Applying Social Internet of Vehicles in Smart Cities to Reduce Traffic Congestion

Tariq Mahmood[*], Asad Hussain[†], Huansheng Ning[‡]

Abstract

Traffic congestion issues are getting worse today as the number of vehicles on the road is increasing exponentially at an unprecedented rate. These roads have limited space but the number of huge vehicles on the roads. As a result, in many cities around the world, traffic congestion is a serious problem. Vehicle congestion is a severe issue since it has an impact on several aspects of travel, including time spent traveling, distance to the destination, fuel consumption, and environmental pollution. The Internet of Vehicles (IoV) has been able to include social components to build a new intelligent transportation system termed the Social Internet of Vehicles (SIoV) as a result of technological advancements and social transformation. The evaluation of real-time traffic data patterns is the most unpleasant challenge in smart cities, and based on that real-time data, it should be simple to estimate the prospective amount of traffic congestion. In addition, it can be challenging to forecast the likelihood of congestion on a given road. Several technologies are existing to resolve congestion-free traffic. By using SIoV we overcome the traffic congestion in smart cities. We used the Simulation of Urban Mobility (SUMO) tool for vehicle-to-vehicle communication to reduce traffic congestion. We evaluate our proposed scheme with existing work and also on the basis of message size, upload, and response time.

Keywords: Intelligent transportation system, Open Street Maps, Reduction of Traffic Congestion, SIoV, Smart Cities.

Introduction

Nowadays, the Internet of Things (IoT) is the rapidly expanding platform for linking all hardware components, such as sensors, electronics, gadgets, etc. Their integration with software provides the way for various inventive types of applications. With the help of IoT, various vehicles can be connected to the internet and exchange information with their local network, automating tasks for people and improving their quality of life. IoT is a category of international network that joins intelligent items and

[*] Department of Computer Science and Technology, University of Science and Technology Beijing, China, tarriqmahmud@gmail.com
[†] Department of Computer Science, University of Science and Technology Bannu, Pakistan, chasad1303@gmail.com
[‡] Department of Computer Science and Technology, University of Science and Technology Beijing, China, ninghuansheng@ustb.edu.cn

allows them to communicate to one another. Smart objects are a subset of devices that have built-in communication capabilities. The IoT network becomes the Internet of Vehicles (IoV) when smart objects like vehicles are connected to it. Thus, IoV is a wider use of IoT for smart transportation. (Amer et al., 2019; Sharma & Kaushik, 2019).

With the addition of a social factor and continual connectivity, the Social Internet of Vehicle (SIoV) has advanced the existing intelligent transportation system to the next level of intelligence. SIoV provides a vast amount of real time data that is enhanced by context and social relationship information about the surrounding environment, the drivers, the passengers, and the vehicles themselves. When it comes to creating a generic architecture, SIoV is now in its emerging phase and requires substantial research (Mehmood et al., 2017; Yaqoob et al., 2017).

Traffic congestion is a major problem for traffic management authorities in practically all smart cities as the number of vehicles increases quickly each year. Realtime traffic management systems (RTMS) are made up of a small network of Road Side Units (RSU), Junction Units (JU), and Mobile Units (MU) to dynamically determine the timing of traffic lights to prevent formation of gridlock, along with a web-based application for vehicle drivers that will derive the data from real-time traffic analysis to indicate the local traffic flow and use it to evaluate real-time traffic condition.

Only information on traffic congestion is available from the existing infrastructures. However, they have little effect on reducing it and offer no indication of how terrible it will get in the near future. Therefore, the main goal of this research project is to provide a novel approach for smart cities that can use SIoV to help reduce traffic congestion.

Background Study

Related Work

The number of vehicles has been closely correlated with the daily rise in traffic congestion. The problem is that there is currently no system in place that can both predict and reduce traffic congestion (Siddiqui, Mahmood, Sheng, Suzuki, & Ni, 2021). In the transportation network, traffic congestion results from a demand-supply imbalance. When there are more vehicles on the roads or the capacity of the road is reduced for a variety of reasons, traffic flow slows down. Fewer traffic on the roads is made possible by modern vehicles. (Ahmed, 2020) described a qualitative analysis of how connected vehicles can ease traffic congestion on the highways. The same vehicle concept is combined with several aspects of smart cities. Two test scenarios are frequently taken into account: one involves the current type of roads, and the other includes automated highways.

Urban sustainability challenges in developing countries of the world are addressed in large part by the transportation infrastructure that daily serves most metropolitan areas. In fact, severe traffic congestion is a frequent problem in urban areas, increasing air pollution, fuel consumption, and travel time. A hierarchical operation framework was created by (Li, Al Hassan, Shahidehpour, Bahramirad, & Khodaei, 2017) for controlling traffic lights in a flexible and effective manner under dynamic traffic situations. The proposed framework, which is based on a multi-agent system, is able to reduce average driving times and potential traffic jams in urban areas. The implementation of a closed-loop management system can result in further increases in traffic efficiency. (Roopa et al., 2020) proposed a traffic scheduling algorithm to achieve the greatest throughput for the flow of vehicles at a road intersection while taking into account the social ties that are developing between the moving vehicles and the RSUs. The algorithm uses the quantity of traffic on the given road to estimate the flow rate of vehicles for lanes at intersections. A condition matrix is created to ensure smooth traffic flow while taking into account various road segment routes. In order to make driving more secure, responsive, and enjoyable, social interactions are developed on a variety of travel-related demands.

In order to improve service, (Rizwan, Suresh, & Babu, 2016) and (Sharif et al., 2017) created a Real-Time Smart Traffic Management System that uses traffic indicators to update traffic information quickly. Every 500 or 1000 meters, sensors for detecting vehicles are integrated alongside the road. IoT are being utilized to quickly collect and deliver traffic data for analysis. Real-time streaming data is necessary for big data analytics. To monitor the traffic density and propose solutions using predictive analytics, there are numerous analytical techniques. As a user interface, a mobile application is created that offers an alternate method of traffic management while allowing users to investigate the traffic density at various locations.

The real-time traffic management system (RTMS) that (Saikar, Parulekar, Badve, Thakkar; Deshmukh, 2017) proposed consists of a real-time traffic monitoring system made up of a small network of RSUs, JUs, and MUs to dynamically determine the time of traffic lights to prevent the formation of gridlock, along with a web-based application for vehicle drivers that will use the data from real-time traffic analysis to show the local traffic flow and advise the incoming vehicles to use alternate routes in order to further reduce congestion.

A straightforward method is utilized in (Dhakad & Jain, 2014) to identify traffic congestion in any location in a developing area. Here, a user's device application will retrieve their GPS and speed data before transmitting it to the server. Once the data has reached on the servers, it is evaluated, and an algorithm is used to determine whether there is congestion. The application then informs the user of the traffic on the specific route so that they can choose an alternate route. This method is extremely effective and optimized because it relies on crowdsourcing for data and only minimal infrastructure building.

(Elsagheer Mohamed & AlShalfan, 2021) presented a new traffic management system that is appropriate for Smart Cities and future traffic systems and is based on the current VANET and IoV. They demonstrated how to manage local traffic at an intersection in accordance with the needs of upcoming smart cities, which include promoting equity, cutting down on commuting times, ensuring an acceptable flow of traffic, minimizing the congestion of traffic on specific location, and providing precedence to vehicles that are in emergency situation.

To reduce urban traffic congestion, (T. Wang, Hussain, Zhang, & Zhao, 2021) emphasized on the CEC in the SIoV system. According to recent research, intelligent traffic light control using metropolitan area mobile edge computing (MEC) servers can decrease the average amount of time that vehicles must wait at signal crossings. In order to decrease on long queues, this article has emphasized a CEC-based traffic management system (CEC-TMS). The MEC servers that communicate with IoV and traffic lights to generate dynamic green waves at busy intersections use multiagent-based deep reinforcement learning (DRL).

Organization of paper

The remaining article is structured as follows. The proposed framework is explained in Section 2, the proposed algorithms are explained in Section 3, and the result is defined and discussed in Section 4. The conclusion is presented in Section 5.

Proposed Framework

Utilizing simulation, we took the proposed research technique into practice. And the simulation tool known as Simulation of Urban Mobility (SUMO) is used to construct that simulation environment. Realtime data storage on cloud and current data transfer method for vehicles is used to send data to cloud server and receive from it. The activities that were performed to carry out the plan are listed below:

1. Every vehicle in a cloud repository has a unique vehicle identification that will be matched with specific data that includes vehicle information as well as coordinates for the congested location.
2. A message is generated and sent to the vehicular cloud repository when

congestion is predicted so that it can be sent to all of the vehicles that are a part of a VANET.

3. This specific congestion prediction message will be forwarded to the RSU, who in turn passes it to the incoming vehicles in the domain.
4. Additionally, RSU sends congestion data over a secure cloud server.
5. It uses an inductive loop detector (ILD) to measure speed, length, and vehicle occupancy. ILD and the online server will be interconnected. We will be able to get congestion coordinates and other data with the help of RSUs and On-Board Units (OBU).
6. Vehicles passing through the conjunctive place are therefore warned that congestion may occur there and are forbidden from contributing to it. This stored data can also be used to look into the root causes of congestion. Fig. 1 shows the procedure for forecasting and reporting congestion.
7. It is important to efficiently transport the data packet through the VANET, even to the far-off cars, when a congestion prediction message is sent by vehicle V to a distant vehicle D.

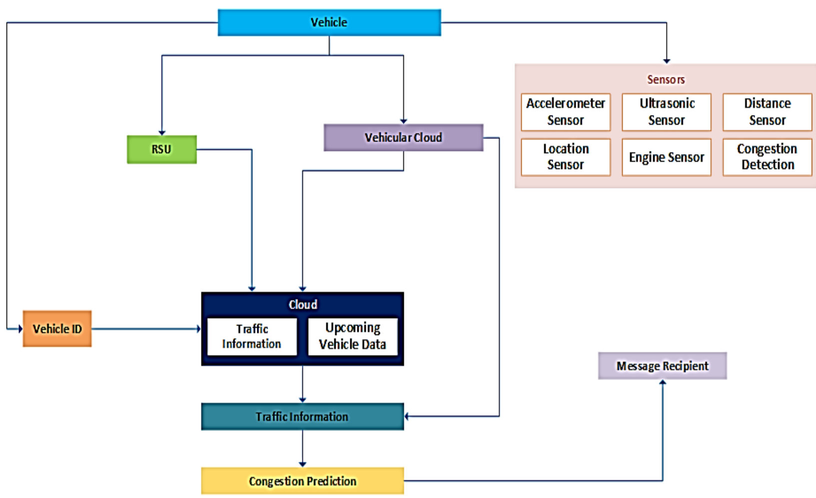

Fig. 1 Proposed framework and working mechanism

Proposed Algorithms

Prediction of Traffic Congestion

All smart cities, in our opinion, are well-connected and well-developed, with all sensors thoughtfully positioned at crucial intersections. Data is collected at multiple junction positions using a variety of sensors. It's thought that the information is time-dependent stream data. Our goal is to forecast when there will be a certain amount of traffic on any particular route. We must first understand the data that were used to solve the aforementioned problem before the answer to that problem can be presented. Therefore, the four attributes of the data used in this challenge have a combined type of category and statistical data. The algorithm listed below utilizes 4 distinct attributes. Vehicle (V); threshold value (T); vehicular counter (C); and congestion area (P) are these attributes. Every vehicle travel in the direction indicated along the designated path in order to reach its destination.

A vehicle may approach a junction point from a distance of a few meters, at which point it may become congested on all of the paths leading to and from the junction. So that if he sees the congestion message on the road, the driver might select a different route. Positively, the complexity of this algorithm will remain constant. All of the data of vehicles is kept on the cloud storage. Latitude and longitude are also included in this data. The vehicle counter C and the threshold value T are then set up. It alerts that the congestion is at a moderate level by comparing its value of the C with the threshold value T. Otherwise, if the value of C exceeds the value of T, there is significant congestion. Then it sends the message M through the network to the vehicle. Another example is when a car is removed from the cloud network and the vehicle counter if it is too distant from the congestion area P.

Sending of message M from vehicle to RSU

A congestion prediction message with congestion position coordinates can be sent to an RSU using an algorithm, and the RSU can then store the message on the cloud server for future transmission. The RSU R is receiving the information for the congestion prediction message M. When R is within the specified range, the vehicle generates message M, that is intended to be delivered to the RSU for that reason. If R is within that range, the message M is transmitted end to end. However, if it is beyond the specified range, the source vehicle examines the various routes leading from the source to the R. And when the message has been sent to its neighbor's vehicles, it keeps travelling till it reaches the RSU. As was previously indicated, each vehicle has a special identification number that is saved on a cloud server. This number is used to identify each vehicle and to send messages.

For delivering the message packet to long distance, the transmitting vehicle creates a communication chain with its surrounding vehicles (K), after which the message is transferred to the nearest vehicle, which then sends it to the next and so on until it reaches the RSU. Additionally, the message can be readily sent from that RSU to the cloud server and back again between vehicles.

Algorithm 1: *Prediction of Traffic Congestion*

Vehicle (V);
Threshold value (T);
Vehicular counter (C);
Congestion area (P):
Step 1: Prediction of congestion message
For all vehicles on the cloud;
Determine the vehicle lat, lang;
if
C<=T ***then***
C= C+1;
Congestion if moderate;
Go to end;
else
Congestion is high;
Deliverance of message M to vehicles;
Follow step-1 and step-2 from algorithm-2;
end
Step 2: Removing vehicles from cloud
if
V is away P range ***then***
C=C-1;
Congestion is moderate;
Go to end;
end

The method we chose to send a packet P from RSU R to vehicle V is for the vehicle to send packets P to the vehicles that are approaching it, and those vehicles will manage a list that contains various parameters, including the coordinates, speed information, direction, and timestamp of that specific moving vehicle. These packets are passed back and forth amongst the nearby cars before being sent to the RSU through those vehicles. The purpose for transmitting those packets to the RSU is so that far located cars can communicate with the RSU and easily learn about the congestion prediction message. Additionally, the communication infrastructure integrated within the roadside infrastructure R can be used to store the congestion prediction message.

These packets are travelling between the RSU and the vehicles. On the other hand, there are instances where a Packet P is transmitted from an RSU R to a target destination, in this case, a vehicle. The nearby vehicles to the RSU are informed of the message. Each car has a distinct vehicle id that is saved with the message as well. The key is compared to each vehicle id, and as a result, it is transferred in this manner. The nearby vehicles in that particular domain, K, receive the communication from R. These communication packets are quite short in size; thus, the network does not lose any additional bandwidth as a result.

Algorithm 2: *Sending of message M from vehicle to RSU and from RSU to vehicle*

Vehicle V (source);
RSU D (destination);
Message M (congestion prediction);
Step 1: Transmission of message from vehicle to RSU
if
D is within V range ***then***
V send message directly to D;
Go to end;
else
V defines total path between itself and D and the set of Vn of neighbors that are nearer from it to D;
if
Vn=0 ***then***
Go to delay routine;
else
V sends M to K neighbors in Vn;
V drops M;
end
end
Step 2: Transmission of message from RSU to vehicle
if
V is within D range ***then***
D send message directly to V;
Go to end;
else
D defines total path between itself and V and the set of Dn of neighbors that are nearer from it to V;
if
Dn=0 ***then***
Go to delay routine;
else
D sends M to K neighbors in Dn;
D drops M;
End
end

Results and Discussion

With the help of SUMO, we have constructed and demonstrated the prototype system in this part. We have also evaluated the primary evaluation techniques that will be employed to support the suggested plan. This section also contains essential data regarding the system specification and the findings of the simulation environment evaluation of the proposed system. Additionally, we used SUMO to demonstrate the simulation of the suggested technique and contrast it to earlier studies.

SUMO Tool

SUMO is a persistent highway simulation toolkit for huge networks that is free, open-source, and available. It is feasible to simulate multimodal traffic networks that include vehicles, public transportation, and pedestrians. For activities like route planning, visualization, network import, and pollutant prediction, SUMO has a lot of helpful resources. A variety of APIs can be used to remotely control the simulation and add custom models to SUMO. Figure 2 depicts the SUMO graphic interface.

OpenStreetMap (OSM)

OpenStreetMap, or OSM, is a project used to build a free, world geographic database. The long-term objective is to create a database of every geographic feature on the planet. Street mapping was the starting point, but it has since grown to encompass walkways, homes, rivers, pipelines, woods, beaches, postboxes, and even specific trees. The project covers administrative borders, details of land use, bus lines, and other abstract ideas that are not apparent in the landscape in addition to physical geography (Arsanjani, Zipf, Mooney & Helbich 2015). On OpenStreetMap, contributors are referred to as mappers. They build the database by travelling by car, bicycle, or foot along roads and trails while using GPS to record their every move. Using this information, a collection of points and lines that can be used to make maps or navigational aids is produced. Figure 3 shows the Map of Islamabad as downloaded from OSM.

Simulation Demonstration

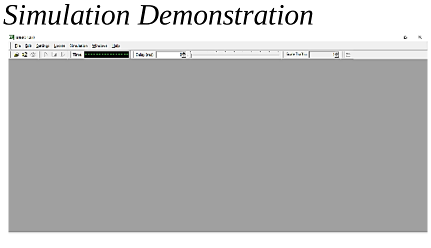

Fig. 2 SUMO Open-Source Tool

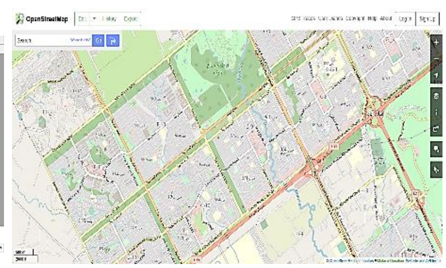

Fig. 3 Map of Islamabad

1. The proposed technique is simulated using the SUMO. Vehicle traffic is produced after obtaining an OpenStreetMap of Islamabad.
2. In addition to the completely accessible traffic, a small number of vehicles having message transmission capabilities for simulation.
3. SUMO produces an output trace in the form of .xml that, among other things, contains the vehicle id, latitude and longitude of the vehicle, and the vehicular congestion forecast message.

4. Figure 5 displays the XML output produced by the simulation, which comprises the coordinates and other data. The vehicles that are receiving congestion prediction messages are indicated.
5. Extract data from the SUMO as XML, that is encoded using DER to minimize the size of the message before being sent to RSUs, that is then transmitted to the cloud storage and any other domain-related vehicles. The prognosis for automobile congestion is shown in Figure 4.
6. The XML trace and the Congestion Prediction message are transferred to the cloud storage for delivery to the destination.
7. Within 4-5 seconds, data is transferred to the cloud storage.
8. And using the OpenStreetMap's vehicle-to-vehicle communication architecture, this data is sent to the other vehicles.

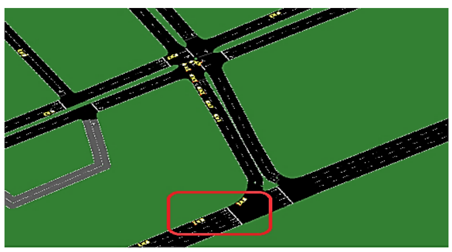

Fig. 4 Vehicle Congestion Prediction Simulation

1	time	id	latitude	longitude	angle	type	speed	pos	lane	slope
81	12	80	1955.95	1463.54	150.15	DEFAULT_VEHTYPE	5.79	40.52	-23342006#0_0	0
82	12	81	2076.51	1602.07	149.98	DEFAULT_VEHTYPE	6.16	30.28	23489579#1_0	0
83	12	82	1976.67	1691.16	330.15	DEFAULT_VEHTYPE	8.58	26.16	-23367609_0	0
84	13	83	1665.06	1717.32	289.69	DEFAULT_VEHTYPE	3.42	1.1	:252750824_9_0	0
85	13	84	1756.75	1780.62	239.28	DEFAULT_VEHTYPE	12.1	122.77	-23489553#0_0	0
86	13	85	1629.01	1450.08	58.32	DEFAULT_VEHTYPE	2.52	7.62	9894449#0_0	0
87	13	86	2022.07	1787.41	238.68	DEFAULT_VEHTYPE	0	5.1	-23342457#11_0	0
88	13	87	2106.65	1463.26	58.05	DEFAULT_VEHTYPE	15.68	120.71	307553334#9_1	0
89	13	88	2326.45	1513.16	58.41	DEFAULT_VEHTYPE	19.48	116.93	9894449#0_0	0
90	13	89	2220.91	1473.26	5.45	DEFAULT_VEHTYPE	3.67	3.77	:253017431_4_0	0
91	13	90	2290.76	1534.33	330.15	DEFAULT_VEHTYPE	10.93	64.8	-23367609_0	0
92	13	91	2332.44	1566.71	127.85	DEFAULT_VEHTYPE	3.16	0.1	:253016191_11_0	0
93	13	92	2327.32	1621.27	139.78	DEFAULT_VEHTYPE	3.23	1.5	:253017808_8_0	0
94	13	93	2306.65	1567.26	330.15	DEFAULT_VEHTYPE	10.29	36.45	-23367609_0	0
95	14	94	2416.21	1463.21	178.65	DEFAULT_VEHTYPE	3.61	2.2	-23489554#0_0	0
96	14	95	2406.65	1561.46	239.28	DEFAULT_VEHTYPE	12.35	135.12	-23489553#0_0	0
97	14	96	2706.11	1863.28	58.32	DEFAULT_VEHTYPE	5.09	12.71	9894449#0_0	0
98	14	97	2806.68	1663.21	238.68	DEFAULT_VEHTYPE	2.12	7.22	-23342457#11_0	0
99	14	98	2407.15	1563.26	58.05	DEFAULT_VEHTYPE	15.65	136.36	307553334#9_1	0
100	14	99	2706.65	1579.23	58.41	DEFAULT_VEHTYPE	21.81	138.74	9894449#0_0	0
101	14	100	2876.65	1587.06	264.27	DEFAULT_VEHTYPE	3.31	2.41	-23342047#6_0	0
102	14	101	2326.69	1561.21	330.15	DEFAULT_VEHTYPE	7.76	72.56	-23367669_0	0
103	14	102	2706.65	1763.28	20.45	DEFAULT_VEHTYPE	3.58	1.34	23342006#0_0	0
104	14	103	2777.12	1763.36	65.6	DEFAULT_VEHTYPE	3.18	0	-23489579#1_0	0
105	14	104	2960.61	1662.36	330.15	DEFAULT_VEHTYPE	11.95	48.4	-23367669_0	0
106	15	105	2990.69	1763.12	149.38	DEFAULT_VEHTYPE	5.19	7.39	-23489554#0_0	0

Fig. 5 Vehicles Receiving Congestion Prediction Message

Data Retention and Reaction Time

Figure 6 illustrates the data retention and reaction time of cloud storage. It also shows how long it takes for vehicles to transmit requests to the cloud storage and receive responses.

Sharing and Compressing Congestion Forecast Information

C++ ASN.1 and Objective System Nokalva-ASN.1 are the compression standards that are used to compress and reduce the size of the uncompressed messages. We used dynamic encoding standards to determine the size of a message in conjunction with an analysis. Figures 6 and 7 show the magnitude of the message that will be transferred between vehicles and to the cloud. The size of the message determines how much room it takes up in the cloud storage. The Packed Coding Rule has the shortest message size, according to experimental study results, while the DER and BER have somewhat bigger messages than the PER. The DER (Qureshi & Noor, 2013) coding rule is utilized in the VANET (Kenney, 2011) communication standard. Canonical XML Encoding Rules (XER) are encoding techniques that contain data in simple text format.

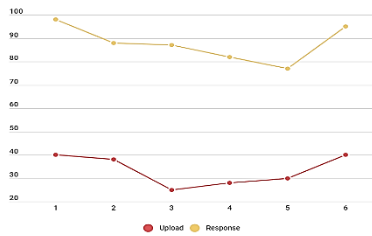

Fig. 6 Data retention and reaction time

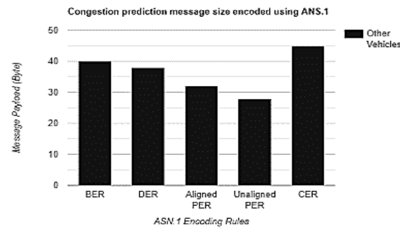

Fig. 7 Size of the messages using encoding scheme.

Conclusion

Science and technology have been able to make vehicles smarter and more sophisticated by giving them network equipment. With the introduction of more devices, like as vehicles, into this global village, traffic management becomes a significant problem that needs to be resolved. Using SIoV vehicles communicate with each other and increases road safety. The SIoV would surely be made possible by the proposed work. By using this proposed work traffic congestion was significantly reduced. Data for congestion forecasting can be automatically collected and distributed throughout the network, making congestion forecasting simple.

Contribution of research

This study's ultimate goal is to reduce traffic congestion in smart cities and alert the vehicle network of imminent congestion. By employing a novel method that involves automobiles sharing congestion prediction messages across a network, this study redirected ongoing efforts to identify congestion. We proposed congestion prediction message exchange using the SUMO tool, and then we put it into practice in a simulated setting.

References

Amer, H. M., Al-Kashoash, H., Hawes, M., Chaqfeh, M., Kemp, A., & Mihaylova, L. (2019). Centralized simulated annealing for alleviating vehicular congestion in smart cities. *Technological Forecasting and Social Change*, 142, 235-248.

Sharma, S., & Kaushik, B. (2019). A survey on internet of vehicles: Applications, security issues & solutions. *Vehicular Communications*, 20, 100182.

Mehmood, Y., Ahmad, F., Yaqoob, I., Adnane, A., Imran, M., & Guizani,

S. (2017). Internet-of-things-based smart cities: *Recent advances and challenges. IEEE Communications Magazine*, 55(9), 16-24.

Yaqoob, I., Hashem, I. A. T., Mehmood, Y., Gani, A., Mokhtar, S., & Guizani, S. (2017). Enabling communication technologies for smart cities. *IEEE Communications Magazine*, *55*(1), 112-120.

Siddiqui, S. A., Mahmood, A., Sheng, Q. Z., Suzuki, H., & Ni, W. J. E. (2021). A Survey of Trust Management in the Internet of Vehicles. 10(18), 2223.

Ahmed, A. H. (2020). Role of smart vehicles concept in reducing traffic congestion on the road.

Li, Z., Al Hassan, R., Shahidehpour, M., Bahramirad, S., & Khodaei, A. (2017). A hierarchical framework for intelligent traffic management in smart cities. *IEEE Transactions on smart grid*, 10(1), 691-701.

Roopa, M., Siddiq, S. A., Buyya, R., Venugopal, K., Iyengar, S., & Roopa, M. S., Siddiq, S. A., Buyya, R., Venugopal, K. R., Iyengar, S. S., & Patnaik, L. M. (2021). DTCMS: Dynamic traffic congestion management in Social Internet of Vehicles (SIoV). *Internet of Things*, 16, 100311.

Rizwan, P., Suresh, K., & Babu, M. R. (2016). Real-time smart traffic management system for smart cities by using Internet of Things and big data. *Paper presented at the 2016 international conference on emerging technological trends (ICETT*).

Sharif, A., Li, J., Khalil, M., Kumar, R., Sharif, M. I., & Sharif, A. (2017). Internet of things—smart traffic management system for smart cities using big data analytics. *Paper presented at the 2017 14th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP).*

Saikar, A., Parulekar, M., Badve, A., Thakkar, S., & Deshmukh, A. (2017). TrafficIntel: Smart traffic management for smart cities. *Paper presented at the 2017 International Conference on Emerging Trends & Innovation in ICT (ICEI).*

Dhakad, R., & Jain, M. (2014). GPS based road traffic congestion reporting system. *Paper presented at the 2014 IEEE International Conference on Computational Intelligence and Computing Research.*

Elsagheer Mohamed, S. A., & AlShalfan, K. A. (2021). Intelligent traffic management system based on the internet of vehicles (IoV). *Journal of advanced transportation,* 2021.

Wang, T., Hussain, A., Zhang, L., & Zhao, C. (2021). Collaborative Edge Computing for Social Internet of Vehicles to Alleviate Traffic Congestion. *IEEE Transactions on Computational Social*

Systems.

Jokar Arsanjani, J., Zipf, A., Mooney, P., & Helbich, M. (2015). An introduction to OpenStreetMap in Geographic Information Science: Experiences, research, and applications. In *OpenStreetMap in GIScience* (pp. 1-15). Springer, Cham.

Kenney, J. B. (2011). Dedicated short-range communications (DSRC) standards in the United States. *Proceedings of the IEEE*, 99(7), 1162-1182.

Qureshi, M. A., & Noor, R. M. (2013). Towards improving vehicular communication in modern vehicular environment. *Paper presented at the 2013 11th International Conference on Frontiers of Information Technology.*