same way, infrared sensors are affected to a large extent by fog. The primary aim of this research is to overcome the bottlenecks mentioned above of conventional V2X communication by introducing C-V2X communication. C-V2X communication is developed to facilitate data communication by exchanging information between vehicles. C-V2X enables V2V, V2I, and V2P services with a high data rate. Emerging of 5G communication has led to the enhancement of C-V2X concerning high data rate, efficient data delivery, and low latency of V2X communication even in poor climatic and high-density conditions. To attain an improved network performance in a dynamic environment, effective coordination among various C-V2X communication is necessitated. Recently, D2D communication has evolved as an enhanced form of communication in cellular networks; C-V2X having the feasibility to employ D2D communication in vehicular networks. The incorporation of D2D communication in a vehicular network enhances network performance in terms of vehicular communication. Besides, C-V2X incorporates routing in a vehicular network. Routing assists the transmission of data packets to the requested destination, which improves vehicular communication.

However, most studies concerned with C-V2X do not emphasize achieving high QoS in routing and D2D communication to enhance network performance. Furthermore, broadcast storm mitigation in emergency message dissemination has not been focused on in C-V2X studies.

The proposed method initiates the following objectives:

- Achieving high QoS in routing by selecting the best forwarder that reduces packet and link losses.
- Improving transmission rate and reducing interference in D2D communication by discovering the best device.
- Reducing broadcast storm in emergency message dissemination by selecting the best forwarder to disseminate an emergency message.

B. RESEARCH CONTRIBUTION

Our proposed work novelty is relied on performing routing, D2D communication, and emergency dissemination in the urban C-V2X environment. Most of the research works rely on either performing routing or emergency dissemination in the urban C-V2X environment. However, it is vital to perform both in the C-V2X urban environment because the urban environment faces numerous accidents nowadays. Besides, we have also performed D2D communication to communicate with other vehicular users. The main contribution of this work is summarized as follows:

- QoS is critical to enhancing the proficiency of routing and is also required to improve the performance of C-V2X in 5G communication. To accomplish this, our method proposes three sequential processes; Stable Matching based Routing, Sphere oriented D2D communication and Optimization-based Emergency Dissemination.
- The novelty of our study is presented in Stable Matching-based Routing, which adopts the Stable Match(SM) algorithm to select the best forwarder. The SM algorithm estimates the reputation function for each vehicle by considering succeeding metrics that are far from the destination, link stability, jerk, and concurrent moving direction of the vehicle. This method of selecting a forwarder results in a high QoS in data transmission.
- Sphere-oriented D2D communication is established to achieve a high transmission rate in D2D communication; the ESDL algorithm is proposed, in which a sphere is constructed around the discoverer device based on the moving direction and communication range of the device. Only within the sphere, the ESDL algorithm selects the best device, thereby avoiding frequent link losses in D2D communication.

To reduce broadcast storms, Q-REDD proposes optimized emergency dissemination. It selects the best forwarder to disseminate an emergency message to the neighboring vehicle. The forwarder is selected using the CCSA algorithm, which updates the position of the crow using a sine variant that enhances accuracy in best forwarder selection.

C. RESEARCH OUTLINE

Section 2 explains available research related to the current work, along with its limitations. Section 3 demonstrates the specific issue associated with Q-REDD. Section 4 indicates our proposed Q-REDD method briefly, with proposed algorithms. Section 5 describes the experimental results of Q-REDD in comparison with the existing methods. Finally, Section 6 concludes the contributions of this study and provides future research directions.

II. RELATED RESEARCH

A. ROUTING

Li *et al.* [17] introduced an effective routing scheme for data delivery to destinations in V2X. Routing was performed utilizing the Carry and Forward (CF) strategy, where V2V communication was established. To determine the best vehicular pair, Karush Kuhn Tucker (KKT) conditions were used. The heaviest vehicle was selected for V2V communication. If the best vehicle was not determined within the required time frame, it requested the Road Side Unit to discover a vehicle for V2V communication.

Yao *et al.* [18] pointed out V2X routing with the aid of the Hidden Markov Model (HMM) algorithm. HMM exploits the regularity of vehicle moving behaviors to enhance transmission performance; it predicts future locations based on previous user traces. The Forward-Backward (F-B) algorithm was used to train the Hidden Markov Model, which predicted the probability of the short-term route of the vehicle and its packet delivery for a specific mobile destination.

Kumar *et al.* [19] suggested the Ant Colony Optimization (ACO) algorithm for routing in vehicular environments. The ACO algorithm was employed to determine the best path to transmit data to the destination. To estimate the traffic intensity, an estimated logic was implemented, where the traffic intensity was considered in the ACO algorithm to select the best path.

Khan *et al.* [20] offered an effective routing scheme in 5G assisted V2X. Here, the Improved Q-Learning (IQL) algorithm was used to select the best path in data transmission; it uses an estimated algorithm that considers three factors, including link reliability, connectivity, and relative velocity factors. With the use of the Q-table, IQL selects the best path between the source and destination.

Wagh *et al.* [21] emphasized the Modified Lion Optimization (MLO) algorithm routing method in vehicular networks. MLO considers three various metrics to select the best route, including costs of congestion, travel, QoS, and collision. QoS cost was estimated using the estimated member function. Using the three cost values, MLO estimates the fitness for each vehicle.

Naghsh *et al.* [22] discovered the MUCS heuristic algorithm for effective routing in the C-V2X environment. MUCS selects the best path based on link-oriented metrics. Link-oriented metrics are used to avoid frequent packet and link losses during communication between two different vehicles. Qi. *et al.* [23] have proposed cluster-based routing in the C-V2X environment. Here, the cluster-based V2V communication is performed using multihop communication. In this, the cluster head transmits data to the respective destination. This paper compares C-V2X performance with DSRC performance.

B. D2D COMMUNICATION

Abbas *et al.* [24] have proposed low latency-based communication in the C-V2X environment. Here, the greedy-based algorithm is utilized to perform D2D communication. In this, the vehicular users communicate with other users with the aid of D2D communication. The greedy-based approach is utilized to perform D2D communication.

Liu *et al.* [25] have introduced Chance Constrained Optimization (CCO) in D2D based cellular vehicular communications. To analyze the CSI uncertainty in D2D communication, this method uses the Bernstein method. Bernstein's method is used to satisfy the conditions to form effective D2D communication among different vehicles in cellular communication.

Chour *et al.* [26] have offered D2D discovery in a vehicular network. Here, Expected Time based D2D (ETD^2) communication was established. On-Board Unit (OBU) executes the device discovery process for D2D communication. It initiates the device discovery process whenever it receives a device discovery request. Here, the device was discovered based on the ET computation via executing a Machine Learning (ML) algorithm in each vehicle.

Qi *et al.* [27] have suggested D2D based Vehicle to Vehicle communication in cellular-based VANET. Here, the Two-Step (TS) algorithm was used to establish and optimize D2D communication between different vehicles. D2D communication was established based on the distance constraint between vehicles. The device which satisfies the distance constraint only is selected to establish D2D communication.

Gupta *et al.* [28] have offered D2D device discovery in a vehicular network. Devices transmit a request message to the base station in order to discover devices for D2D communication. The base station establishes Evolved Packet Core (EPC) level discovery where the peer device was discovered. It also preserves minimum delay while discovering a D2D device.

Sharmila *et al.* [29] have pointed out D2D based vehicular communication in the V2X environment. In this, device discovery was established using two different techniques that are direct discovery and direct communication. It also describes the protocol stack for D2D communication established in the V2X environment.

Li *et al.* [30] have introduced D2D based V2V communication in a vehicular network. In this, D2D communication was established based on the Channel State Information (CSI) of the device. In addition to it, device discovery also considers the speed and delay time metrics while selecting a device for D2D communication.

C. EMERGENCY MESSAGE DISSEMINATION

Wang *et al.* [31] have introduced the local information-based broadcast scheme for emergency dissemination in the C-V2X environment. Here, the best disseminator or forwarder is selected based on the characteristic information such as maximum forwarding distance, global traffic density and candidate number.

Hang *et al.* [32] have offered emergency message broadcasting in the V2X environment. In this, the Best Transmission Reliability Enhancement Mechanism (OTREM) was used to transmit an emergency warning message to the neighbor vehicles. OTREM approach broadcast emergency warning messages with less delay via reducing the redundant data transmission.

Zhang *et al.* [33] have introduced Adaptive Link Quality (ALQ) based emergency message dissemination scheme for urban VANETs. In this, the physical channel connectivity calculation method was utilized to estimate the connectivity probability among vehicles. A score-based priority allocation mechanism was used for candidate forwarders (CFs) to synchronize the contention among CFs. Minimum waiting time and contention window size were estimated for each vehicle in CFs to disseminate the emergency message.

Benkerdagh *et al.* [34] have suggested emergency message dissemination in V2V communication-based VANET. Data handling was performed before disseminating the emergency message to the neighboring vehicle. If any accident has occurred on the road, it checks the nearby vehicle to determine the same event. After optimizing the event only, it disseminates emergency messages to the neighboring vehicles.

Wu *et al.* [35] have offered Distributed Broadcast Algorithm (DBA) for a vehicular environment. Here, the emergency message was disseminated based on the priority allocated to the messages. Here, an emergency message forwarder was selected based on the previous successful emergency message received values. Selected nodes set the delay timer to reduce delay during emergency message dissemination.

Velmurugan and Manickam [36] have suggested an efficient and reliable emergency message dissemination scheme in a vehicular environment. Herein, the GHN algorithm was used to disseminate the emergency message to the neighbor vehicles. GHN algorithm performs two different phases to disseminate the emergency message, which are DAR and talking phases. These phases are executed to reduce the flooding problem in a vehicular network.

Naja *et al.* [37] have suggested the New Broadcasting Protocol (NBP) for emergency message dissemination in V2X. This protocol sets a waiting time for each vehicle before broadcasting an emergency message to its neighbor. Here, waiting time was allocated to each vehicle based on their mobility speed in the dense and sparse scenarios.

Wang *et al.* [38] have introduced a broadcast scheme for disseminating the emergency message. In this, emergency information was disseminated based on the probability of the forwarding strategy. Here, the emergency message was disseminated based on the vehicle's probability to forward the emergency message.

Ali *et al.* [39] have suggested Position based Emergency Dissemination (PED) in a vehicular network. In this, the optimum forwarder was selected to disseminate the emergency message to the neighboring vehicle. Here, the forwarder was selected based on the interested compatibility. The selected forwarder disseminates the emergency message to vehicles nearby the accidental zone

D. DISCUSSION ON RELATED RESEARCH

This section discusses the limitations of existing works related to routing, D2D communication, and emergency message dissemination processes Table 1 shows the research gaps in detail. The proposed Q-REDD method tackles the limitations that are listed in the prior research.

III. SPECIFIC PROBLEM STATEMENT

This section signifies problems present in the existing C-V2X network associated with the routing, D2D communication, and emergency message dissemination.

Our Q-REDD method predominantly concentrated on two major problems that are QoS provisioning in routing and D2D communication and reducing broadcast storm in emergency message dissemination. The issues that are present in the existing studies are listed as follows:

- Transmission delay is high while transmitting the packet to the destination because of the complex route selection procedure.
- Packet drop and hops between source and destination are high due to the absence of significant parameter consideration in routing.
- Optimum device discovery is difficult in D2D communication owing to its mobility.
- A broadcast storm is high while disseminating the emergency message.

We also define problems in the following works. A greedy traffic light and queue-aware routing protocol were introduced in urban VANETs [40]. Packet drop is high in transmission since all vehicle selects high connectivity street to discover the path, which increases queue size of the vehicles. Furthermore, the number of hops is large in path discovery due to the selection of the street with the absence of distance to the destination. A Microbial inspired routing protocol was utilized for the vehicular network to select the optimum candidate set for selecting forwarder [41]. The transmission delay is more since the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) algorithm runs in each forwarder node to choose the optimum candidate set. The highly complex nature of TOPSIS leads to imprecise results; hence forwarder selection is not effective. Mobility-based Greedy Perimeter Stateless Routing (GPSR) protocol was proposed for routing in VANET [42]. GPSR algorithm induces more delay during packet transmission owing to

TABLE 1. Limitations on prior research.

TOPICS	METHODS	LIMITATIONS
Routing	CF	Consumes more time to deliver packets to the destination. Since periodic updates of route information produce high message overhead.
	HMM	Large parameter setting induces route selection complex and thus produces high latency in new route discovery.
	ACO	Low convergence rate results in an ineffective path. It wastes a large volume of resources that is power, bandwidth, and tendency in loop creation.
	IQL	Takes more time in route selection due to parallel execution of two different algorithms and when a network density increases, then algorithm execution becomes higher complexity.
	MLO	Path selection is not effective on behalf of local search in MLO, and global search requires extra bandwidth
	MUCS	The absence of mobility-oriented metrics in route selection induces packet losses. In this case, overhead increases (number of control packets) when the network size is bigger.
D2D Communication	CCO	It generates ineffective results in a high-density scenario and requires more processing and transmission power to find D2D in on-demand conditions.
	TS	Lack of parameter consideration induces ineffective D2D communication, and vehicular users cannot have simultaneous D2D and cellular transmissions.
	EPC	Interference occurred in D2D communication due to a lack of interference oriented metrics in device selection
	ML	Packet losses are more during the D2D communication and also resource wastage cannot be avoided.
Emergency Message Dissemination	OTREM	Emergency message broadcasting coverage is less and transmission delay becomes very high.
	ALQ	A broadcast storm is more, i.e., high collision and the buffer state is filled with more redundant messages.
	DBA	Forwarder selection is not effective. In this case, every node in the network is allowed for retransmission, and it increases the channel contention.
	GHN	Reachability of emergency message is less. Since threshold is static and it does not adaptive in nature.
	NBP	It takes more time to disseminate the emergency message. It is applicable in sparse network but not suited for dense network due to contention issue
	PED	Location awareness for neighbor vehicles to transmit the emergency messages will be significantly less.

an increase in hop count metric. GPSR generates routing loops in the vehicular network that tends to the circulation of the transmitted data packet. Clustering and D2D communication were introduced, where dragonfly optimizer was adopted [43]. In this, D2D communication is not effective due to the absence of optimum device discovery, which reduces the transmission rate. Time barrier-based emergency message dissemination was offered in VANET with consideration of distance parameters [44]. Herein, emergency message transmission increases the number of broadcasts since there may exist the same distance vehicle from the source vehicle. The performance of the system was degraded when there was an increase in vehicular speed.

IV. PROPOSED Q-REDD MODEL

This section describes the proposed Q-REDD mode briefly and the proposed algorithms for routing, D2D communication, and emergency dissemination.

A. Q-REDD OVERVIEW

This paper proposes the Q-REDD method to incorporate better QoS in routing and D2D communication in C-V2X in 5G communication. The network of Q-REDD comprises vehicular nodes ($V_1, V_2, .., V_3$), pedestrians (5G users) ($P_1, P_{2,} ..P_n$), infrastructure (traffic Lights - $T_{l,1}, T_{l,2}, ..T_{l,n}$) and a 5G base station, as portrayed in Fig. 1.

Q-REDD performs the following three processes: (1) Stable Matching-based Routing – Routing is performed by selecting the best forwarder by a computing reputation function with the help of the SM algorithm. (2) Sphere-oriented D2D communication – The ESDL algorithm selects the best device to establish D2D communication. If the requested video is not presented in devices within the formed sphere, subsequently, the discoverer device requests a 5G base station by selecting nearby pedestrians. (3) Optimization-based Emergency Dissemination – To reduce broadcast storm, the Q-REDD method selects the best forwarder using the CCSA algorithm, which performs faster than other optimization algorithms like PSO, GA, and ACO [52]. The main notations used in this study are listed in Table 2.

1) STABLE MATCHING BASED ROUTING

Improving QoS in routing is crucial to enhance network performance. Q-REDD performs routing by selecting the best forwarder with the help of the SM algorithm.

If the source vehicle has to transmit a packet to the destination, it divides the communication range into two segments in the direction of the destination, as depicted in Fig. 2. The source vehicle prioritizes the segment farthest from its position, followed by the one nearest. This is because vehicles farthest from the source position have a higher probability of reaching the destination first, which reduces routing time. This method of selecting the forwarder also reduces selection time in routing by searching for the forwarder within the prioritized segment. The best forwarder is selected using the SM algorithm by the computing reputation function. Here, the reputation function is estimated using the distance from the destination, ETC, jerk, link stability, and the next moving direction. The next moving direction of the vehicle is obtained from the traffic light. In our study, all vehicles update to the next moving direction toward the traffic light. The source

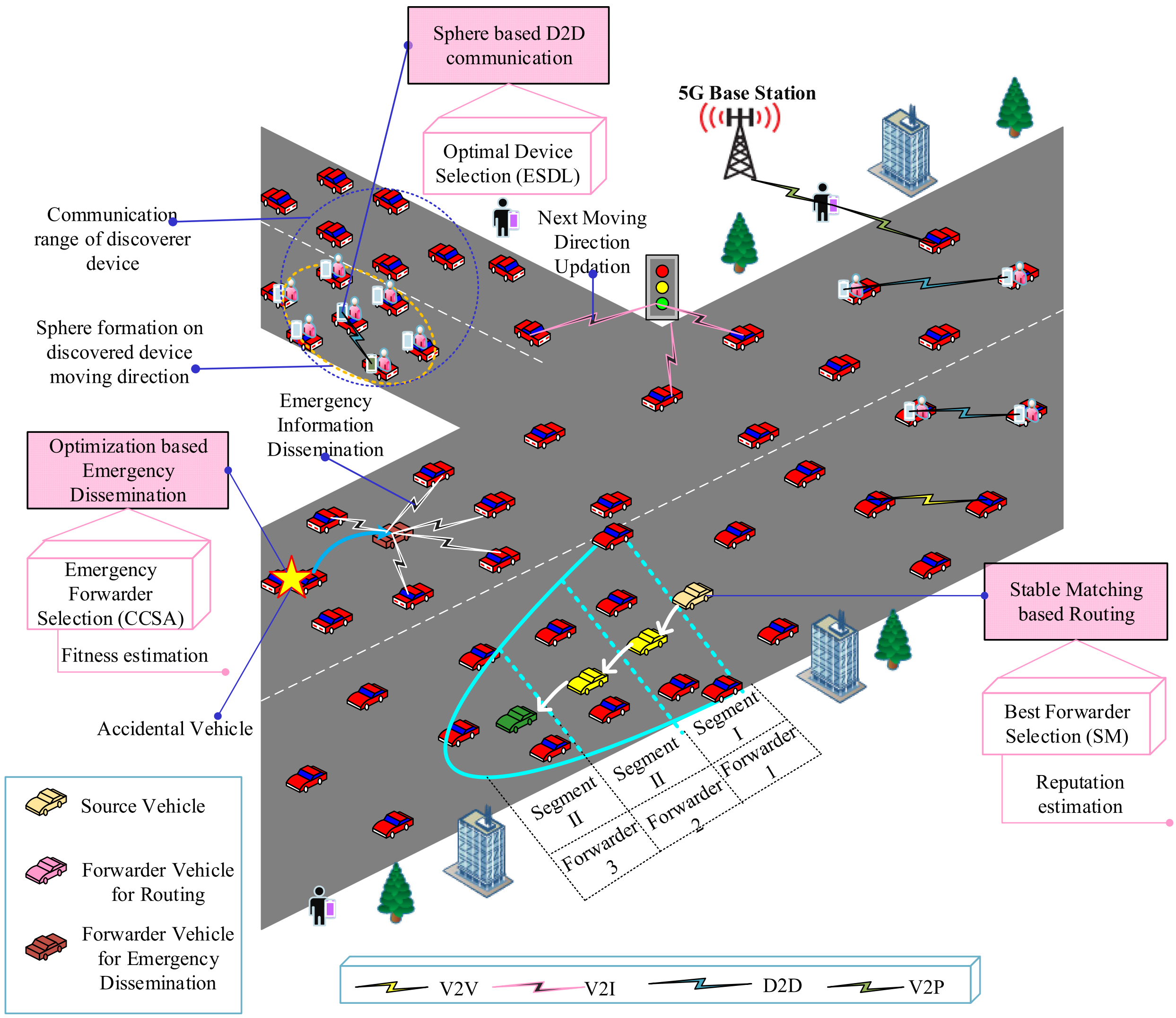

FIGURE 1. Architecture for proposed work.

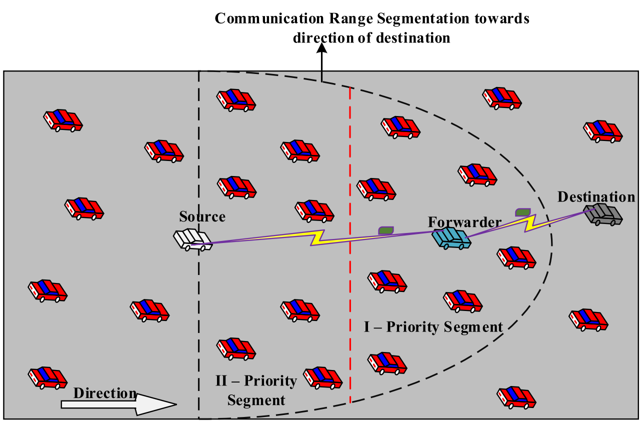

FIGURE 2. Forwarder based routing.

vehicle gathers that information from the traffic light to handle the intersections in the urban scenario. This also reduces the packet travel time to reach the destination vehicle.

Metrics used to estimate the reputation function are described as follows [53], [54]:

1) Distance from the destination: This metric is used to estimate the distance of a vehicle from the destination to reduce the transmission time while routing the packet. It can be expressed as follows:

$$D_f = \sqrt{(V_{i,x} - V_{j,x})^2 + (V_{i,y} - V_{j,y})^2} \tag{1}$$

2) *ETC:* It is used to measure the packet transmission ability of the vehicle to transmit the packet successfully to the destination.

$$ETC = \frac{1}{1 - \mathbb{p}_{l-pro}} \tag{2}$$

where, $\mathbb{p}_{l-pro}$ represents the loss probability of the transmitted packet. Here, we measure the loss probability by considering its buffer size. i.e., the number of packets needs to forward to the destination. Since if we

TABLE 2. Main notation summary.

NOTATION	DESCRIPTION
V_i	i[th] vehicle in the network
P_i	i[th] pedestrian in the network
$T_{l,i}$	i[th] traffic light in the network
D_f	Farness from the destination
ETC	Expected Transmission Count
J_e	Jerk of the vehicle
$\mathbb{P}_{l-pro}$	Loss Probability of a packet
$d(\vec{a}(t))$	Derivative of acceleration of the vehicle
$d(t)$	Derivative of time t
$f_T(t)$	Link Connection duration
r_f	Reputation function
$\mathbb{W}$	Weight value of the vehicle
p	Power of incoming vehicle
$\mathbb{P}_s$	Packet Size
r_s	Relative Speed
R	Radius of the device
n_{di}	Next Moving direction of the vehicle
t_p	Prediction Interval
S	Speed of the vehicle
R	Communication Range of the vehicle

select the high buffer size vehicle as a forwarder, there is a higher possibility the vehicle could drop the packet.

3) Jerk: It is defined as the rate of change of acceleration of the vehicle over time t. This metric plays a vital role in routing the moving ability of the vehicle since fast vehicles lead to frequent link losses during transmission. It can be expressed as follows:

$$J_e = \frac{d(\vec{a}(t))}{dt} \tag{3}$$

where $d(\vec{a}(t))$ indicates the derivative of acceleration at time t.

4) Link Stability: It is defined as the stability of the link between two vehicles. It is used to avoid packet losses during packet transmission.

$$\begin{aligned} L_S &= a\frac{}{\ln R} \\ L_s &= a\frac{RV_{i,j}}{d_{i,j}} \\ d &= \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2} \\ RV &= (V_i \sin\alpha - V_j \sin\beta) + (V_i \cos\alpha - V_j \cos\beta) \end{aligned} \tag{4}$$

where d is the distance between two vehicles and RV is the relative velocity between the vehicles and a is the Transmission range of vehicle V_i.

Next Moving Direction (n_di): This metric is used to estimate the upcoming direction of the vehicle to handle intersections. Since urban scenarios comprise many intersections, vehicles should be selected based on the similarity of direction to the destination vehicle. This equation is also useful in reducing the packet transmission time between the source and destination. In our work, we have measured the next moving direction as 0 and 1. Here, 0 for the opposite direction with the destination and 1 for a similar direction.

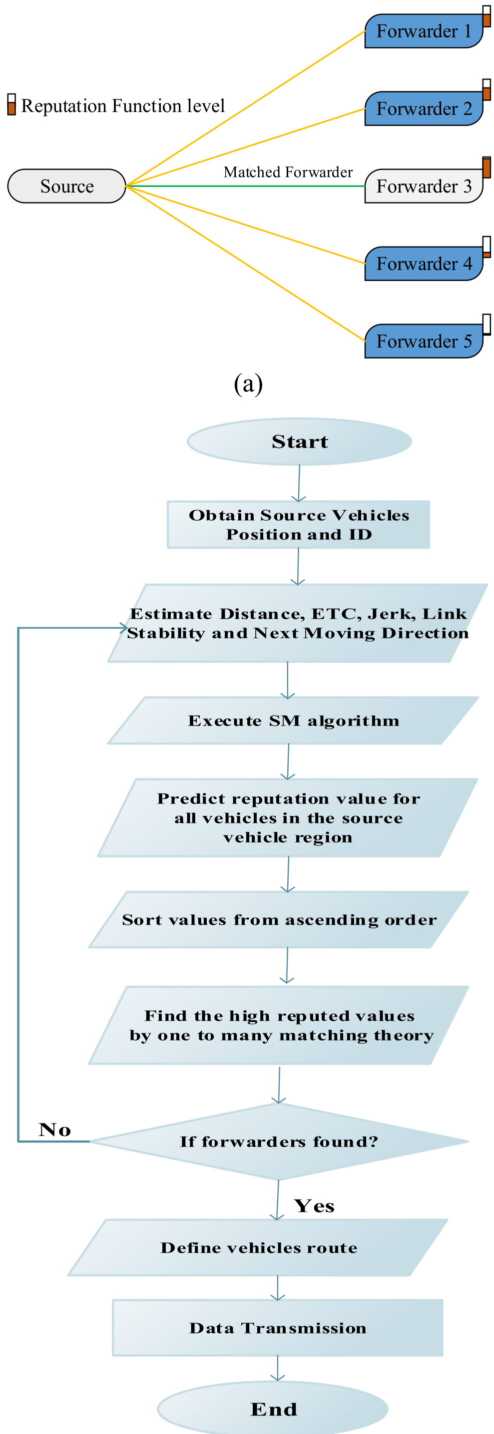

FIGURE 3. Stable Matching based forwarder selection (a). Reputation Function and (b). Flowchart.

Fig. 3 depicts the forwarder selection using the SM algorithm. Using the metrics mentioned above, the SM algorithm selects the best forwarder to transmit a packet. SM algorithm matches a source vehicle with other vehicles by a computing reputation function. The vehicle which has the highest reputation function is considered the best match for the source vehicle. The reputation function is estimated as follows:

$$r_f = \sum_{i=1}^{n} \frac{ETC_i + L_{si}}{D_{fi} + \mathbb{n}_{di} + J_{ei}} \tag{5}$$

Using the abovementioned expression, each device calculates the reputation function to select the best match to transmit a packet. The vehicle with the highest reputation function is selected as the best match (forwarder) that transmits the packet successfully to the destination. Routing with these procedures results in QoS enhancement of packet transmission.

2) SPHERE ORIENTED D2D COMMUNICATION

D2D communication in C-V2X plays a vital role in enhancing data communication among vehicles in an effective manner. Q-REDD adopts the ESDL algorithm to discover the best device to form D2D communication.

The ESDL algorithm is executed in the discoverer device to establish D2D communication. Initially, the ESDL algorithm forms a sphere around the discoverer device. Here, sphere is constructed based on the moving direction and communication range of the discoverer device; the device moving in the opposite direction of the discoverer device leads to frequent link breakages in D2D communication. Therefore, Q-REDD avoids packet loss during D2D communication. The ESDL algorithm decreases complexity in D2D communication by searching a device within the formed sphere, reducing device discovery time. For device x, the ESDL constructs a sphere based on the radius 'r', which is expressed as follows:

$$r = \left\| C_{Ra,x}, di_x \right\| \tag{6}$$

where $C_{Ra,x}$ represents the communication range of device x, and di_x represents the direction of device x. Devices D_s are in the sphere of radius r, if the condition mentioned below is satisfied:

$$r^2 \geq \|x - D_s\|^2 \tag{7}$$

By using the equations mentioned above, the ESDL algorithm constructs a sphere based on the radius and determines devices that are present inside the sphere to reduce searching time.

After completing the sphere construction, the discoverer device transmits a video request to the devices within the sphere. Devices consist of requested videos that send acceptance messages to the discoverer device. After the message is received, the discoverer selects the best device by calculating the weight for each vehicle. The weight is computed using three metrics: Signal to Interference Noise Ratio (SINR), Channel State Information (CSI), and relative speed. These metrics are illustrated below:

a) SINR: This is used to avoid interference during D2D communication since interference induces packet losses during data transmission. The mathematical form of SINR is illustrated as follows:

$$SINR = \frac{\mathcal{P}}{I + \mathbb{n}} \tag{8}$$

where $\mathcal{P}$ refers to the power of the incoming signal, I represents the interference power from the signal in the network, and $\mathbb{n}$ represents the noise.

b) *CSI:* This is used to determine the information regarding communication links. It also describes the manner in which our data propagates from the source to the destination. It can be expressed as follows:

$$a = Hb + \mathbb{n} \tag{9}$$

where a and b represent the receive and transmit vectors. H indicates the channel matrix, and $\mathbb{n}$ represents the noise vector.

c) *Relative Speed:* This is used to measure how long these devices are in D2D communication without link breakages. Mathematical description of this metric is illustrated as follows:

$$r_s = \mathcal{S}_i - \mathcal{S}_d \tag{10}$$

where, $\mathcal{S}_i$ represents the speed of the device 'i,' and $\mathcal{S}_d$ represents the speed of the discoverer device.

Using the described metrics mentioned above, the weight is computed for each device, which can be expressed as follows:

$$\mathbb{W} = \frac{CSI + SINR}{r_s} \tag{11}$$

The device with the highest weight is selected for D2D communication, as it enhances the transmission rate and avoids interference during communication.

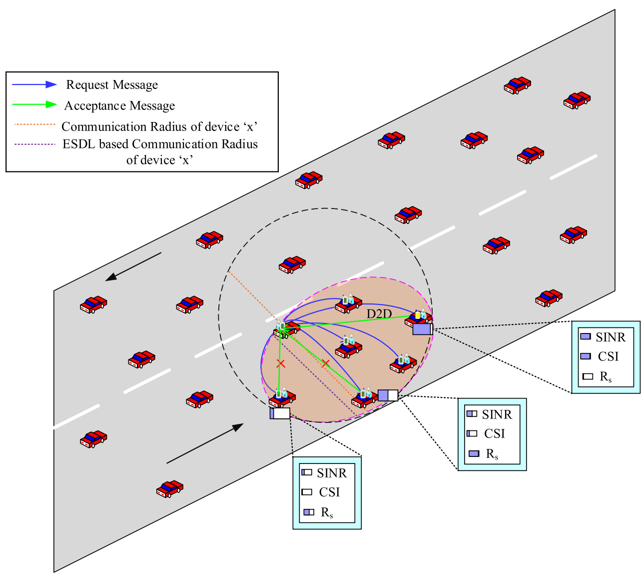

FIGURE 4. Sphere oriented D2D communication.

Fig. 4 represents the proposed sphere-oriented D2D communication. If the requested video is unavailable in the devices that exist within the constructed sphere, the discoverer device sends a video request to the 5G base station through pedestrians.

Here, the pedestrian is selected based on the shortest distance. Subsequently, the 5G base station transmits the video requested device via a selected pedestrian.

3) OPTIMIZATION-BASED EMERGENCY DISSEMINATION

This portion implies the emergency message dissemination in C-V2X communication. The major issue in emergency message dissemination is the broadcast storm. For reducing the broadcast storm, Q-REDD selects the best forwarder to disseminate emergency messages.

Q-REDD adopts the CCSA algorithm, a newly proposed heuristic algorithm that integrates the chaotic theory and Crow Search Algorithm (CSA) [45]. The Chaotic theory is combined with the CSA algorithm to avoid a low convergence rate. The CCSA algorithm is executed in an accidental vehicle, which selects the best forwarder to disseminate an emergency message. Fig. 5 illustrates the flow of the proposed CCSA method.

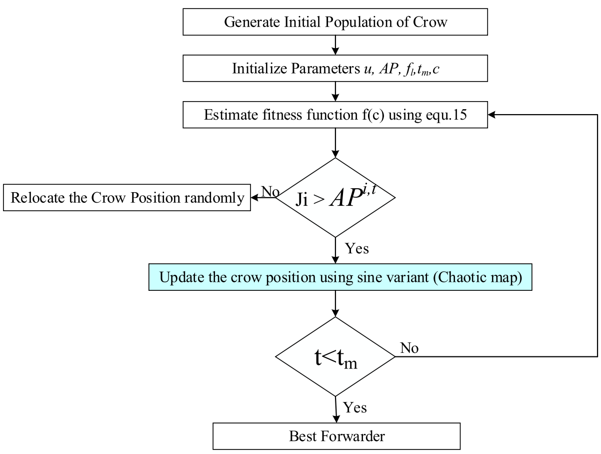

FIGURE 5. **Flow of CCSA.**

To the best of our knowledge, we are the first to use the CCSA algorithm in the best forwarder selection of emergency message dissemination. It provides the best solution and a faster convergence rate compared to the other optimization algorithm [52]. Here, the best forwarder is selected with the consideration of three metrics, the forwarding probability, Expected Transmission Time (ETT), and speed. These metrics are described as follows:

a) Forwarding Probability: This is used to estimate the ability of the vehicle in terms of forwarding an emergency message. The forwarding probability metric is considered to disseminate an emergency message to the neighboring vehicles that are traveling toward the accidental region and can be described as follows:

$$F_{\mathbb{p}} = \alpha * \frac{v}{v_{max}} + \frac{\beta}{R} \tag{12}$$

Algorithm 1 Pseudocode for Emergency Forwarder Selection

Input : Number of Vehicles $V_1, V_2, ., V_3$
Output : Best Forwarder
Initialize ← u, AP, f_l, t_m, c;
Estimate ← fitness function using equ. (15);
While $(t < t_m)$ **do**
{
  For (j=1: j≤ u) **do**
  {
    Get —chaotic map J;
    If $(J_i \geq AP^{i,t})$ **then**
      $c^{j,t+1} \leftarrow c^{j,t} + J_j \times fl^{j,t} \times (N^{i,t} - c^{j,t})$;
    Else
      $c^{j,t+1}$ ←Random position of search Space;
  }
Verify—feasibility of the $c^{j,t+1}$;
Estimate—new crow position $(f\ (c+1))$;
Update—crow position using equ. 16;
}

where α and β represent the weight factors, and v represents the velocity of the vehicle with respect to the maximum velocity v_{max}. R indicates the communication range of the vehicle.

b) ETT: This is used to estimate the time required to disseminate an emergency message to neighboring vehicles. It is used to reduce the delay in emergency message dissemination and can be expressed as follows:

$$ETT = ET_c * \frac{\mathbb{p}_s}{L_c} \tag{13}$$

where ET_c indicates the expected transmission count, $\mathbb{p}_s$ represents the packet size, and L_c represents the link capacity.

c) Speed: This metric is used to estimate the speed of the forwarder vehicle to reduce the link losses. It can be measured through the expression below:

$$\mathcal{S} = \frac{D}{T} \tag{14}$$

where D represents the distance moved by the vehicle over time T.

Next forwarder priority is computed based on the range of individual value of four parameters. When the forwarding probability rate of a vehicle 'high', ETT is 'less', speed of the vehicle is 'less', then the node has a high priority to opt as the next forwarder. It is updated after the successful and unsuccessful packet transmission. Based on the current priority value, the next forwarder is selected, and in this way cooperation between the vehicles and the next forwarder is executed.

The pseudocode illustrates the forwarder selection process, using CCSA to disseminate emergency messages to neighboring vehicles. Using the metrics discussed earlier, CCSA estimates the fitness function for each vehicle. CCSA initiates the forwarder election process by setting adjustable parameters such as maximum number of crows (u), Awareness Probability (AP), flight length (fl), maximum iterations (t_m) and crow position (c) initialization. The fitness function is estimated using the following expression:

$$f(c) = \frac{F_{\mathbb{P}}}{ETT + \mathcal{S}} \tag{15}$$

The proposed CCSA uses sine variants to update the new position of the crow, which performs better than variants that are in the chaotic map, and this can be expressed as follows:

$$c_{q+1} = \frac{k}{4}\sin(\pi c_q); \quad k = 4 \tag{16}$$

where k represents the control parameters, and q represents the chaotic sequence. This variant updates the position of the crow to avoid a low convergence rate. The selected forwarder disseminates the emergency message to the vehicles positioned in an accidental zone. It also disseminates emergency messages to the pedestrian moving along the roadside in the accidental zone. This method of selecting the forwarder avoids storm broadcast to provide proper emergency message information to the neighboring vehicles.

Routing cost of the proposed routing protocol is determined by various cost criteria as Congestion Cost Cn_{ct}, Travel Cost T_{ct}, QoS Awareness Cost QoS_{Ct} and Collision Cost Cl_{ct}. The sum of these four cost criteria are used in routing cost R_{ct} computation. It is denoted as,

$$R_{ct} = \sum\nolimits_{i=1}^{n} Cn_{ct} + T_{ct} + QoS_{Ct} + Cl_{ct} \tag{17}$$

Cn_{ct} is the estimation of the current serving load at Road Side Unit(RSU) and cellular BS 5G. T_{ct} is estimated by the distance, time and amount of fuel contained by the vehicle, QoS_{Ct} is estimated by the RSS and congestion level of the network, which is computed by the communication overhead and computation overhead in the network and Cl_{ct} is the network and vehicle collision.

V. EXPERIMENTAL RESULTS

Here, we briefly describe the performance of the proposed Q-REDD method. This section is further divided into three subsections: simulation setup, application study, and comparative analysis.

A. SIMULATION SETUP

To validate the performance of Q-REDD, we implement it in Objective Modular Network, tested in C++ (Omnet++), and Simulation of Urban MObility (SUMO) simulators.

Our simulation environment contains 100 vehicular nodes, eight pedestrians (5G users), and four traffic lights over a 2.5 km simulation area, as depicted in Fig. 6.

Omnet++ is an event-based network simulator, and SUMO is a road traffic simulator. In this, the veins framework is used to integrate both SUMO (traffic) and Omnet++ (network) simulators and also simulates those in parallel [46].

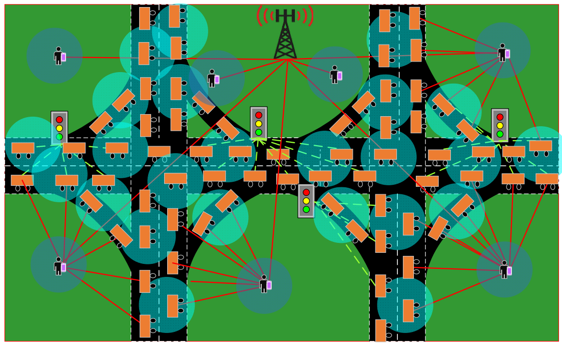

FIGURE 6. Simulation environment.

We have tested our proposed work with these DSRC and 5G technologies. It is highly suitable for our proposed C-V2X environment. For V2V communication, we have utilized the DSRC standard (IEEE 802.11p) and other communication such as V2I, V2P and D2D are performed using the 5G communication standard [47]. TraCI mobility model is used for interlinks the road traffic and network simulators. It permits us to control the behavior of the vehicles in simulation run time, and consequently, it is used to understand the cellular V2X applications on the traffic patterns. This model can easily connect the TraCI server to the subscribers located in the vehicular environment. At regular intervals, the mobility information including node position, speed and direction is updated to the server, and thus, the behavior of vehicle and other cellular devices are monitored. Additionally, it has the functionality to stop any device in the coverage range for the predefined time [54].

In our work, we have utilized the communication channel model as a ray-tracing derived model, which is highly suitable for the urban environment [49]. This is achieved through making the Transmission Control Protocol (TCP) connection between SUMO and Omnet++, simulating both the traffic and network. INET is an open-source model library of the Omnet++ simulation environment. Vehicles are generated in SUMO and then transmitted to the network simulator. Omnet++ considers all the vehicles as nodes and simulates the scenario. If any changes occur in the network environment, the veins change the vehicle scenario in SUMO. Simulation parameters that are used in our simulation environment are listed in Table 3 [54].

B. APPLICATION STUDY

Q-REDD can be utilized for smart applications in urban scenarios with C-V2X in 5G communication. It provides driving safety and effective communication, including V2V, V2I, and V2P. Our application scenario comprises four nodes: vehicles, vehicle user (D2D), a pedestrian (cellular user), traffic light, and 5G base station, as depicted in Fig. 7.

In this application, if any vehicle requires information regarding infotainment services (parking slot traffic jams, etc.), it requests nearby vehicles. Vehicles with the requested

TABLE 3. Simulation parameters.

PARAMETER		VALUE
Cells Coverage (simulation area)		2500*2500m
Simulation Time		100s
Simulation Area		Highway with eight lanes
Network Model	Number of vehicles	100
	Number of RSU	4
	Number of Base station	1
	Number of Pedestrians	8
	Number of Simulation Rounds	1000
Vehicle Model	Vehicle Speed	0-50 km/hr
	Mobility Model	TraCl Mobility Model
	Transmission Range	Min 200- MAX 250 m
Packet Model	Traffic Type	Traffic Control Interface
	Packet Interval	1S
	Total Packets	10000 (approx.)
	Packet Size	400 KB
Communication Model	Communication Technology	DSRC & 5G
	Communication channel model	Ray tracing derived model
	Transport Protocol	TCP
	Transmission Rate	250 Mbps
	Channel Model	Pathloss with Channel Fading
	MAC Protocol	CSMA/CA
	Channel Bitrate	2Mbps
	Channel Bandwidth	10MHZ
CCSA Parameters	Lower bound	0
	Upper bound	1
	u	30
	AP	0.1
	f_l	2
	t_m	50

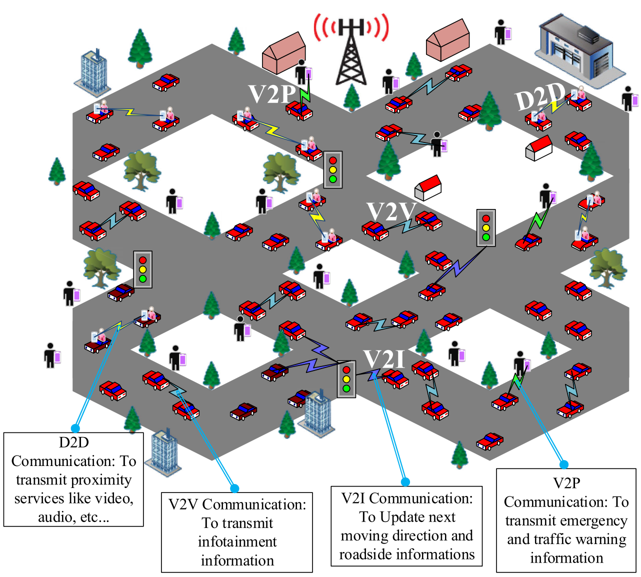

FIGURE 7. Smart application scenario.

information forward data to the destination node via the best path to reduce the packet losses, as the urban scenario is comprised of several vehicles with high mobility. If the vehicle user requires D2D service regarding the video, then it selects a device from a nearby vehicle to form the D2D communication. In this scenario, vehicles communicate with road-side pedestrians via V2P communication. Vehicles also communicate with road-side infrastructures, such as traffic lights, to obtain information regarding the next moving direction of the vehicle destination. Vehicles update their information with respect to the infrastructure by establishing V2I, which is useful for the upcoming vehicle to provide effective services. If an accident occurs in the vicinity of the vehicle, the source vehicle transmits an emergency message to the neighboring vehicles to provide safe driving for vehicle users.

C. VALIDATION METRICS

A significant objective of performance evaluation is to analyze the efficiency of the proposed Q-REDD method in a simulation environment. This is achieved by estimating the following validation metrics.

1) *PDR:* It is designated as the ratio of the successfully received packets ($S_{\mathbb{P}}$) at the destination vehicle, with respect to the total transmitted packets ($T_{\mathbb{P}}$) from the source vehicle. It is used to estimate the efficiency of the Q-REDD method in terms of efficacious packet transmission. This can be illustrated mathematically as follows:

$$PDR = \frac{S_{\mathbb{P}}}{T_{\mathbb{P}}} \tag{18}$$

2) *Throughput:* It is defined as the amount of data effectively transmitted (S_{da}) from the source to the destination vehicle over a given time period,t. It is used to measure the transmission ability of the network. It can be expressed as follows:

$$Throughput = \frac{S_{da}}{t} \tag{19}$$

3) *End to End delay:* It is defined as the difference between the time at which the packet transmitted from the source ($t_{s_{\mathbb{P}}}$), and the time at which the packet reached the destination vehicle ($t_{d_{\mathbb{P}}}$). It can be measured as follows:

$$E_d = t_{s_{\mathbb{P}}} - t_{d_{\mathbb{P}}} \tag{20}$$

4) *Emergency Information Coverage:* It is defined as the amount of area covered by the emergency message, which indicates the reachability of the emergency message dissemination mechanism.

D. RESULTS COMPARISON

This section compares the simulation of results of Q-REDD with those of the existing methods, including GTLQR [35], GPSR [36], MIR [37], ETD^2 [24], ALQ [30], and TBED [39]. These methods were chosen for comparison because the contribution is similar to the proposed Q-REDD method.

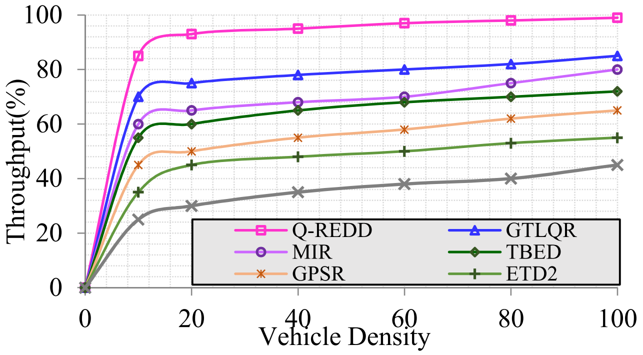

FIGURE 8. Comparison of throughput.

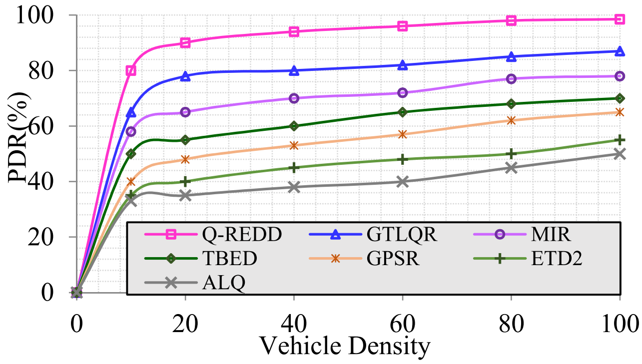

FIGURE 9. Comparison of PDR Vs. vehicle density.

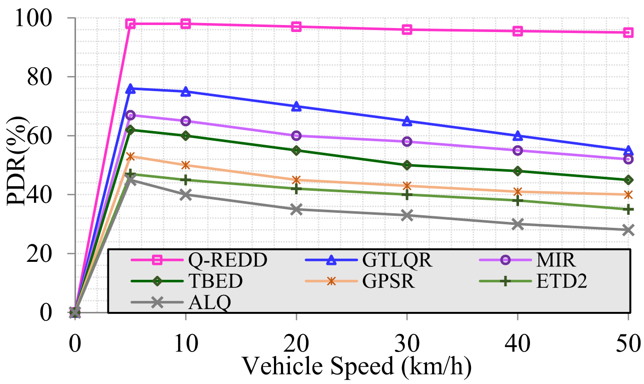

FIGURE 10. Comparison of PDR Vs. Vehicle Speed.

1) IMPACT ON THROUGHPUT

Throughput metric has an impact on the performance of the proposed Q-REDD method in terms of network connectivity. We measure the throughput impact by varying vehicle density.

As shown in Fig. 8, there is an increase in throughput using Q-REDD compared to the other existing methods. Notably, an increase in vehicle density leads to an increase in throughput. This is due to the improved probability of data transmission. Q-REDD executes the Stable Matching-based Routing to transmit the packet to the destination. The next forwarder is selected based on the five metrics: distance from the destination, jerk, next moving direction, link stability, and ETC. These metrics are used to select the best forwarder to transmit the packet, reducing packet loss during the transmission. Consequently, our method achieves a high throughput compared to the existing methods. Meanwhile, existing methods such as GPSR, ALQ, and ETD^2 attain less throughput compared to other methods since they do not consider link losses while routing, which increases packet loss. In contrast, GTLQR, MIR and TBED methods achieve a high throughput compared to the GPSR and ETD^2 method since they consider forwarder selection while routing packets to the destination. These methods have less throughput than the Q-REDD method due to the absence of significant parameters such as link stability. Therefore, our method improves throughput by up to 25% compared to the existing methods.

2) IMPACT ON PDR

This plays a vital role in performance validation, which measures the efficacy of Q-REDD in terms of data transmission. It can be evaluated by varying vehicle density and speed in the network.

Fig. 9 demonstrates the comparison of PDR results relative to Q-REDD and existing methods such as GTLQR, GPSR, MIR, ALQ, ETD^2, and TBED; PDR increases as vehicle density increases. This is because the increase in vehicle density induces an increase in the probability of data transmission. The Q-REDD method selects the best forwarder to route the packet to the destination. Here, the best forwarder is selected using the SM algorithm, which performs faster for forwarder selection. Additionally, we consider the next moving direction of the vehicle as one of the metrics to select a forwarder. Next, moving direction information is gathered from the traffic light where the vehicle stores the next moving direction. This metric is significant to reduce the packet loss during routing. In addition, we also select an optimum device to establish D2D communication, where the ESDL algorithm is used. Best device discovery in D2D communication results in a high transmission rate. Hence, Q-REDD achieves higher PDR in data transmission compared to the existing methods.

Fig. 10 demonstrates the comparison of PDR of the Q-REDD method and existing methods, including GTLQR, GPSR, MIR, ETD^2, ALQ, and TBED. Notably, PDR decreases when the speed of the vehicle increases. This is because the increase in vehicle speed causes concurrent link losses. However, our method undergoes a minute decrease in the PDR when there is an increase in vehicle speed. This is because of the proposed Stable Matching-based routing mechanism, which selects the best forwarder to route the packet to the destination; thus, enhancing the PDR performance, even under a high mobility scenario. In contrast, ALQ, ETD^2 and GPSR methods achieve a smaller PDR compared to the other methods. During high mobility scenarios, these methods suffered significant link losses that reduce the PDR percentage when vehicle mobility increased. Likewise, GTLQR, MIR and TBED methods achieved a higher

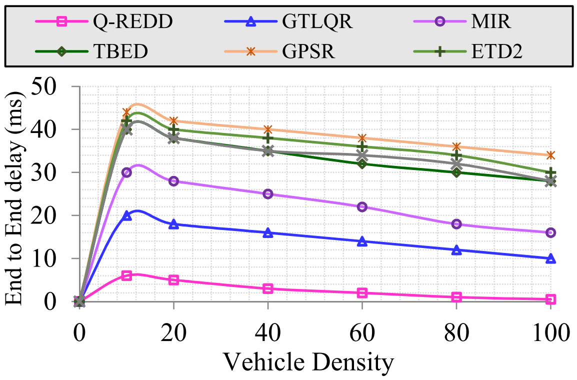

FIGURE 11. Comparison of End-to-End delay Vs. Vehicle Density.

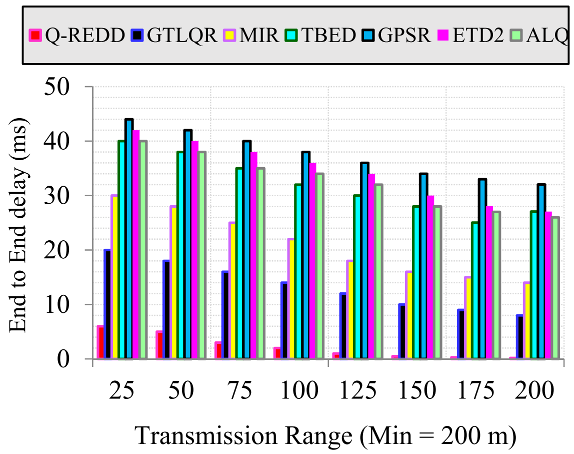

FIGURE 12. Comparison of End-to-End delay Vs. Transmission Range (Min = 250 m).

PDR percentage compared to the ETD^2 and GPSR methods. These three methods rely on an improved data transmission mechanism compared to the other two mechanisms; however, these three methods achieved a lower PDR than our approach. This is because of the loop formation while routing, and the packet also drops more due to a lack of mobility. Q-REDD attained better performance for both, increase in vehicle speed, and an increase in vehicle density. Consequently, our method improves PDR by up to 30% compared to the existing methods.

3) IMPACT ON END TO END DELAY

This metric is used to evaluate the performance of the Q-REDD method considering the delay incurred due to end-to-end data transmission. The impact of end-to-end delay is measured by varying the vehicle density and speed.

Fig. 12 and Fig. 13 describe the performance of end-to-end delay. The graphical plots proved that the proposed Q-REDD method gives lower end-to-end delay for both emergency message transmission and also periodic message transmission. When the packet transmission rate is higher, then the node can obtain a lower end-to-end delay. In urban and highway environments, it further reduces because transmission coverage of 5G enables more nodes to be active in transmission.

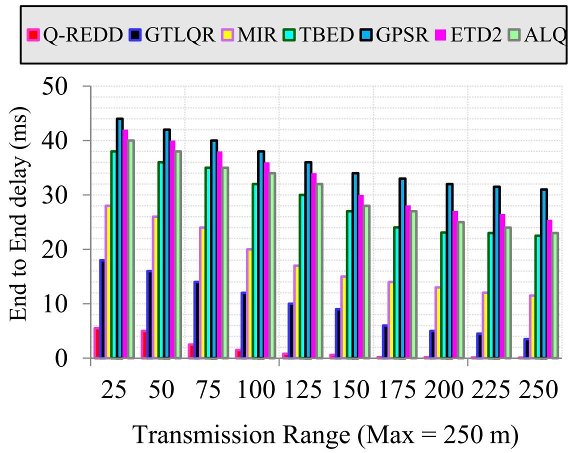

FIGURE 13. Comparison of End-to-End delay Vs. Transmission Range (Max = 250 m).

As presented in Fig. 11, the end-to-end delay of the proposed Q-REDD method is better than the existing methods; the delay decreased as vehicle density increased. This is due to the increase of in-network connectivity while increasing the number of vehicles. Q-REDD reduces end-to-end delay while routing by dividing the communication radius into two, where vehicles presented in the second part of the radius are prioritized as they reach the destination with a delay. If there is no vehicle in the second part of the communication radius, then the method only elects the best forwarder from the first part of the communication radius. This reduces the time and complexity in forwarder selection by reducing the search space. In addition, device discovery time was also reduced with the use of the ESDL algorithm. The ESDL algorithm reduces the search space by shrinking the communication range to the moving direction of the discovering device. Therefore, Q-REDD achieves better performance in reducing delay than the existing methods such as GTLQR, MIR, TBED, ALQ, GPSR, and ETD^2.

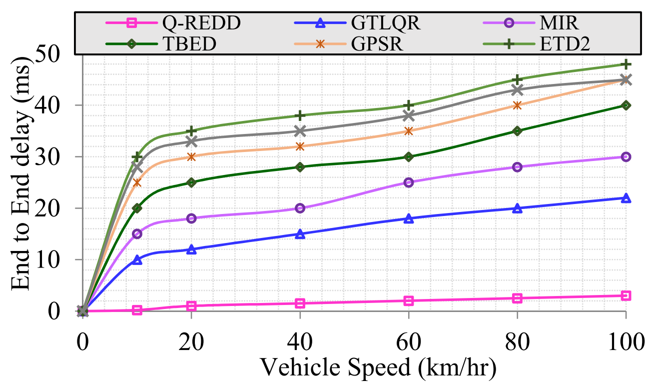

FIGURE 14. comparison of End-to-End delay Vs. Vehicle Speed.

Notably, in Fig. 14, the increase in vehicle speed also increases the end-to-end delay. This is due to the frequent loss of links during high mobility scenarios. Additionally, under these circumstances, Q-REDD achieves a smaller delay compared to the other methods, thereby indicating better routing, D2D communication, and emergency dissemination mechanism. In contrast, existing methods such as GTLQR, MIR, TBED, GPSR, ALQ, and ETD^2 exhibit higher delays compared to Q-REDD. In these methods, the number of hops between the source and destination is high, which increases the delay during routing. This is because the next moving direction, which plays a vital role in reducing the delay during packet transmission, is not considered. Therefore, Q-REDD achieved a reduction in end-to-end delay, up to 30%, compared to the other methods, including GTLQR, MIR, TBED, GPSR, ALQ, and ETD^2.

4) IMPACT ON EMERGENCY INFORMATION COVERAGE

Evaluation of emergency information coverage has a significant impact on the performance of the Q-REDD method relative to emergency message transmission, which can be simulated by varying the vehicle density.

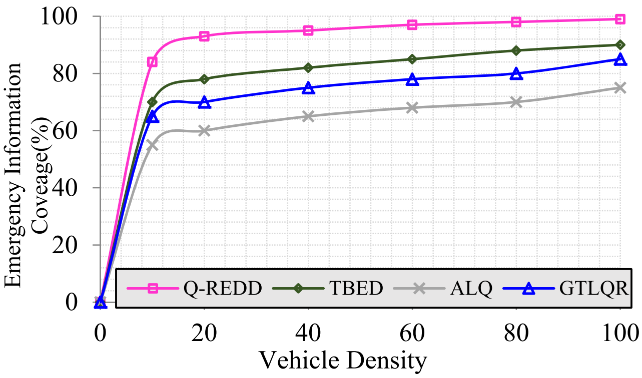

FIGURE 15. Comparison of emergency information coverage.

Fig. 15 compares emergency information coverage of the proposed Q-REDD method and existing GTLQR, TBED, and ALQ. Here, we compared these three methods with Q-REDD, as they are similar to the proposed emergency message dissemination.

Fig. 16 and Fig. 17 depict the performance of emergency information coverage with respect to the transmission range. The maximum transmission range considered for cellular network transmission is that 250 m, and the minimum coverage is that 200 m. However, a higher transmission range gives high emergency information coverage (%). When compare Fig. 16 to Fig. 17, the transmission range of 250 m provides better performance. Optimum node identification delay is reduced for emergency information transmission. Thus, it results in higher emergency information coverage.

Notably, Q-REDD achieves higher coverage compared to the other methods. It proposes the optimization-based emergency dissemination to selects the best forwarder to disseminate an emergency message using the CCSA algorithm, based on three metrics: forwarding probability, Expected Transmission Time (ETT), and speed. This leads to a significant reduction in the broadcast storm problem. Consequently, our method achieves high information coverage compared

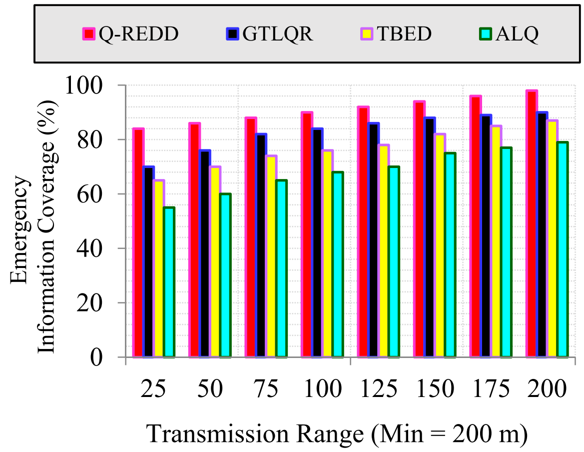

FIGURE 16. Comparison of Emergency Information Coverage (%) Vs. Transmission Range (Min = 250 m).

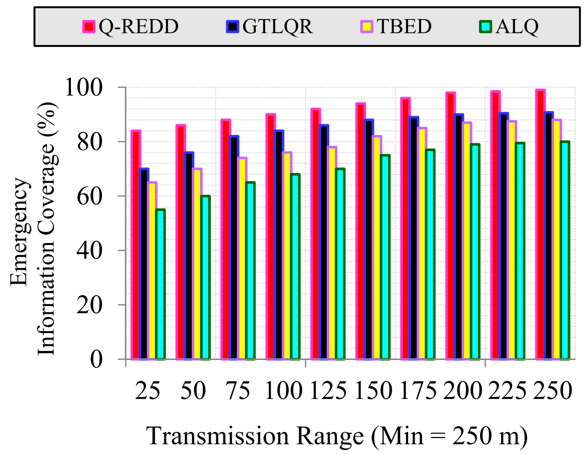

FIGURE 17. Comparison of Emergency Information Coverage (%) Vs. Transmission Range (Max = 250 m).

to the other methods, TBED and ALQ. In contrast, ALQ and GTLQR methods achieve less emergency information coverage due to the ineffective forwarder selection mechanisms as priority is allocated to the forwarder based on the distance metric only. Similarly, the TBED method also has lower emergency information coverage compared to the proposed method. TBED selects the forwarder without using an effective algorithm, which leads to an ineffective forwarder selection in emergency dissemination. From this analysis, we conclude that the proposed method improves emergency information coverage by up to 23% compared to the existing methods of GTLQR, TBED, and ALQ.

5) PACKET TRANSMISSION RELIABILITY

Packet transmission reliability is a positive metric that must be higher to summarize the system is better in packet transmission. For any road case such as urban, highway, or mixed, reliability must be higher since emergency message dissemination through optimum nodes must be improved with reliability. Network connectivity is one of the significant factors

TABLE 4. Comparison of existing and proposed methods.

Author	Described Method	Core Contribution	QoS Concern	Research Statements [Average]									
				PDR (%)		Throughput (%)	End to End Delay (ms)				Emergency Information coverage (%)		
				Vehicle Density	Vehicle Speed		Vehicle Density	Vehicle Speed	Transmission Range		Vehicle Density	Transmission Range	
									Min	Max		Min	Max
Yang et al. [35]	GLTQR	Routing	✓	82.4	65	80	14	17.4	13.3	9.8	77.6	83.1	84.63
Daxin et al. [37]	MIR	Routing	×	72.4	58	71.6	21.8	24.2	21.0	18.0	--	--	--
Zhihao et al. [36]	GPSR	Routing	×	57	43.8	58	38	36.4	37.3	36.1	--	--	--
Hussian et al. [24]	EID²	D2D communication	×	47.6	40	50.2	35.6	41.2	34.3	32.71	--	--	--
Syed et al. [39]	TBED	Emergency Dissemination	✓	63.6	51.6	67	32.6	31.6	31.8	29.1	84.6	77.1	79.25
Zhang et al. [30]	ALQ	Emergency Dissemination	×	41.6	33.2	37	33.4	38.8	32.5	30.6	67.6	68.6	70.85
Proposed	Q-REDD	Routing, D2D communication and Emergency Dissemination	✓	96	96.3	96.4	2.3	2	2.25	1.649	96	97.5	98.55

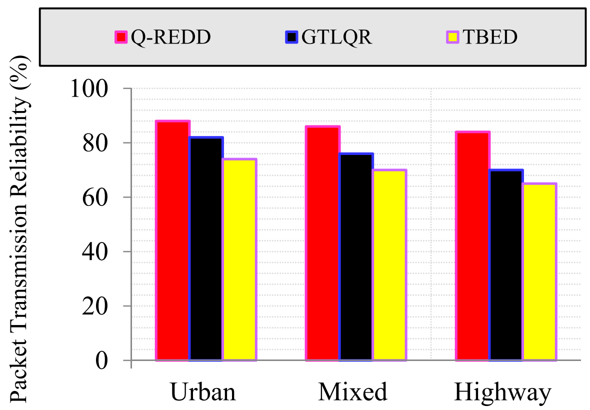

FIGURE 18. Packet Transmission Reliability vs. Road Scenarios.

that enhance reliability. In 5G, packet transmission is faster and easier than other cellular networks. Expect speed between the vehicles is higher even the network high congestion. For both sparse and dense networks, the proposed system gives higher packet transmission reliability. In Fig. 18, packet transmission reliability is compared with the previous works for three different scenarios such as highway, urban and mixed. For all three scenarios, the proposed work's performance is better; that is, it has a higher packet transmission reliability.

E. DISCUSSION ON SIMULATION RESULTS

To achieve the goals, i.e., QoS network performance improvement such as high throughput, high PDR, and Low End-to-End Delay, Q-REDD presented with routing, D2D communication, and emergency message dissemination. Based on the evaluation, the Q-REDD method outperformed compared to the other existing methods such as TLQR, TBED, ALQ, MIR, ETD^2 and GPSR. The Q-REDD method increases the throughput and PDR by up to 30% compared to the listed existing methods. Its superior performance was due to the increase in vehicle speed and density. Thus, the proposed method improves the efficiency of packet delivery, which is beneficial to data transmission. This can be attributed to selecting the best forwarder in routing and device discovery in D2D communication, using SM and ESDL algorithms, respectively.

Moreover, the proposed method reduces the end-to-end delay by up to 30% compared to the existing methods. This is because Q-REDD mitigates delays in routing and D2D communication by decreasing the searching space for best forwarder selection and device discovery. The major challenge in emergency dissemination is a broadcast storm, which is effectively minimized using optimization-based emergency dissemination. Consequently, Q-REDD was able to enhance the emergency information coverage by up to 23% compared to the existing methods of GLTQR, TBED, and ALQ. Table 4 details the comparison of the existing and proposed methods along with their research statements. From this comparison, we can conclude that the Q-REDD method achieves better performance compared to the existing methods such as GTLQR, TBED, ALQ, MIR, ETD^2 and GPSR.

VI. CONCLUSION

This paper proposes the Q-REDD method to design an efficient C-V2X network with 5G communication. The key merit of Q-REDD is enhancing network performance in terms of QoS. Q-REDD performs three successive processes: Stable Matching-based Routing, Sphere oriented D2D communication, and Optimization-based Emergency Message Dissemination. Primarily, Q-REDD performs routing to enhance QoS while routing a packet to the destination. Herein, routing is established by selecting the best forwarder using the SM algorithm. With regard to achieving better D2D communication, the Q-REDD selects the best device by adopting the ESDL algorithm. The mitigating of broadcast storms in emergency message dissemination is accomplished by selecting the best forwarder. In this case, the best forwarder is selected through the CCSA algorithm, which uses a sine variant to update the metrics that provide a faster convergence rate and best solution. Finally, the performance of the Q-REDD is validated through five performance metrics: Packet Delivery Ratio (PDR), End-to-End delay, Throughput, and Emergency Information Coverage. These metrics are compared with existing methods such as GTLQR, GPSR, MIR, ALQ, and TBED. After performing a comparison of the results, we proved that the proposed method outperforms other existing methods, including GTLQR, GPSR, MIR, ALQ, and TBED.

A. FUTURE WORK

In the future, we intend to propose a vehicle collision avoidance and congestion control system in the C-V2X network with 5G communication.

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