1-4-2021

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Repository Citation

Feroz, Bushra; Mehmood, Amjad; Maryam, Hafsa; Zeadally, Sherali; Maple, Carsten; and Shah, Munam Ali, "Vehicle-Life Interaction in Fog-Enabled Smart Connected and Autonomous Vehicles" (2021). *Information Science Faculty Publications*. 82.
https://uknowledge.uky.edu/slis_facpub/82

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Digital Object Identifier (DOI)
https://doi.org/10.1109/ACCESS.2020.3049110

Notes/Citation Information

Published in *IEEE Access*, v. 9.

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IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received December 10, 2020, accepted December 22, 2020, date of publication January 4, 2021, date of current version January 13, 2021.

Digital Object Identifier 10.1109/ACCESS.2020.3049110

Vehicle-Life Interaction in Fog-Enabled Smart Connected and Autonomous Vehicles

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This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) through the Academic Center of Excellence in Cyber Security Research-University of Warwick under Grant EP/R007195/1, The Alan Turing Institute under Grant EP/N510129/1, Autotrust under Grant EP/R029563/1, and the National Centre of Excellence for the IoT Systems Cybersecurity, PETRAS under Grant EP/S035362/1.

ABSTRACT Traffic accidents have become a major issue for researchers, academia, government and vehicle manufacturers over the last few years. Many accidents and emergency situations frequently occur on the road. Unfortunately, accidents lead to health injuries, destruction of some infrastructure, bad traffic flow, and more importantly these events cause deaths of hundreds of thousands of people due to not getting treatment in time. Thus, we need to develop an efficient and smart emergency system to ensure the timely arrival of an ambulance service to the place of the accident in order to provide timely medical help to those injured. In addition, we also need to communicate promptly with other entities such as hospitals so that they can make appropriate arrangements and provide timely medical information to emergency personnel on the scene including alerting those related to the injured person(s). In this paper, we have developed an intelligent protocol that uses connected and autonomous vehicles' scenarios in Intelligent Transportation System (ITS) so that prompt emergency services can be provided to reduce the death rate caused. The proposed protocol smartly connects with all the relevant entitles during the emergency while maintaining a smooth traffic flow for the arrival of the ambulance service. Moreover, our protocol also mitigates the broadcasting of messages circulating over the network for delay sensitive tasks. The evaluation results, based on the performance metrics such as channel collision, average packet delay, packet loss, and routing-overhead demonstrate that our proposed protocol outperforms previously proposed protocols such as Emergency Message Dissemination for Vehicular (EMDV), Contention Based Broadcasting (CBB), and Particle Swarm Optimization Contention-based Broadcast (PCBB) protocols. Finally, we discuss several issues and challenges that need to be addressed in the network in order to achieve more a reliable, efficient, connected, and autonomous vehicular network.

INDEX TERMS Accident, smart emergency, ambulance service, VANETs, intelligent transportation system.

I. INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) have been a hot topic of research in the past decade. Many vehicles cause serious issues such as road accidents and traffic congestion. Intelligent Transportation Service (ITS) introduced the concept of VANETs to make traveling safer and more comfortable. In the VANETs communication paradigm, each vehicle communicates with other vehicles by using protocols such as the Dedicated Short Range Communication (DSRC) protocol and the Wireless Access in Vehicular Environment (WAVE) protocol. The Vehicle to Vehicle (V2V) communication framework provides real-time wireless data exchange and provides significant safety benefits. Moreover,

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

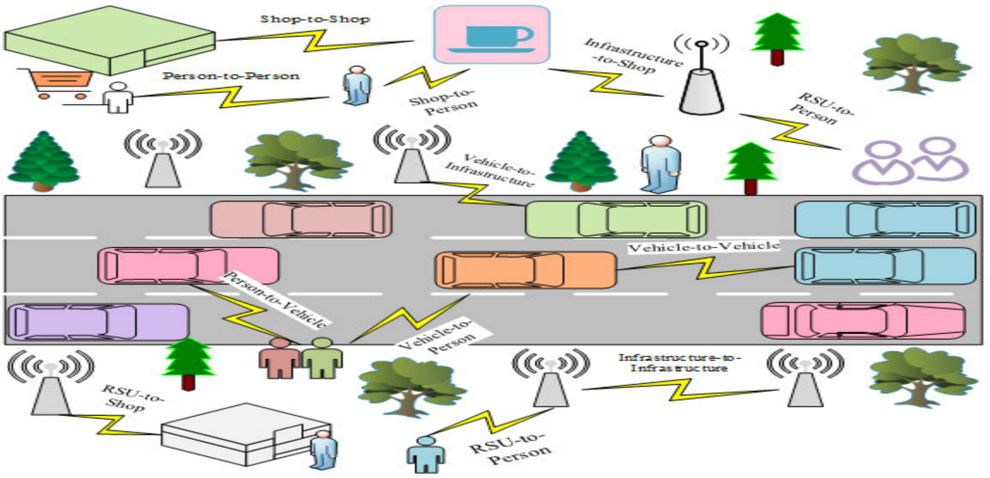


FIGURE 1. General vehicular environment – urban scenario.

smart vehicles also communicate with the Road Side Unit (RSU) (also called Vehicle to Infrastructure (V2I) communication). V2V and V2I communications support a new generation of active safety applications and safety systems. In the VANET communication paradigm, there are two main types VANETs applications namely, safety and non-safety applications. VANETs safety applications send safety messages to provide assistance to drivers and prevent accidents as in connected vehicles. Connected vehicles help drivers or cars to receive more useful information in order to make safer and informed decisions. Connected vehicles have navigation system installed in then in order to provide different vehicles' functionalities such as dynamic route guidance. The GPS in cars receives information about congestion on the road ahead through cellular information (such as 4G, Long-Term Evolution (LTE) or 3G) and recommends alternatives routes to drivers. Furthermore, connected vehicles do not give choices to drivers. Rather, they provide information to them, including potentially dangerous situations to avoid. In contrast, non-safety applications provide comfortable and efficient driving experience [1]. Connected vehicles play a vital role in non-safety applications and are further categorized into two types of vehicle that are autonomous vehicles and connected and autonomous vehicles.

A. AUTONOMOUS VEHICLES

Autonomous Vehicles have self-parking or auto-collision avoidance features, but until a vehicle does not drive itself independently; it is not a true autonomous vehicle. A vehicle is said to be fully autonomous if it does not require a human driver but is totally computer driven [2]. At present, the definition of autonomous vehicles varies among vendors.

B. CONNECTED AND AUTONOMOUS VEHICLES

It is important to note that autonomous vehicles do not depend on the connected vehicle technology to work because they must function independently and navigate the road network on their own (as Figure 1 shows). Nevertheless, the connected vehicle technology helps in providing valuable information about the road ahead, rerouting based on new information such as lane closures or obstacles on the road. It is worth noting that the connected vehicle technology makes the autonomous vehicles safer, faster, and more efficient. The traditional VANET communication paradigm may not be efficient for handling huge amounts of traffic content (i.e., sensor, video and audio generated by smart vehicles). In order to process and collect a large amount of traffic content, more sensors are required in a distributed area. To handle such type of situations, VANETs using cloud computing might be a good solution. Cloud computing using the VANETs paradigm must satisfy its key requirements, such as location awareness, delay, mobility support and transmission delay. In the connected vehicle communication paradigm, a lot of data is generated due to sensors and applicable hardware in VANETs which needs to be distributed across in the networks. There are over 250 million vehicles alone in the United States alone. Each vehicle produces 20 GB of data per hour [3] which brings about various challenges, such as: collecting large amounts of data, performing analysis and aggregation, and processing and storing the collected data [4]. Although cloud computing benefits vehicular communications in terms of computation and big data processing, high end-to-end latency limits the use of cloud computing for delay-sensitive tasks in connected and autonomous vehicles [4]. In vehicular fog computing, vehicles are considered as an infrastructure for communication and computation. This infrastructure uses a collaborative collection of end-user clients or near edge devices to perform communication and computation by considering each vehicle's resources effectively. In vehicular fog computing, the data is quickly analyzed, aggregated, filtered, processed and stored for further analysis to make decisions at runtime. Traffic safety applications play a very important role in emergency response systems as they help to prevent traffic accidents. Emergency vehicles refer to any vehicles used for rescue operations and they include ambulances, police car, and the fire brigade. Although, in some scenario, aerial vehicles such as helicopter or drone equipped with medical kit are used in the rescue operation, however, we do not consider these aerial vehicles in our scenarios because other road-side vehicle have less impact on the route and rescue operation by these aerial vehicles [3]. We consider the following scenario in which an accident has occurred and after a road-side accident the following three basic crucial operations are required.

1) RESCUE OPERATION

This is the most critical operation to transfer the victim to the nearest hospital in the shortest period of time. Emergency vehicles, including ambulances, fire brigades, and police cars all require a clear road to the nearest hospital. Nevertheless, some previous experience suggests that there is a high chance that the emergency vehicles also face potential accidents with other vehicle due to lack of co-ordination among the rescue vehicle and other vehicles.

2) INFORMATION TO THE RELATIVES AND FAMILY

Normally, it is considered to inform the close friends and family of the victim(s) about the accident for assistance and accompany ship.

3) ROAD CONGESTION

Generally, after a road accident, there is immense traffic congestion on the road irrespective of the nature of the accident. The situation becomes worse if the accident happens in a tunnel or bridge or during peak hours.

After a road accident, to provide the fastest and most efficient response, we need to consider the following issues:

I. How to plan a path for emergency vehicle?
II. How to broadcast the accident message to the other vehicle and suggest routes for them?
III. After an initial evaluation of the patient, we need to route the emergency vehicle to the correct hospital.

Normally, an RSU broadcasts the accident and rescue messages to all the vehicles in its neighborhood. However, the accident messages are more important to the vehicles that are moving toward the accident area rather the vehicles that are going away from the accident zone. Therefore, sending message to all the vehicles will create unnecessary panic to the other vehicles. Despite the potential advantage of connected and autonomous systems, there are numerous design challenges that need to be addressed before their widespread deployment. Researchers must overcome intermittent connectivity issues in VANETs. Moreover, different routing protocols have been proposed by different researchers. However, message broadcasting is common in any traditional wireless networks. Therefore, message broadcasting in VANETs needs to be handled using some particular techniques like flooding and timely message dissemination. In case of an emergency, timely arrival of an ambulance at the accident location is crucial and needs to be handled promptly because any delays in the ambulance arrival may cause the loss of human life. In fact, in many cases, injured people have died while waiting for an ambulance which did not come on time because of traffic congestions.

C. CONTRIBUTIONS OF THIS WORK

We summarize the main contributions of this work as follows:

I. We propose a fog computing-enabled protocol that can provide efficient emergency services with minimum delay by ensuring the arrival of an ambulance on time at accident locations.
II. The proposed protocol reduces the number of emergency messages broadcast over the vehicular network. As a result, the end-to-end latency for delay sensitive tasks in connected and automated vehicular communications in an emergency area is reduced.
III. We highlighted the future research challenges in vehicular networks.

The rest of this paper is arranged as follows. In Section II, we present a survey of related works on emergency response systems for roadside accidents. In Section III, we present our proposed fog computing enabled methodology for ambulance services after an accident. In Section IV, the simulation results obtained with our proposed approach are presented. Section V highlights some future research challenges because of the unique nature of VANETs paradigm. Section VI accomplishes the whole paper.

II. RELATED WORK

This section reviews related works on the prevention of road accident's prevention with a focus on when an accident occurs, we need to locate an ambulance which is close to the location of the accident. By sending the ambulance to the location of crashed vehicles the injured people can be transported to the hospitals immediately. The literature review is further divided into the different proposed schemes aimed at providing emergency services with the minimum delay.

A. ROUTE CLEARANCE FOR EMERGENCY VEHICLES

To ensure the quick arrival of an emergency vehicle such as ambulance, the location of the accident must be known. When there is a high traffic congestion, emergency vehicles cannot reach their destination on time, which can result in loss of lives. In this [5], the authors proposed a traffic signaling system to clear the route for the emergency vehicle in such a way that the green signal is turned on for the route used by the emergency vehicle and does no turn to red until the emergency vehicle moves out of the route [5]. To achieve this goal, the authors have employed the V2V and V2I communication for emergency packet delivery to the traffic signal node. Recently, Nellore and Hancke [6] proposed a visual sensor-based emergency vehicle priority scheme in VANETS. In the proposed scheme, the acoustic sensors attached to RSUs sense the presence of an emergency vehicle and calculate its distance from road intersection using different distance calculation algorithms. This information is also forwarded to the traffic management center for the change of traffic signals so that the emergency vehicle can immediately be moved out of the congested traffic route. In this scheme, authors modified the medium access procedure used in standard IEEE 802.11p also named as Priority Emergency- Medium Access Control (PE-MAC) protocol. In PE-MAC protocol a new back off selection and contention window adjustment scheme is used to achieve low broadcast delay for emergency messages. Simulation results show that PE-MAC yields high throughput, low energy consumption and low end-to-end delay compared with IEEE 802. 11p delay.

B. EMERGENCY VEHICLE ARRIVAL AT THE LOCATION OF THE ACCIDENT

The authors of [7] proposed a Global Positioning System (GPS)-based ambulance support system for the emergency services. The primary idea of this work is to uncover the emergency vehicle which is in near region of the mischance and send it to the area of smashed vehicles so that patients can be conveyed to the hospital instantly. In this work, a GPS tracker is connected to each emergency vehicle and the healing center can track all the ambulances at any time. At whatever point a healing center gets the call for an emergency vehicle, to begin with it looks for emergency vehicle vehicles that are closer to the mischance area through GPS and sends that emergency vehicle, rather than sending the emergency vehicle from the clinic. Through this scheme, the clinic minimizes the time it takes to expedite an emergency vehicle to the mishap area.

C. EMERGENCY HEALTHCARE SERVICE BEFORE REACHING THE HOSPITAL

In [8], the presenters centered on the issue of conveying the current condition of mishap casualties to the clinic framework, in arrange to create it mindful of the administrations required by the persistent and diminish the planning time expended by hospitals/doctors after the entry of the persistent at a clinic. To attain the investigate objectives, the creators have conveyed the blood weight measurements of the persistent, sound and video recordings information with respect to patient's condition from the rescue vehicle to the healing center [9]. The research was evaluated using performance parameters such as packet loss, delay and throughput for the packets sent between the ambulance and the hospital system. Although the simulations were performed to compare the performance of two IEEE standards (802.11p, 802.11b) none of these standards meets the QoS requirements for delay-sensitive tasks [10].

D. FOG COMPUTING-ENABLED EMERGENCY SERVICES

In [11], the authors proposed an architecture called Fog and Software Defined Networks (FSDN) that combines fog computing and Software-Defined Networking (SDN) for VANETs. The fog server offers the administration of roadside location for delay-sensitive emergency vehicles while the SDN is used for the over-all knowledge of the network. FSDN delivers information to the automobiles so that they can change the lane securely through the SDN controller which contains the information about the complete vehicular topology (lanes on the road) instead of deciding by itself. Consider a scenario, when an accident occurs on the road or if there is congestion or traffic jam, FSDN uses the SDN controller which contains the global information of the network can be used to offer the information to the nearby vehicles through V2V and V2I communication so that they may take an alternative route or leave the route.

E. EMERGENCY MESSAGE DISSEMINATION

In [12], the vehicles on the road are grouped into the clusters based on the driving direction. Each cluster head is responsible for the information management for that specific cluster. Nodes receiving the emergency message forward it using the carry and forward scheme. If the cluster head is moving in the direction of the accident or emergency spot, then it forwards that emergency message to its cluster members so that they may change the route. Simulation results demonstrate that packet delivery ratio increases when the number of nodes increases. The cluster head node remains as the cluster head for a more extended time because vehicles moving in the same direction are grouped into clusters. Thus, topology change and the broadcast storm are better managed. In [13] the authors have proposed a scheme called ''Road Accident Prevention (RAP)'' which uses the possibility of an emergency situation (i.e. an accident) predicted in advance, instantly RAP initiates a highway road traffic accident prevention scheme in which RSU Prediction Report (PR) is generated on the status of the vehicles based on the traffic available on the road, by using RSU's prediction, an emergency message is disseminated over the network so that nearby vehicles may reduce the speed or become aware of the situation. The proposed scheme is efficient for 4-lane highway and highway road segment is denser which achieves a low end-to-end delay between the vehicles. The authors in [10] also propose another emergency message broadcast scheme in which they group the network nodes into a number of overlapping clusters. Clustering makes a hierarchical routing in which paths are recorded within a cluster. Moreover, with in a cluster, there is no collision between the transmitted messages among the nodes. The cluster head forwards the emergency message to the cluster members about the traffic jam situation or accidents. The proposed scheme was simulated on groovenet. The authors use each node's spectrum speed as is set as 24 to 50 miles per hour, with the transmission range from 200 meters. In the limited time, the algorithm showed higher delivery ratio as compared to the other scheme like Signal Processing (SP) [14].

F. CELLULAR-BASED P2P ARCHITECTURE

In [14] and [15], the authors proposed an efficient system called D4V to sense the data near to the geographical position using traffic information system on a smartphone-based vehicular network, where nodes interact and share information in decentralized, peer-to-peer fashion. D4V relies on a P2P Overlay Distributed Geographic Table (DGT). DGT uses the concept of a virtual and physical neighbor node for application-level services which allows nodes to maintain virtual neighborhood relationships with peers located around any physical location. As all P2P approaches, the DGT allows to inform and broadcast information directly, at minimum cost and with high scalability [16]. It may also simplify the process of joining the virtual community and publishing new location-based services. The proposed system was simulated in a 4G wireless communication environment. The proposed system achieved better results in terms of disconnected nodes, peers.

G. LOCATION-BASED SEARCH

In [17], the authors proposed an efficient location-based protocol for a client-server-based service which is derived from traces of Twitter. The author used the traces of twitter to address the peer to-peer approach in which the high churn rate is caused by joining and leaving peers. Moreover, author developed a model for location-based services in which was they derived traces of Twitter, containing 22 million location-based status updates from 220,000 users [17]. The protocol provides a realistic placement of peers and generation of location-based search requests in simulations. The proposed P2P protocol achieves a 46% packet delivery ratio and incurs 18% higher traffic overhead.

In [11], the authors identified the two major drawbacks related to location-based services. The first drawback is the P2P overlay does not store data persistently and the second drawback is that it does not allow the fast retrieval of large files. These limitations prevent the user from sharing large files with high resolutions. The authors proposed the new protocol to address the GeoSwarm problem they do not allow for the fast retrieval of large files, especially under asymmetric link conditions. This immensely limits the use of current and future P2P location-based services as users are not able to share larger files such as high resolution pictures or video snippets. This protocol combines the strengths of Bit Torrent like content distribution overlays with locality awareness of location-based search. GeoSwarm achieved 95% of all download files are carried under churn, while downloads benefit from a 100% increased throughput in comparison to traditional single-source downloads.

We reviewed vehicular networks papers published between 2015 and 2018. In the existing literature, various protocols have been proposed in which sensors are attached to RSUs which sense the emergency vehicle and calculate its distance from the RSU using a distance calculation algorithm. Some existing schemes proposed the concept wherein a GPS tracker is attached to each vehicle to locate the ambulance which is in close vicinity of the accident area and sends it to the location of the crashed vehicle [18], [19]. Moreover, the hospital can track all the ambulances and in this way the hospital saves the time it takes for the ambulance to arrive at the accident location. Many researchers [20], [21] have proposed the concept of fog computing and SDN in which information is provided to the vehicles nearby the accident area through V2V and V2I communication so that they may take an alternative route to clear the route for the emergency vehicle [22]. Table 1 shows different techniques (based on routing schemes used) that have been proposed for traffic accident prevention and avoidance. Based on the limitations of the routing schemes presented in Table 1, we propose a situation awareness approach considering human and vehicle interaction to minimize the delay in dispatching an ambulance to an accident scene.

III. PROPOSED METHODOLOGY

Based on the literature review above, we found that most V2V based approaches which deal with emergency situations cause congestion and, as a result, an ambulance may not arrive on time which can lead to loss of life [23]. Although, there are many protocols which only deal with Vehicle to RSU (V2I) communications to mitigate the congestion of vehicles but they also need to focus on bandwidth of the network which can cause network congestion and increase in latency [23]. Moreover, a number of researchers presented the concept of fog computing and SDN in which information is provided to the nearby vehicle through V2V and V2I communication. Hence, the emergency vehicle takes another route. Whereas, the existing research papers neither consider the rest of the entities which resides on the road like social services (Twitter and Facebook) nor provide the social awareness of the occurrence of accident to the hospital, people and RSUs around the accident area. Based on the discussions above, we need a protocol that addresses this challenge to provide the social awareness via social media with minimum delay.

Social media that plays a very vital role in vehicular networks. To provide social services, a device must be connected with cellular infrastructure. Also, through social media many vehicles on the road can share a lot of useful content on board that can be shared and posted with other vehicles, and pedestrian by using social services. However, there is a lot of possibility that driver is concentrated on road, but they do not share or report any information such an accident while driving [24]. So, the uniqueness of the proposed protocol is to provide the social awareness via social media (Twitter, Facebook). Moreover, we take all entities such as people, smartphone, and social media which are not mostly detectable from traditional network into consideration. In our proposed protocol we have introduced the post notification system which displays on the screens of user by using social media services. When an accident occurs, information is posted successfully via social media and the posted notification generates a sound to inform the driver about the accident event and the alternative route will be re-calculated. People can provide access to the relevant and timely information to the individuals in an accident area. It is logical that people walking on the road cannot constantly check the social media application, but the goal

TABLE 1. Literature review of traffic accident prevention and avoidance schemes based on routing scheme.

Year	Goal	Tools	Evaluation parameters	Contributions	Limitation
2015 [8]	• To make emergency vehicle reach destination in shortest time	SUMO NS-2 MOVE	End-to-end delay	• Delivers emergency packet from emergency vehicle to traffic signal at low end-to-end delay	• No comparative performance results. • Flooding limits the network throughput.
2015 [11]	• To create an exceedingly solid and delay delicate framework for VANE	————	————	• Provides the benefits of both SDN and Fog computing with VANETS	• The proposed framework isn't mimicked in real scenario and isn't assessed against parameters
2015 [13]	• To disseminate the emergency message in VANET clusters	NS-2	Packet delivery ratio. Delay	• Delivers the emergency message in less time.	• The vehicle validation is not carried out. • The role of proposed scheme in emergency service provision to victims is not addressed
2016 [7]	• To clear the path for ambulance at shortest most limited time	NS-2	End-to-end delay. Residual energy throughput	• Provides route clearance for emergency vehicle at high throughput and low end-to-end delay	• Requires the expensive acoustic sensors to be deployed on RSUs.
2016 [6]	• To deliver ambulance service at accident spot in short time	GPS module IDLE Arduino	————	• Hospital saves time of ambulance arrival at the accident location by sending the ambulance which is nearest to the accident spot	• No experimental results. • No evaluation parameters. • Traffic congestion on the road, near to the accident spot, is totally ignored which might cause the ambulance to reach the spot with high delay.
2017 [10]	• To deliver the current state of victim to the hospital before the patient is arrived to hospital	NS-3 SUMO	Packet loss Delay Throughput	• Delivers audio, video and blood pressure information to the hospital • Comparative analysis of IEEE 802.11 standards under three evaluation parameters	• Cannot achieve required QoS
2017 [12]	• Aim to reduce the accidents on highway roads	NS-2	End-to-end delay Network processing overhead Reception rate	• Reduces the end-to-end delay	• High network processing overhead

of our protocol is to least inform them about the occurrence of an accident [24]. So, our proposed protocol contributes to saving human lives by communicating timely information to the nearest vehicles or people who walk along the road using social media. After, an accident occurrence, the social entities interact with the other people through social media and send all date to the fog computing. Furthermore, the similarity between existing and the proposed protocol is to connect Fog based RSUs with the vehicles. Fog based RSUs communicate with the vehicular node to take information and store on the edge of the network or at the central server (cloud). Fog computing is the best source that provides the huge benefit to deal with the real time emergencies and natural disasters.

This paper proposes a new methodology to rescue the affected person in minimum time. The proposed protocol utilized the fog-based computing strategyU in which headers of data packets are modified to provide the efficient communication between cloud to fog enabled RSUs, V2V and people who are walking or driving near to the accident areas with fog based RSUs. There are many message dissemination protocols that have been proposed for VANETs [25]. However, their operations differ in terms of broadcast mode. There protocols are categorized into counter-based scheme, location-based scheme, distance-based scheme, and cluster-based scheme which address the broadcasting storm issue [26]. However, in [27], [28], the authors use broadcast mode at every hop, and they ignore the duplicated messages and they also used periodic hello messages which leads to a broadcast storm. Consequently, a broadcast storm is not addressed is later works discussed. In this context, we introduce some entities and several assumptions that enable the smooth operation of our proposed routing protocol are as below.

A. ENTITIES

The entities are involved in the proposed fog-based computing strategy are as follows:

1) SMART VEHICLES

In VANET paradigm, every vehicle is prepared with On Board Unit (OBU) in arrange to communicate with the other vehicles and the Road Side framwork e.g., the RSU. In this way, each smart vehicle gets better awareness of their surrounding through RSUs and other vehicles and response in time in some situation like traffic accidents.

2) TRUSTED AUTHORITY (TA)

The Trusted Authority (TA) basically acts as an administrative authority. RSUs, mobile devices, and vehicles are already registered with the trusted authority which assigns them unique identifiers. Moreover, the trusted authority keeps all the records of the registered entities which are accountable to it.

3) GOVERNMENT AUTHORITY (GA)

The Government Authority (GA) acts as a passive entity and it is not directly part of the implementation of the proposed protocol. However, if a non-registered vehicle or mobile device enters the vicinity of any RSUs then it should not affect the security of the VANET paradigm.

B. DIFFERENCE BETWEEN TRADITIONAL RSUS AND FOG ENABLED RSUS

RSUs are Road Side Units and they are intelligent entities for taking care network activities. In VANETs paradigm RSUs communicate with the vehicle. Traditional RSUs keep the information of those smart vehicles, which are moving in its transmission range. In case of any event occurrence, the RSU sends warning message to the other RSUs and vehicles in its vicinity. However, we extended the scope of the RSU in traffic information and each RSU behaves like a fog node. The range of fog enabled RSUs contain is 1000-1500m, whereas the traditional RSUs only have a range 400-600m [29], [30]. Moreover, the Fog enabled RSU provides the storage computation and services to the edge of the network within proximity to provide the real time services. Table 2 presents the differences between traditional RSUs and Fog based RSUs in detail.

C. ASSUMPTIONS

All mobile devices and smart vehicles must be equipped with Global Positioning System (GPS) technology in order to get the exact location information.

I. All RSUs, mobile devices, and vehicles must be registered with the TA.
II. RSUs' data cannot be modified and the data is not affected by a malicious attack. Basically, the entity cannot be compromised.

ARCHITECTURE OF SOCIAL AWARENESS

The integration of the VANETs with the fog computing widens the area of the different possibilities regarding services and applications on the edge of cloud computing. Any device with the network connectivity, storage and computation can be a fog node. In VANET environment, the fog node closest to the network edge consumes the data from different type of devices. In our proposed methodology we used RSUs in two ways. Firstly, we take a traditional RSU, which obtains the information of vehicle and accident location etc., and Secondly, the data taken from the traditional RSUs are offloaded and stored into the fog enabled RSUs. Fog enabled RSUs are used to keep the information, stored for the future use. We have considered RSUs as fog nodes and these are supposed to further be connected with the cloud or central server. The benefit of the usage of the fog enabled RSU is to extend the scope of RSU in terms of range, storage, computation and services. Smart vehicles are equipped with communication devices to communicate with the other vehicles and the fog-based RSU to take appropriate actions based on the received message.

This communication is used to broadcast safety information to the fog-based RSU's closest vehicles (up to one hop neighbor) in real time. The purpose of broadcast safety information is to alert drivers to undertake early countermeasures against any uncertain circumstances. Each vehicle is also equipped with storage and high computation unit. However, maximum times these units start malfunctioning to fully utilize. So, cloud computing is the best way to utilize VANETs resources efficiently and effectively. Our proposed methodology presents a three-layered vehicular network i.e., network layer, fog layer and cloud layer. Different devices like smartphones, vehicles, social services such as Facebook, Twitter and people collect the various information including speed, location, emergency area and accident etc. They then upload the data through V2I communication, and store at fog enabled RSU nodes. The Fog enabled RSUs located at the edge of the network and connected furtherly with the cloud or central server adopting a ''fog-cloud'' collaborative storage and computation methodology to provide a real service effectively and efficiently with less delay as Figure 2 shows. Here, we suppose the vehicles request contents from fog enabled RSUs and if there are unable to serve then the request they are forwarded to the cloud. Moreover, these RSUs also regularly update the content from cloud thorough synchronization.

D. SOCIAL AWARENESS METHODOLOGY

In the proposed methodology, each (traditional) RSU obtains the related information such as vehicle's location, speed, driver or passengers behavior, victims personal contacts, accident size and location, availability of emergency vehicles, route for emergency vehicles from nearby RSUs, shops, offices, filling stations, police stations, hospitals, clinics, cinemas, ambulances, fire brigades, and bomb disposal squads, etc. These data are offloaded and stored in fog node.

TABLE 2. Differences between Fog-based RSUs and Traditional RSUs [31].

Fog based RSUs	Traditional based RSUs
Fog based RSUs efficiently monitor and gather data (such as traffic conditions) by using sensors. They efficiently organize, store, and process instantaneous traffic data to avoid delays especially when they execute delay sensitive tasks.	Traditional RSUs monitor, gather and store data but they do not efficiently process and filter instantaneous traffic information from a large amount of the data especially when processing delay sensitive tasks.
In case of an emergency, content is sent/uploaded on the Fog based RSUs. For instance, consider a scenario wherein the driver is driving faster than the expected speed. In this case, the Fog-based RSUs have a global access perspective that covers a wide area (all the possible vehicle locations) with additional bandwidth to handle accidents.	In traditional RSUs, a vehicle will pass by the RSU and collect the emergency content while being within the range of the RSUs. However, the bandwidth and global perspective of the RSU is limited. Moreover, if the driver is driving faster than the expected speed, then the delay sensitive content may not be delivered at the RSU at the proper time.
Fogs based RSUs can communicate with hospitals, ambulances, nearby volunteers, relatives of those involved in accidents, and the current situation of the road. They can provide different types of instructions to be followed in order to maintain smooth traffic flow and reduce the chances of death. They also assist the vehicle to access the current positions of road junctions and analyze the direction of packet movement toward the destination nearby a certain junction point.	Traditional RSUs do not cover hospitals, ambulances, volunteers, and relative. They only send notification to the vehicles and other RSUs. Also, they use a store-and-forward message mechanism. In a store-and-forward message mechanism, if road conditions are not updated on time drivers may be guided to erroneous routes when a traffic accident occurs.
Fog based RSUs are straightforwardly linked with the cloud that permits much bigger storage capacity and makes a difference in keeping up a history of already prepared cases that can be retrieved on an on-demand basis. It shares communication resources locally that includes both Geo-distribution characteristics and local decision making to minimize delay due to virtualized computing and communication facility at the proximity of closed nodes such as vehicles.	Traditional RSUs contain limited storage capacity which is why they do not maintain a history of previously processed data. In case of emergency, if RSUs do not contain the previously processed data that can be accessed in the near future, it means that RSUs cannot make a local decision efficiently especially for time-sensitive applications.
Fog based RSUs extract the position information of specific vehicles, lane number of vehicles based on pre-assigned road segments of that region and also get some sensitive information related to emergency due to the wide coverage of the RSUs.	Traditional based RSUs learn the position of vehicles, lane number based on pre-assigned road segments of the specific region but they do not cover all the possible positions of the vehicle due to the limited coverage of the RSUs.
Fog based RSUs use location awareness and spatial crowdsourcing to collect real time information as well as provide real time navigation services to drivers of ambulances, vehicles on the road, hospitals, volunteers and relatives who need to be informed to get to the location smoothly and safely.	Traditional RSUs are not efficient in using spatial crowdsourcing to collect real time information based on the previous history already stored in them.
Fog based RSUs provide services at the edge of the network within the close vicinity of the vehicles.	Traditional RSUs provide services in a distributed manner.

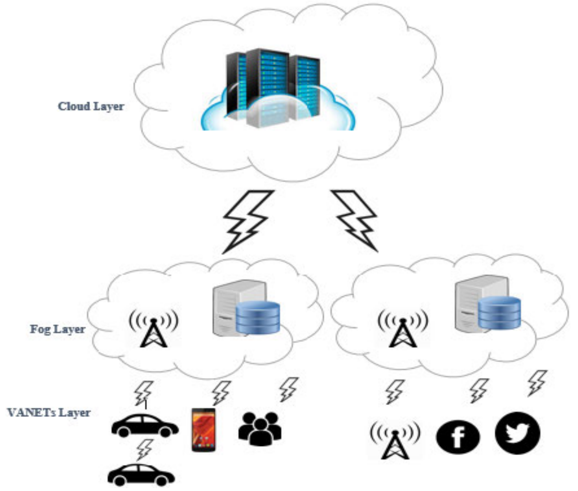


FIGURE 2. Architecture of social awareness in a vehicular environment.

Fog nodes are here RSUs in which information is stored for the future perspective. Note that these fog nodes share the information with each other to support on demand emergency response for the victims and other vehicles. Thus, when there is a danger of an accident on the road, the nearby fog-enabled RSU can decide the appropriate action based on the information it stores as Figure 3 shows. These fogs-enabled RSU can inform far-ended traditional RSUs to guide their respective vehicles to adopt alternative paths with the appropriate guideline in order to avoid any inconvenience caused due an accident or danger. On the other hand, the fog-enabled infrastructure can determine the size of an accident or danger and informs the respective agencies, helpline, hospital with appropriate emergency requirements, number of ambulances needed. They infrastructure can use social media such as Facebook, twitter, and WhatsApp, to request pedestrians to provide them proper emergency-treatment guidelines for helping the patients or saving the nearby infrastructure accordingly. In order to transport the messages, the broadcasting is one of the primary tasks in any traditional wireless networks.

Nevertheless, due to high mobility issues in VANET, wireless links become unreliable. Therefore, the broadcasting of messages in VANETs needs to be handled using some particular technique that is different from handling the messages in other traditional wireless networks. As intended for the challenge as mentioned above, we propose an efficient broadcasting technique that provides an optimum section to ensure the network more reliable and efficient. Thus, our

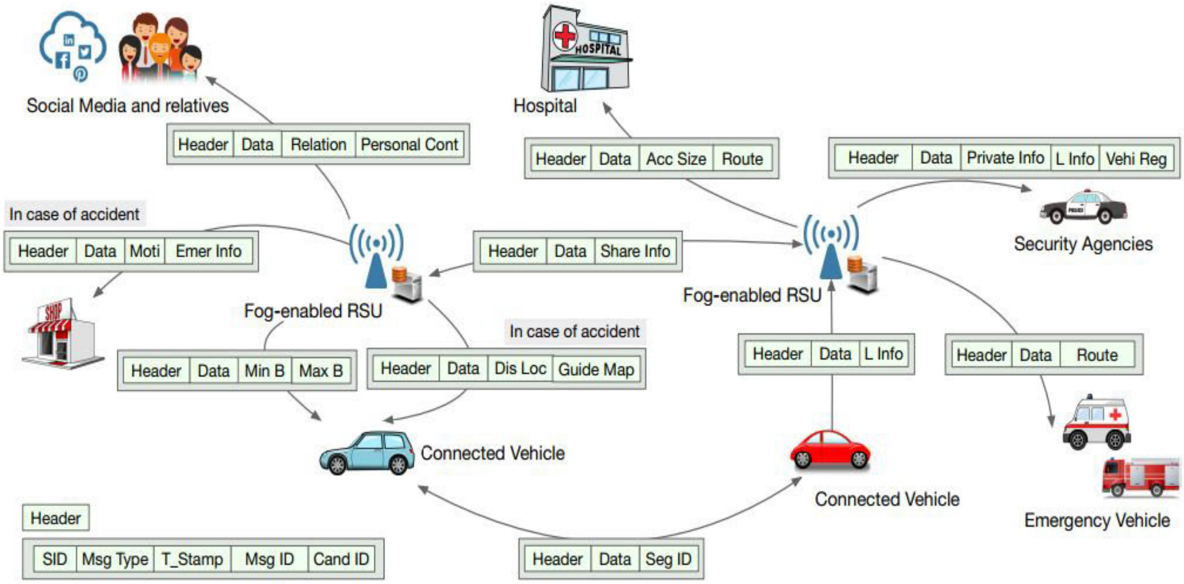


FIGURE 3. The format of the messages circulating over the network of the messages circulating over the network. In the header, for all messages contains sender ID (SID), message type (Msg Type), time stamp for the message (T-Stamp), message ID (Msg ID), and destination ID (De ID). At first, the fog-enabled RSU sends a message that contains minimum (MinB) and maximum boundary (MaxB) information of the segment to the connected vehicles. The connected vehicles upload the location information (L Info) with latitude and longitude to the fog-enabled RSUs. The connected vehicles can share the segment ID (Seg ID) with each other. Further, RSU share information (Share Info) to the others RSUs. Moreover, the RSU can send personal information (Private Info) and location information (L Info), and vehicular registration (Vehi Reg) to the security agencies in case of emergencies. Furthermore, the fog-enabled RSU sends family and friend-relation information (Relation) and personal contact (Personal Cont) to social media to inform them in an emergency situation. The hospitals obtain the message that contains accident size (Acc Size), and location information including the route details (Route) to the emergency situation. When an accident occurs, the RSU sends the disaster location (Dis Loc) and guide map for the alternative route (Guide Map) to the other vehicles as well as motivation information (Moti) and emergency information (Emer Info), i.e., tips for the recovery to the nearby person, shop, and other available infrastructure.

design offers high reliability with reduced latency in both single and multi-hops communications. It further minimizes the problem of collision occurred due to a large number of broadcasting messages over the network, hidden node problem, and the lack of feedback. In the proposed scheme, each fog node makes a logical group (say, segment) comprising of nearby vehicles. The primary objective of this division is to minimize the communication and control message between vehicle-to-vehicle (V2V) and vehicle-to-RSU (V2R) which directly reduces the number of broadcast messages over the network. Also, the security perspective can be carefully considered in the segment; however, this is beyond the scope of this article. If a vehicle asks for any related information such as road condition, traffic flow, and location or size of the road-side accident from the RSU, the request will be fulfilled, and at the same time, it would be published to other vehicles for further usage. When the other vehicles of the same segment need the related information, the already published information can fulfill their request from that connected vehicles within the segment instead of requesting the RSU. Furthermore, the vehicles forward the information to other vehicles, which has been the part of the segment for a long time. With the partial knowledge of the global network, the fog nodes give an illusion of a single network to the connected vehicles, RSU, human, and other connected infrastructures such as a hospital, security agencies, and nearby shops. At first step, a vehicle is registered to a fog node after proper authentication. The fog server obtains the access to the passengers ‘drivers’ social networks and other relevant information about the vehicle from the vehicle’s service center and vehicle’s manufacture.

E. TOPOLOGY SCENARIO

Next, we describe the experimental scenario where vehicles communicate with each other by using beacon messages. Each vehicle shares its vehicle Id, speed, direction, sender ID (SID), message type (Msg Type), time stamp for the message (T-Stamp), message ID (Msg ID), and destination (Destn) as shown in Figure 4. A Fog based RSU is a resource entity that keeps the information about vehicles and the infrastructure. Smart vehicles also upload their location latitude and longitude information to the fog-enabled RSUs as shown in Figure 4. In the current setup for vehicular networks, Fog based RSUs are used to manage delays and routing tasks especially in the case of an emergency. Similarly, they are also commonly used for reducing delays caused by direct data exchanges with a cloud server. A Fog based RSU extracts the position parameters shared by a smart vehicle to collect further information about the RSUs mounted in the specified region. A Fog based RSU identifies the direction and the lane number of vehicles based on minimum (MinB) and maximum boundary (MaxB) information of that region. Finally, it provides emergency information to other RSUs and

Beacon message

Vid	Speed	Direction	Sender-id	Message-type	Time-stamp	Message-id	Destination
1	50	West	2	emergency	12:00	1	West

Interest packet

RSU-id	Vid	Content-id	Destination	Longitude	Latitude	Route	Message-type
1	1	1	West	103	145	south-west	Emergency

Data packet

RSU-id	Vid	Content-id	Destination	Longitude	Latitude	Route	Content	Message-type
1	1	1	West	103	145	highway	Complete	emergency

Rescue packet

RSU-id	Vid	Content-id	Message-id	Destination	Route	Message-type
1	1	1	1	west	south-west	Emergency

Emergency message

Vid	Speed	Destination	Route	Message-type	Longitude	Latitude
1	70	west	south-west	emergency	103	145

Congestion message

RSU-id	Speed	Direction	Route	Message-type	Longitude	Latitude
1	70	west	south-west	emergency	103	145

FIGURE 4. Proposed protocol table header.

precautionary measures to vehicles that are approaching an emergency.

In the case of an emergency, the Emergency Message is broadcast to the nearest Fog based RSU and smart vehicles. The RSU maintains an entry for the broadcast message and forwards an interest packet including location information and route details (Route) to a hospital in its vicinity (as shown in Figure 4). Next, the hospital checks its resources and sends the rescue message to the ambulance which immediately analyzes the direction and extracts the accident's location using the destination id, time-stamp, latitude and longitude and route information received in the rescue message as Figure 4 shows.

The Fog enabled RSU also broadcasts an emergency message to other traditional RSUs and vehicles to clear the specific affected location, which helps the ambulance to reach the accident area on time and rescue the victims with a minimum delay. Moreover, the Fog based RSU also alerts the traditional RSU by considering the human interaction (involvement of human beings for interacting with the vehicles) and crowding (social interaction-existence of populated residential areas) chances based on the previous history of that area and the presence of populated commercial areas. In addition, Fog based RSUs inform nearby RSUs (both traditional and Fog enabled) to alert only smart vehicles approaching that region. This will also help to reduce the probability of further accidents and damages. The Fog-enabled RSU requests the cloud server to upload information about the emergency situations and also sends family and friend-related information (Relation) and personal contact (Personal Cont) to social media to inform them about the emergency situation. It also sends messages to registered vehicles in its vicinity to limit the amount of additional information with next RSUs because of the emergency situation. This means that the event has already been noted and rescue efforts have been initiated. Furthermore, it minimizes the communication overhead and message broadcasting storm in the entire network. In a highway scenario, the number of vehicles is divided into the remaining lanes to avoid traffic congestion. The RSU employment the acquired signal message to choose the course or path in which the activity will be occupied. After emergency message has been gotten by vehicles within the same path, all vehicles move to other paths and the vehicles which are close to the influenced region alter their paths. This enables the ambulance to reach the location of the accident faster. After the rescue process is completed, the ambulance unicasts data packets to the Fog based RSU, which then broadcasts the message to delete all the entries from the RSU as Figure 4 shows. Traffic then resumes normal operations. This topology focuses more on the V2I scenario than on the V2V scenario. However, consider a scenario of V2V wherein there is no RSU in the range of the smart vehicle. In this case, the vehicle broadcasts the message in its vicinity up to one hop until it reaches a Fog based RSU.

The Fog enabled RSU then responds to that smart vehicle. Moreover, smart vehicles act as a good message carrier to transmit information to other vehicles by using intermittent connectivity and dynamic network topology to make new connections continuously. The Fog enabled RSU also communicates with the cloud server to upload or access data related to a region, road, segment and vehicle's direction. In Algorithm 1, after the occurrence of an accident, the RSU receives an emergency message and examines the message type. If message type is an emergency, then the Fog enabled

Algorithm 1: Emergency Message and Traffic Management System

```
procedure Emergency System(RSU, Hospital);
Input: Emergency;
if $Beacon = True$ then
    RSU extracts $V_{id}$;
    if $V_{id}$ is registered then
        if $Msg - Type = Emergency$ then
            Broadcast Emergency message to the nearest RSUs and Vehicles to move out from the effected lane;
            RSU sends Emergency Message to Hospital;
            RSU sends emergency message to family, friends and personal contacts on their mobile phone;
            if Hospital is registered then
                RSU send Interest to the nearest Hospital;
                Hospital extracts Message-type and $V_{id}$;
                Hospital send Rescue Message to Ambulance;
                if $EmergencyMessage = Ambulance$ then
                    Ambulance extracts Rescue Message;
                    RSU wait for some period and monitors velocity;
                    Wait for T-period;
                    Congestion Message and count = 0;
                    if After some T-period, RSU send T-alert then
                        Broadcast congestion message to Ambulance when it is in the range of the fog enabled RSU;
                        Identify high traffic load in the affected area;
                        Count+1;
                    else
                        Not do anything;
                        if $count \geq$ T-alert then
                            Send congestion alert message to the last fog enabled RSU to reroute the ambulance;
                        else
                            Wait for Congestion End Message;
                        end
                    end
                else
                    Broadcast Emergency Message to other vehicle to move out form the affected area;
                end
            else
                Ambulance extracts RescueMessage;
                RSU wait for some period and monitors velocity;
            end
        else
            Broadcast Emergency Message to other vehicle to move out form the affected area;
            Ambulance Rescue Victims;
            if $RescueMessage = TRUE$ then
                Hospital send D-Packet to the RSU Remove all entries;
                Send end Rescue Message to the previous RSU and Vehicles means rescue process is complete;
            else
                Send to TA
            end
        end
    else
        Send to TA
        if $V_{id}$ is registered then
            Send verification message to RSU;
            Go to Line 3;
        else
            Contact to GA;
        end
    end
else
    Do Nothing;
end
```

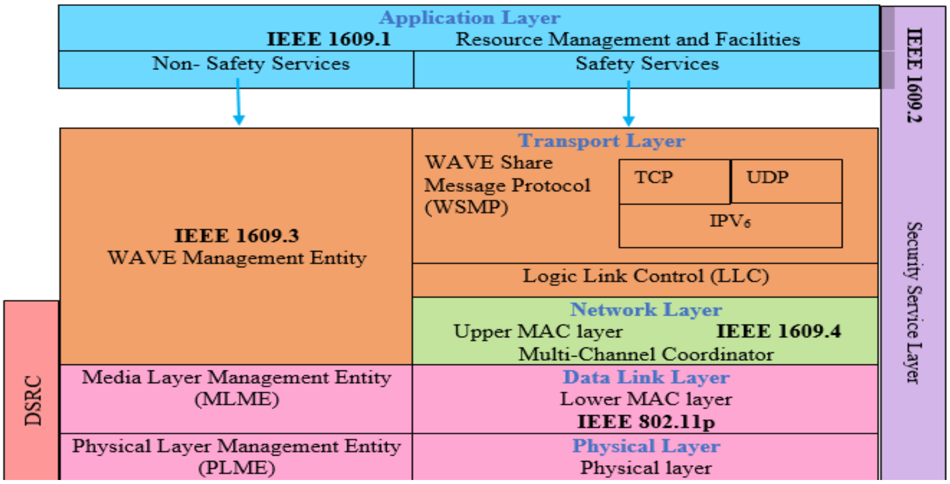


FIGURE 5. WAVE architecture for IEEE 1609 and 802.11p.

RSU broadcasts an emergency message to the nearest RSU so that vehicles move out of the affected lane and also unicasts an interest message to the registered nearest hospital for assistance. The RSU also informs family, friends and personal contacts on the person's mobile phone to inform them about the emergency situation. The hospital receives this information and sends the rescue message to the ambulance which analyzes the route, longitude, latitude, and destination information. It then starts the rescue process. While the ambulance is going to the affected area, the RSU also monitors the traffic congestion, and after some time period if a high traffic load is identified then the RSU sends a time alert (T-alert) message to the previous RSU after 3 or 5 seconds to reroute the ambulance. After the completion of the rescue process, the hospital sends a Data Packet (D-Packet) to the RSU. The Fog enabled RSU receives the D-Packet and removes all the entries, which means normal flow of traffic starts again.

IV. PERFORMANCE EVALUATION

We evaluated the performance of the proposed routing protocol and analyzed it by using the real time simulation tool Simulation of Urban Mobility (SUMO) integrated with NS-2.35 [30], [31]. Moreover, the proposed protocol uses an 802.11p based MAC layer to access the wireless channel in the VANET environment [32], [33].

The Wi-Fi 802.11p standard is dedicated for VANETs. To implement it in a vehicular environment, the WAVE architecture was developed for IEEE 802.11p [34]. This standard works as a DSRC on Physical and Data Link (MAC) layers for high reliable vehicle communications as Figure 5 shows. Furthermore, DSRC also provides minimum delay of communication and data transmission in the entire network. IEEE 802.11p defines the lower part of MAC layer [34], [35]. Whereas the standard IEEE 1609 represents the upper part of MAC layer as Figure 5 shows.

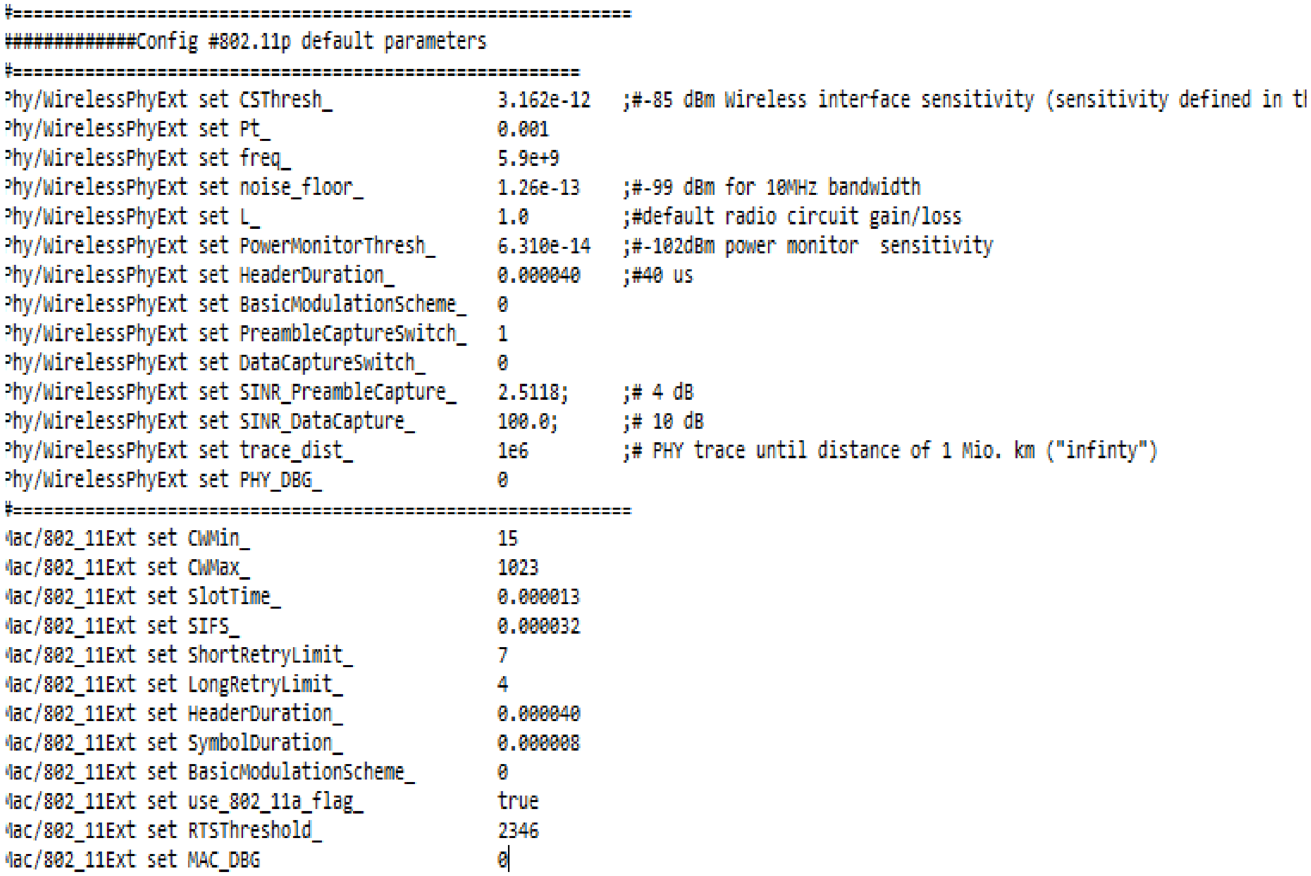
In VANETs, IEEE 802.11p is combined with IEEE 802.11a (with small modifications) to achieve Quality of Service (QoS). Furthermore, two modules are also used: i) MAC 802.11 Ext and ii) Wireless Physical-Ext based on the IEEE 802.11p standard. The goal of this standard is to support Intelligent Transportation System (ITS) applications in NS-2.35. We have used MAC 802.11 Ext and Wireless Physical-Ext to configure the VANET environment in NS-2.35. The frequency of the Phy/WirelessPhyExt parameter used ranges from 5.85 to 5.92 GHz [33], [34]. This frequency is used for high data transmissions.

The access categories of 802.11p are implemented in NS-2.35 as Figure 6 shows.

SUMO is a free open-source simulator to simulate vehicular traffic [30]. To implement a realistic highway scenario, we obtained the mobility file of the real time traffic for the vehicular environment over the highway network by using SUMO as Figure 7 shows. Next, the resultant mobility trace file is imported into the TCL file in which the proposed protocol is implemented.

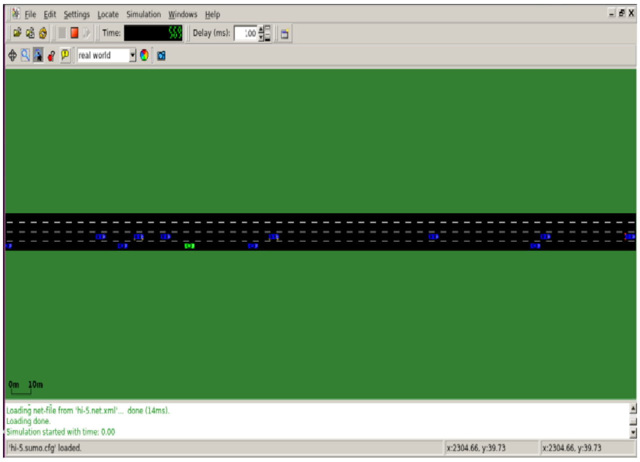
The 6 km length of highway is divided into 4 lanes. All vehicles are equally distributed along the road lanes at the beginning of simulation. We have used AODV routing protocol for sharing information and effective communication. Furthermore, the protocol simulation used a 2000$*$2000 m2 grid map with different numbers of vehicular nodes (i.e. 50-80). All vehicular nodes are generated and deployed randomly using the Random Direction Mobility Model with velocities ranging from 60 km/h to 90 km/h [35]. The velocity threshold (65 km/hr) enables the RSU to maintain a map between the identity and the location of each vehicle moving in its range. Figure 8 presents the operation of our proposed scheme.

In the proposed protocol we assume that all vehicles are equipped with GPS technology to communicate with the RSU, people, hospital, and security agencies. Moreover, Wireless Access in Vehicular Network (WAVE or IEEE 1609.4) and Dedicated Short Range Communication (DSRC



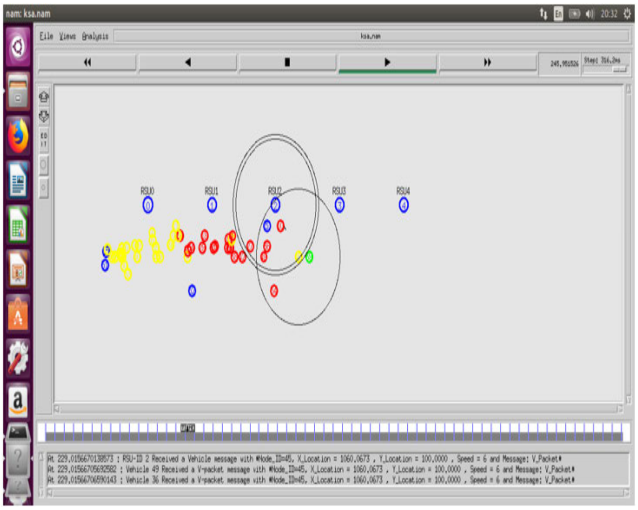
```
#=============================================================
#############Config #802.11p default parameters
#========================================================
Phy/WirelessPhyExt set CSThresh_            3.162e-12   ;#-85 dBm Wireless interface sensitivity (sensitivity defined in tl
Phy/WirelessPhyExt set Pt_                  0.001
Phy/WirelessPhyExt set freq_                5.9e+9
Phy/WirelessPhyExt set noise_floor_         1.26e-13    ;#-99 dBm for 10MHz bandwidth
Phy/WirelessPhyExt set L_                   1.0         ;#default radio circuit gain/loss
Phy/WirelessPhyExt set PowerMonitorThresh_  6.310e-14   ;#-102dBm power monitor  sensitivity
Phy/WirelessPhyExt set HeaderDuration_      0.000040    ;#40 us
Phy/WirelessPhyExt set BasicModulationScheme_  0
Phy/WirelessPhyExt set PreambleCaptureSwitch_  1
Phy/WirelessPhyExt set DataCaptureSwitch_   0
Phy/WirelessPhyExt set SINR_PreambleCapture_   2.5118;     ;# 4 dB
Phy/WirelessPhyExt set SINR_DataCapture_    100.0;      ;# 10 dB
Phy/WirelessPhyExt set trace_dist_          1e6         ;# PHY trace until distance of 1 Mio. km ("infinty")
Phy/WirelessPhyExt set PHY_DBG_             0
#=============================================================
Mac/802_11Ext set CWMin_                    15
Mac/802_11Ext set CWMax_                    1023
Mac/802_11Ext set SlotTime_                 0.000013
Mac/802_11Ext set SIFS_                     0.000032
Mac/802_11Ext set ShortRetryLimit_          7
Mac/802_11Ext set LongRetryLimit_           4
Mac/802_11Ext set HeaderDuration_           0.000040
Mac/802_11Ext set SymbolDuration_           0.000008
Mac/802_11Ext set BasicModulationScheme_    0
Mac/802_11Ext set use_802_11a_flag_         true
Mac/802_11Ext set RTSThreshold_             2346
Mac/802_11Ext set MAC_DBG                   0
```

FIGURE 6. Configuration of 802.11p in NS-2.35.



```
Loading net-file from 'hi-5.net.xml'...  done (14ms).
Loading done.
Simulation started with time: 0.00
'hi-5.sumo.cfg' loaded.
x:2304.66, y:39.73
x:2304.66, y:39.73
```

FIGURE 7. Highway scenario using SUMO.



```
At 229.0156670138573 ; RSU-ID 2 Received a Vehicle message with #Node_ID=45, X_Location = 1060.0673 , Y_Location = 100.0000 , Speed = 6 and Message: V_Packet#
At 229.01566705692582 ; Vehicle 49 Received a V-packet message with #Node_ID=45, X_Location = 1060.0673 , Y_Location = 100.0000 , Speed = 6 and Message: V_Packet#
At 229.0156670659143 ; Vehicle 36 Received a V-packet message with #Node_ID=45, X_Location = 1060.0673 , Y_Location = 100.0000 , Speed = 6 and Message: V_Packet#
```

FIGURE 8. Proposed protocol simulation by using NS-2.35.

or IEEE 802.11p) achieve a transmission range of 600 meters in the vehicular environment [35].

Moreover, the fog-based RSU constantly observes the traffic behavior on the road and forecasts the accident rate on the road. If there is any possibility of high road congestion or accident, it disseminates emergency messages to vehicles and RSUs in its proximity so that the vehicles may reduce their speeds or take some other route to their destinations. We ran the simulation test fifty times for each vehicle density (number of vehicles) parameter and we computed the average results as the results below show.

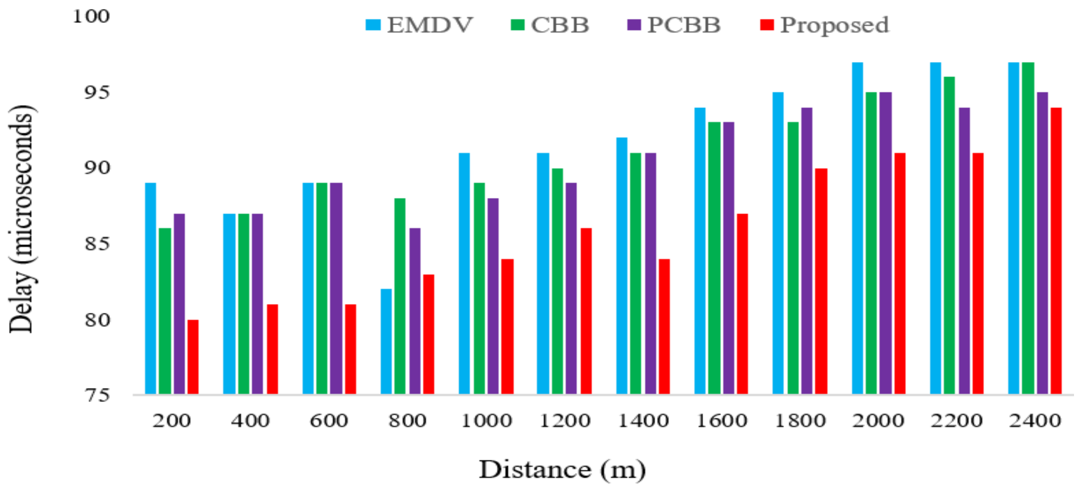


FIGURE 9. Average delay to receive emergency response message.

TABLE 3. Simulation parameters.

Network simulator	NS-2.35
Transmission range of RSU	600 m
Total number of vehicles	50-80
Packet size	1024 bytes
MAC layer	IEEE 802.11p
Total number of lanes on highway	4
Propagation model	Two-way ground/propagation
Velocity threshold	60 km/hr

Table 3 presents the simulation parameters we used in our performance evaluation tests.

A. PERFORMANCE EVALUATION METRICS

We evaluated the performance of our proposed scheme using the following performance metrics: average delay, channel collision, and number of tasks managed at the cloud.

1) AVERAGE DELAY

Average Delay is the time taken by the RSU to send the emergency message to the vehicle when two vehicles cannot maintain the predefined threshold distance between each other.

Average Delay = Sum of all Emergency Messages' Delays/ Total No. of Received Emergency Messages.

2) CHANNEL COLLISION

VANET sends emergency and safety messages through a channel with limited bandwidth, which causes an increase in the number of collisions in the channel.

3) NUMBER OF PACKETS RECEIVED

Total number of data packets successfully received at the end of the transmission.

4) END-TO-END DELAY (E2E)

Average time required for the data packets to be delivered from source to the destination.

E2E $= \sum$ (arrive time $-$ sent time) / $\sum$ Total number of delivered packets.

5) ROUTING OVERHEAD (ROH)

Routing overhead is the number of packets that needs to be routed during network communication.

6) PACKET LOSS

This the difference between the numbers of data packets sent from the source and the number of packets received by destination.

Data packets lost = Number of packets sent$-$Number of packets received

7) EMERGENCY MESSAGES (EM)

The emergency messages show the number of messages transmits from RSU to the vehicle or vehicle to vehicle.

V. RESULTS AND DISCUSSION

In the research paper, the performance of the proposed scheme in terms of end-to-end delay and channel collision with three well known emergency message broadcasting protocol namely, Emergency Message Dissemination for Vehicular (EMDV) protocol [36], Contention Based Broadcasting (CBB) [37] protocol, and Particle Swarm Optimization Contention-based Broadcast (PCBB) [37], [38]. The simulations were performed using NS-2 with the parameters listed in [37], [38]. Each of the results was averaged over at least 100 different runs. Figure 9 illustrates the channel

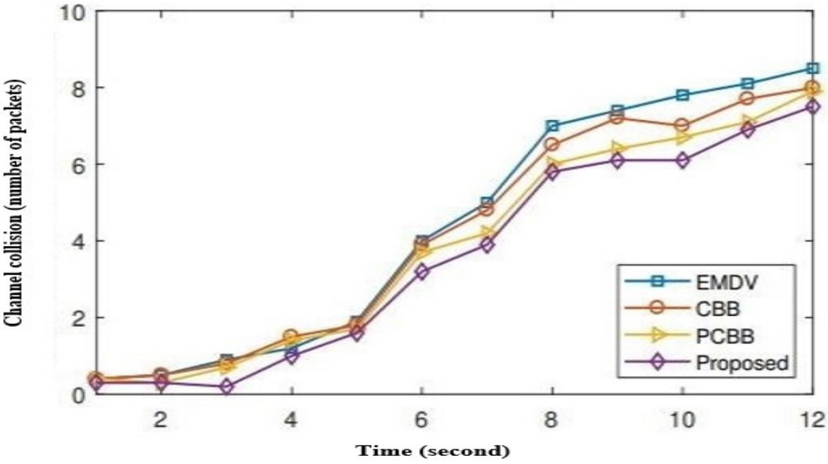


FIGURE 10. **Performance of channel collision with respect to time.**

collision regarding number of packets occurs due to the four schemes. Our proposed scheme outperforms the PCBB, CBB, and EMDV due to the handling of each message type as per its demand and severity. Although the collisions produced by PCBB, CBB, EMDV, and proposed scheme are same at the beginning; our proposed protocol significantly performs better than previous approaches when the number of emergency messages circulating over the network increases.

The proposed scheme exhibits reduced end-to-end delay due to the advantages of intelligent fog node compared to PCBB, CBB, and EMDV protocol using the DSRC communication over the distance of 2400m as shown in Figure 7 [38], [39]. It overcomes the problem of broadcasting and rebroadcasting in previous schemes by supporting Infrastructure-to-infrastructure communication for handling emergency and other communication that is required to be carried out in the network instead of using Vehicle-to-Vehicle communication. Moreover, the type of message attribute helps to handle the particular message according to its priority that in turn minimizes the emergency message delay [1].

The proposed technique aims to use the infrastructure-to-infrastructure communication for the services instead of only vehicle-to-vehicle communication. The message can be sent to Infrastructure using single or multi-hop communication in inside the gap up to 1000 m for the best cases. In Figure 10, the proposed protocol shows less channel congestion to send the message between several entities such as vehicles, RSU, hospital, security agencies, and friend or relatives of the victim as compare to the other protocol. EMDV showed high channel congestion in the network due to sending and receiving more number of packet in less time with limited bandwidth.

There are two types of data that are used in performance evaluation of proposed protocol. First, Emergency based (audio/video) file and emergency based data packets. Audio/video data, like multimedia files, can be obtained from social media. Furthermore, the emergency-based data packets are in different size, types and formats. In this case, various scheduling algorithms are used at the fog layer to increase the efficiency of the whole system. The data packets are stored and synchronized at the fog layer to minimize the delay but at the same time to reduce the security risk data packet is also stored at the cloud. Here, we assumed that the data packets, like multimedia file or any emergency data acts like a task. The task execution time is measured in milliseconds. Moreover, in order to measure the efficiency of the proposed protocol we measure the communication time against the data packet transferred at the vehicle layer, fog layer and the cloud layer. When we increased the number of tasks, the time required to transfer the data and to perform the computation is low as Figure 11 shows. Most of the tasks are performed at the vehicle layer and decrease the latency as compared to the fog and cloud layer.

Moreover, the limitation of this protocol is that it does not focus on the classification of the task which means particular types of emergency tasks performed on the vehicle fog layer and the cloud layer are not categorized or prioritized.

Figure 12 shows the variations in the number of successful data packets received by provider. Nevertheless, for various numbers of nodes, the proposed protocol yields a higher number of packets than EMDV and other mechanisms. Differences in the values of number of data packets because of the network conditions and some predefined thresholds used in our proposed algorithm to check whether the emergency path is clear for the packets which are to be routed to the destination. The simulation results presented in Figure 12 show that the successfully received data packets results are better with the proposed protocol as compared with the other algorithms.

Figure 13 shows the percentage of dropped emergency packets because of an unstable link connection while considering the dynamic nature of the network. The emergency message must be sent to the neighboring RSU and vehicles without delay. Otherwise, the loss of any emergency message may lead to the loss of life. However, the chances of the

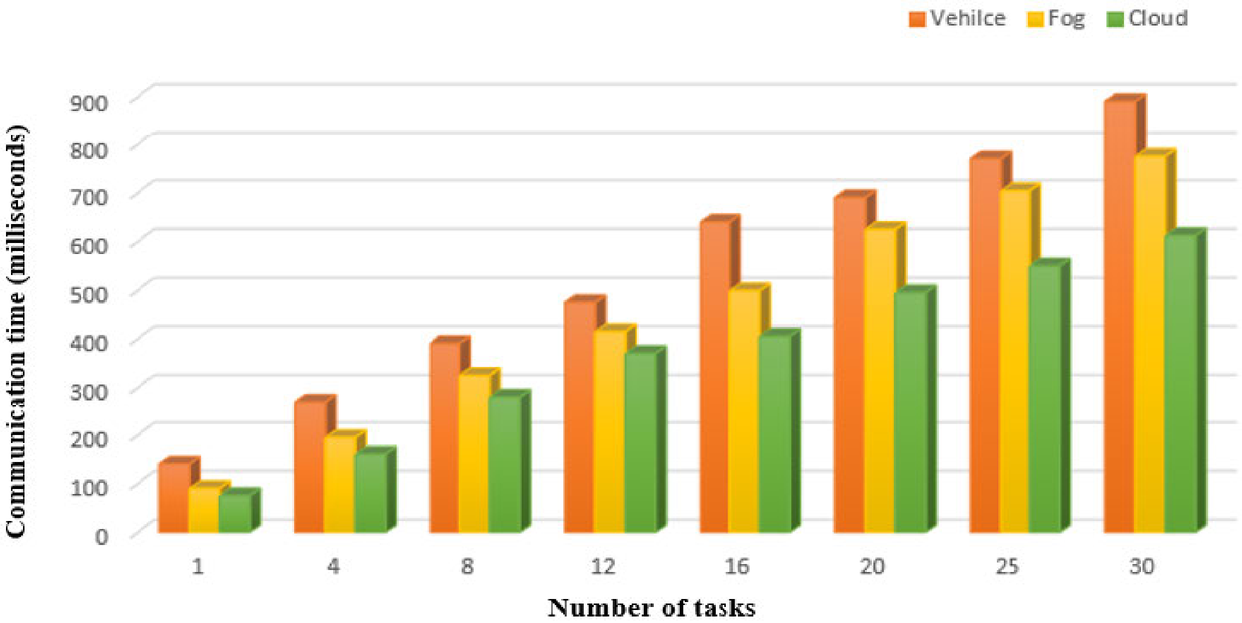


FIGURE 11. Number of tasks managed at cloud, fog and vehicular levels.

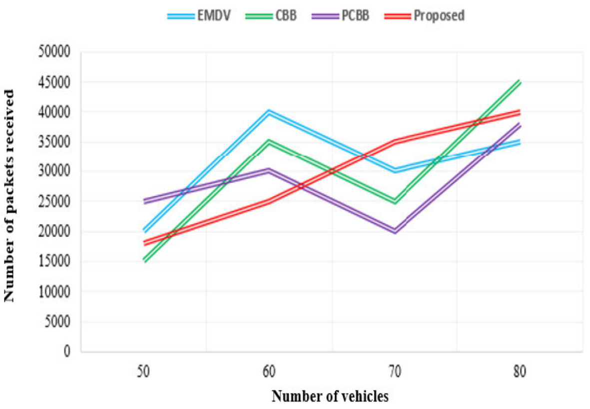


FIGURE 12. Variation of the number of packets successfully received with a number of vehicles.

number of lost packets also increases when the number of vehicles increases and cause instability of the network. Our proposed protocol results in a lower packet loss as compared to the other protocols such as CBB and PCBB. This demonstrates that the proposed protocol improves the stability of the network because more emergency messages are successfully delivered to the specified destination. Moreover, most of the tasks are performed at the vehicle layer which decreases the packet loss from the source to the destination.

Figure 14 shows that the proposed protocol requires less packets to be routed for network communication and hence reduces the processing overhead as compared with the other algorithms.

The Emergency Message (EM) plays a vital role in transferring emergency messages in the vehicular environment. The emergency message must reach its destination and it is therefore important to ensure reliability in the traffic network. The emergency message does not cause channel congestion. Furthermore, sending the emergency message without using

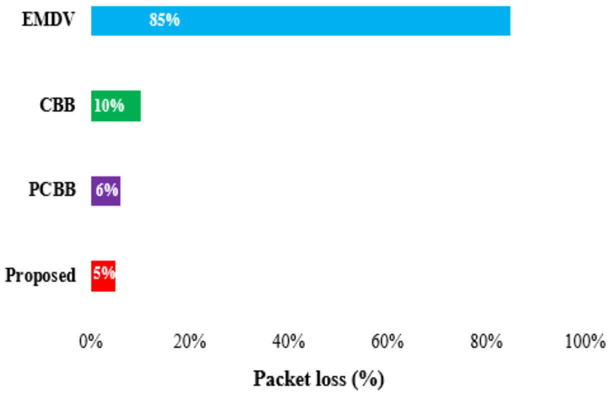


FIGURE 13. Packet loss in the proposed protocol.

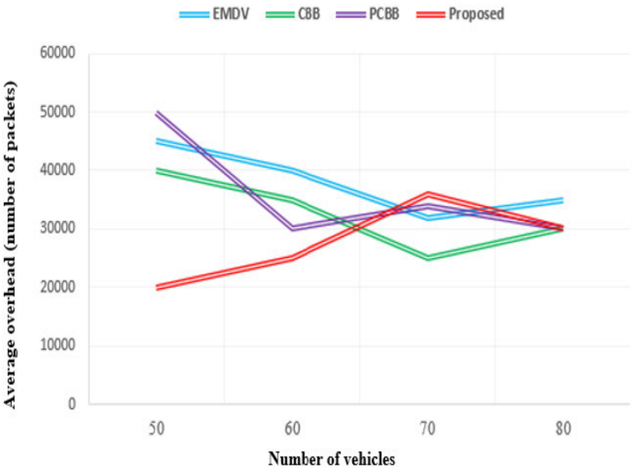


FIGURE 14. Routing overhead.

a mechanism of congestion control causes the broadcasting storm problem. In our proposed protocol when the number of vehicles increases, the number of emergency messages

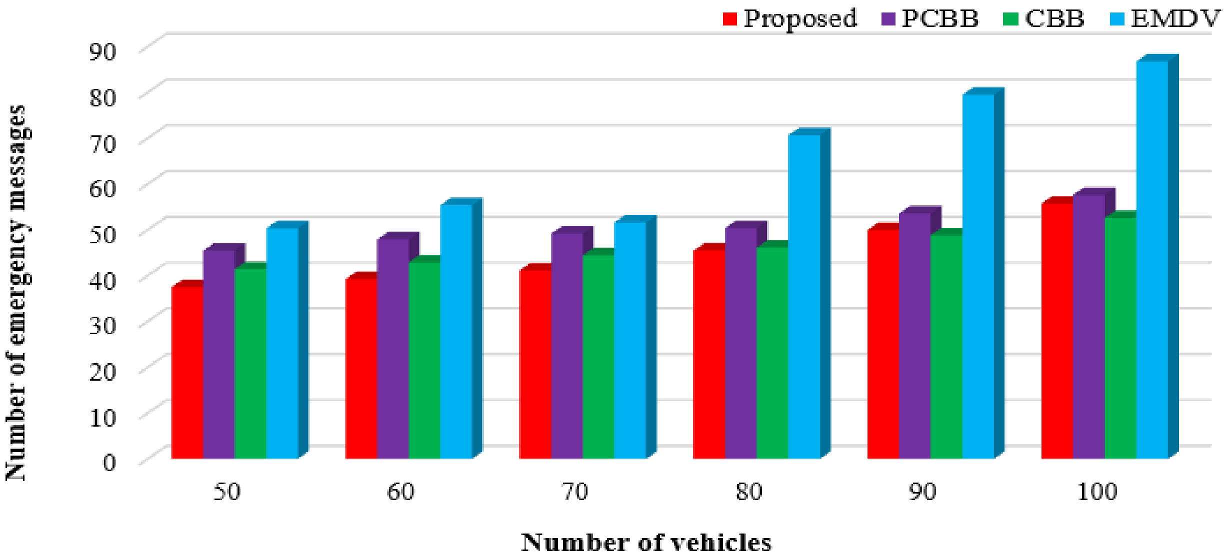


FIGURE 15. Variation of number of emergency messages with number of vehicles.

also increases (as Figure 15 shows). Moreover, the Fog based RSU makes intelligent decisions. It sends the emergency message to the other RSUs and vehicles while considering the broadcasting storm problem and intermittent connectivity to provide the information about the traffic accident. The RSU monitors the emergency situation and also sends the message to other vehicles to make them aware of the status of the traffic network and also to limit communications with the other next RSUs. In order to ensure the stability of the network channel, the RSU and vehicle only send emergency messages when they really need to do so. In our proposed protocol, the number of emergency messages is lower compared with the other protocols. This shows that, with our proposed protocol, we minimize the possibility of channel congestion which in turn improves the stability of the network protocol and the network performance depending on the capacity of the channel. The RSU sends emergency messages after the occurrence of an accident and informs the upcoming vehicle to take alternate routes to avoid congestion as Figure 15 shows.

VI. FUTURE RESEARCH CHALLENGES

Due to the unique characteristics of VANET, it has been receiving a lot of attention from researchers both in academia and industry who are striving to make it more intelligent, robust, and safe [38], [39]. Despite these efforts, it still needs more attention in the design and development of state-of-the-art protocols in the network that address the following important requirements:

I. Minimizing end-to-end delay.
II. Minimizing average routing overhead.
III. Making the network more reliable.
IV. Minimizing the broadcast in the network.
V. More efficient real-time protocols are needed to handle mobility in VANETs.
VI. More work is needed to make it smart and autonomous.
VII. Connecting the network with other networks in order to increase its scope and use.
VIII. Roads, which are required for VANETs to move on, are required to be intelligent in order to assist the vehicles to be connected with all the entities available on the road.
IX. Enhancing QoS support to make the vehicular network smarter.
X. Helping with the recovery of drivers in accidents, disasters, bomb blasts, etc.
XI. Connecting vehicles with the entities directly or indirectly associated with drivers and roads such as hospitals, ambulances, filling stations, security agencies, police, shops with their details, insurances companies, rent vehicles, goods transporters, etc., which helps them to make their life more comfortable.
XII. Security and privacy are the most important concerns because a large amount of personal data is being shared among several entities in the connected and autonomous vehicular networks

VII. CONCLUSION

The proposed methodology has considered human-and-vehicle interaction in connected and autonomous vehicular networks. It is well-known that ensuring a smooth flow of traffic not only minimizes fuel combustion but also improves the overall living standard. In today's networks, state-of-the-art vehicular technologies are working in isolation. We believe that until these technologies are fully integrated, it is not possible to achieve the desired objectives [40]. In this vein, we have proposed the use of the fog node with all the entities available on the road to enhance the capabilities of the vehicle in case of an emergency or need. Furthermore, our fog-based approach also integrates entities such as ambulances, fire departments, hospitals, mechanics, repair shops, gas stations, relatives, offices, security agencies and others that are associated with Fog enabled RSUs, Traditional RSUs and vehicles directly or indirectly to provide better comfort, safe driving, and smooth drive [40].

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