IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received January 6, 2019, accepted January 18, 2019, date of publication February 1, 2019, date of current version February 12, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2895114

Time Barrier-Based Emergency Message Dissemination in Vehicular Ad-hoc Networks

SYED SARMAD SHAH[1], ASAD WAQAR MALIK[1], ANIS U. RAHMAN[1], SOHAIL IQBAL[1], AND SAMEE U. KHAN[2]

[1]Department of Computing, School of Electrical Engineering and Computer Science, National University of Sciences and Technology, Islamabad 44000, Pakistan
[2]Electrical and Computer Engineering Department, North Dakota State University, Fargo, ND 58105, USA

Corresponding author: Asad Waqar Malik (asad.malik@seecs.edu.pk)

ABSTRACT With the advancement in technology and inception of smart vehicles and smart cities, every vehicle can communicate with the other vehicles either directly or through ad-hoc networks. Therefore, such platforms can be utilized to disseminate time-critical information. However, in an ad-hoc situation, information coverage can be restricted in situations, where no relay vehicle is available. Moreover, the critical information must be delivered within a specific period of time; therefore, timely message dissemination is extremely important. The existing data dissemination techniques in VANETs generate a large number of messages through techniques such as broadcast or partial broadcast. Thus, the techniques based on broadcast schemes can cause congestion as all the recipients re-broadcast the message and vehicles receive multiple copies of same messages. Further, re-broadcast can degrade the coverage delivery ratio due to channel congestion. Moreover, the traditional cluster-based approach cannot work efficiently. As clustering schemes add additional delays due to communication with cluster head only. In this paper, we propose a data dissemination technique using a time barrier mechanism to reduce the overhead of messages that can clutter the network. The proposed solution is based on the concept of a super-node to timely disseminate the messages. Moreover, to avoid unnecessary broadcast which can also cause the broadcast storm problem, the time barrier technique is adapted to handle this problem. Thus, only the farthest vehicle rebroadcasts the message which can cover more distance. Therefore, the message can reach the farthest node in less time and thus, improves the coverage and reduces the delay. The proposed scheme is compared with traditional probabilistic approaches. The evaluation section shows the reduction in message overhead, transmission delay, improved coverage, and packet delivery ratio.

INDEX TERMS VANET, emergency messages, data dissemination, 802.11p WAVE, probabilistic clustering, time barrier.

I. INTRODUCTION

Vehicular ad-hoc networks (VANETs) have greatly improved transportation systems and helped reducing many unwanted scenarios causing irreversible mishaps on roads. VANETs make it possible for vehicles to communicate with one another whether on roads or in parking areas. It allows vehicles to form a network of their own without a centralized server. All communications taking place among vehicles is known as vehicle-to-vehicle (V2V) communication while the exchange of information between vehicles and road-side-units (RSUs) is known as vehicle-to-infrastructure (V2I) communication.

In practice, communication frequency used for vehicular information exchange in VANETs is in the range of 5.85 and 5.925 GHz [2]. Service channel (SCH) and control channel (CC) are used for transmitting safety messages regarding accidents, crashes and other hazardous events, additionally, normal data messages other than safety messages.

Though VANETs are coupled with many challenges data dissemination is an important one [3]. In general, normal messages are not time critical, in contrast, safety/emergency messages are time critical and require successful transmission at the earliest [25], [37]. There are different techniques for

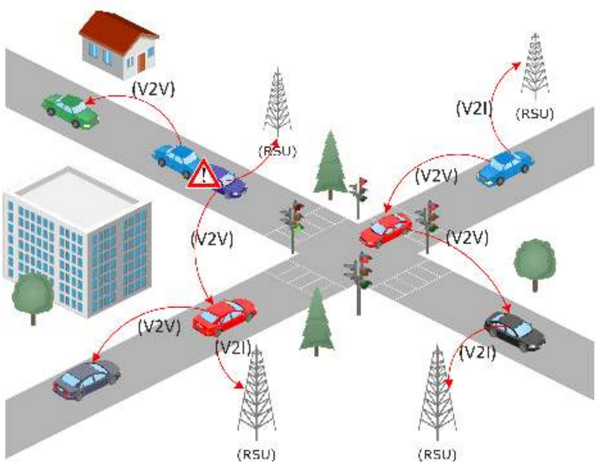

FIGURE 1. VANET communication architecture.

dissemination of emergency messages (EMs), however, many of them are designed to work under particular scenarios. There is still room for much improvements as the technology is still developing and has not reached its maturity yet.

When an incident is detected by a vehicle or some infotainment system, messages need to be delivered to other vehicles on the road. The incident-aware vehicle delivers the message by simply broadcasting it to all vehicles in its transmission range. The vehicles on the receiving end further rebroadcast the same message in order to relay the information to other vehicles. This technique is referred to as flooding. It may deliver the message to the intended recipient but it also causes network congestion; that is, a vehicle broadcasting to other vehicles even if they already received the message. Such unnecessary rebroadcast in the network decreases the overall packet delivery ratio. More recently, improved selective flooding or flooding-based mechanisms are used for data dissemination [8].

With the standardization of the communication protocol for VANET environment, known as IEEE 802.11p [1], [36], they can be used to broadcast alerts as soon as a collision is detected. These alerts are passed down from vehicle to vehicle ensuring driver safety and smooth traffic flow. It is evident that alerts are sometimes not detectable or are far beyond the human peripheral or hearing range. Thus, this could be a massive help to the drivers. Such a mechanism can greatly increase the reaction time of first responders by providing the fastest route possible to the location of the incident.

A major challenge of mechanisms mentioned earlier is the credibility of broadcast messages. Any vehicle can falsely broadcast an incident that never happened. In particular, autonomous cars can be targeted with such attacks. To avoid such issues, clustering based data dissemination can be used. The vehicles form a cluster on the basis of features computed for vehicles intending to group together. A cluster head (CH) is selected with administrative privileges of that specified cluster. Vehicles other than CH are known as cluster members (CM). One of the many advantages of using clustering is to identify intruders and to stop them from falsely broadcasting alerts. Another main advantage of the algorithm is that it handles the broadcast storm problem [7] – where every vehicle receiving the same message further rebroadcasts it, subsequently, causing a major network congestion. The use of such clustering algorithms is to prolong network lifetime of vehicles traveling along the same road. The underlying vehicular network could be either purely ad-hoc in nature with vehicles interacting with other vehicles in V2V or vehicles interacting with RSUs in V2I or hybrid using both types of communication [10].

The proposed algorithm is designed to work in an urban environment while reducing delay and improving coverage compared to other algorithms. The proposed approach is based on a clustering technique to efficiently handle the broadcast storm problem. The proposed technique also reduces the delay introduced due to control messages shared between member vehicles of the cluster. Moreover, the time barrier based technique is defined to restrain vehicles from broadcasting based on their position. The vehicles can only broadcast a message after a time barrier expires; however, upon receiving an EM within Δt cancels the barrier. Thus, reducing network congestion that has a direct impact on the success rate of dissemination.

II. LITERATURE REVIEW

VANETs can play a vital role in intelligent transportation systems (ITS), for instance, real-time road traffic information can be shared among vehicles. This information can be used to select the least congested path, in particular, first responders can use it to timely reach the emergency location. Based on the importance of VANETs, there exist many works in the literature with techniques to reduce the EM dissemination delay and to improve network coverage area. Table 1 summarizes such techniques based on key attributes. It is evident that many are designed to work in particular scenarios. Moreover, with performance gaps that need to be solved for the efficient handling of communication in VANETs environment.

In [42], a hybrid mechanism referred to as vehicular multihop algorithm for stable clustering-long-term evolution (VMaSC-LTE) is proposed. It uses both the IEEE 802.11p protocol and the 4G cellular network to increase packet delivery ratio. It also minimizes delay in successful transmission of packets. Kponyo *et al.* [26] propose a cluster-on-demand (COD) technique that makes clusters on basis of quality of service (QoS). Moreover, among the clusters, it uses a minimum spanning tree algorithm for effective communication. In [13], vehicles are categorized based on their compute and storage capabilities. Each energy zone comprise a CH elected for the specific region of the network with data dissemination made possible using vehicles with more computational power. This tackles the issue of broadcast storm problem that causes the network to sink in and crash.

Mehra *et al.* [34] propose a clustering technique known as optimized link state routing protocol with clustering (OLSR-C). The position and velocity of the vehicle play

TABLE 1. Comparison of different EM dissemination techniques in VANETs.

	Broadcast storm problem	Packet delivery ratio	Delay	Information coverage	Density	Speed	Scenario	Simulator
Farrokhi et al. [18]	✓	✓	✓	×	low	high	highway	NCTUNS
Ihn-Han Bae [5]	✓	✓	×	×	high	low	generic	MATLAB
Khan et al. [24]	×	✓	✓	×	high/low	low	urban	NS-3
Kumar et al. [28]	×	✓	×	✓	high	low	generic	OMNeT++, SUMO, Veins
Liu et al. [29]	×	×	✓	×	high	low	urban	OMNeT++, SUMO
Alwakeel et al. [4]	×	✓	×	×	low	high	generic	NS-2
Liu et al. [31]	×	✓	✓	×	high/low	-	highway	NS-2, SUMO, TranNS
Eyobu et al. [15]	×	×	✓	×	low	high	highway	NS-3
Du et al. [12]	×	✓	✓	×	-	high/low	generic	Kafka, VISSIM
Proposed technique	✓	✓	✓	✓	high	low	urban	OMNeT++, SUMO, VEINS

a vital role in cluster formation, that is, vehicles with low relative velocity and position make a cluster. This results in good packet delivery ratio and low packet transmission delay. In [39], centralized clustering based hybrid vehicular networking architecture (CC-HVNA) is proposed. The hybrid architecture uses VANET and LTE for the underlying clustering scheme.

Jamgekar and Tapkire *et al.* [21] propose a scheme using IEEE 802.11p to address the broadcast storm problem, churn behavior and elevated costs of communication. The result is improved packet delivery ratio and reduced packet transmission delay while keeping cellular network utilization at minimum. In [35], a location-aware cluster formation scheme using global position system (GPS) and online maps is proposed. In the scheme, the broadcast storm is tackled, as well as, unnecessary message transmissions are suppressed. Thus, improving the packet delivery ratio and minimizing the average transmission delay. Another scheme, hybrid based election backbone (HBEB) [20], presents a generic model with several vehicles chosen as backbones of the network and are assigned responsibilities of data dissemination. Though the proposed technique is designed to function in an urban environment but it is inapplicable to EM dissemination.

Similar delay based broadcasting techniques are also adopted for pedestrian safety from car accidents. In these scenario vehicles/pedestrians need to be alerted about the situation at the earliest [11], [16]. In [32], a clustering scheme based on the direction of vehicles is presented. The algorithm uses vehicle density in an area for the purpose of data dissemination. For example, the packets are relayed to other vehicles only if the directions of the sender and receiver vehicles are same. Moreover, a comparison between 802.11p and 802.11b is performed. The simulation results show that wireless access for vehicular environment (WAVE) protocol outperforms TCP/IP protocol under VANET scenario.

Venkata *et al.* [44] proposed a clustering scheme where the CH is elected on the basis of direction and distance. The elected CH assumes the role of routing and delivery of packets generated in the cluster network. This mechanism is implemented using NCTUns simulator. In [22], an opportunistic approach for auto adaptive data dissemination for vehicular ad-hoc networks is adapted. The direction of the moving vehicles is taken into account for this technique. The message broadcast is dynamically adapted to best suit the network to avoid congestion.

Zheng *et al.* [47] proposed a *c*luster-based *o*n-demand *de*lay tolerant routing (CODE) for efficient data dissemination using clustering technique based on the relative speed of the vehicles. The goal is to enhance the network lifetime of the clusters for improving the packet delivery ratio and lowering transmission delay. Maslekar *et al.* [33] proposed a technique called C-DRIVE that considers the direction of vehicles while forming clusters and electing a CH. The technique causes less broadcast and allows the network bandwidth to be used optimally for data dissemination. In [19], medium access control technique is used for identifying the hidden node problem that lies in the network and may cause packet collisions causing packet loss. The elected CHs are authorized to allocate specific network bandwidth for each member of the cluster.

Samaras [38] attempt to construct a basic mechanism to analyze the use of mobile ad-hoc network (MANET) routing algorithms for inspection of data dissemination in VANET scenario. Dubey *et al.* [14] propose routing based mechanisms for the purpose of data dissemination to improve in packet delivery ratio and minimize packet loss in VANET scenario. The results show good performance in high-density areas where vehicles are much closer to each other while generating less packets as compared to simple flooding techniques. Syarif *et al.* [41] prioritize packets for the purpose of data dissemination. Moreover, a prioritized scheduling technique is used to demonstrate improved performance in terms of packet delivery ratio, delay, and throughput.

Farooq *et al.* [17] analyze existing techniques to identify major problem areas. Furthermore, two techniques are proposed: unidirectional flooding and selection flooding, to tackle the broadcast storm problem caused by unnecessary rebroadcasts. Costa *et al.* [9], authors proposed data dissemination protocol based on centrality (DDBC) protocol which is targeted for urban areas. Moreover, their performance analysis shows a decrease in transmission delay and an increase in packet delivery ratio.

All the algorithms discussed above are designed to handle particular challenges in VANETs including transmission delay, packet delivery ratio, information coverage, network congestion, and intra-cluster communication. However, all these parameters directly impact the overall performance of EM dissemination, and our proposed technique is designed to handle many in order to achieve higher packet delivery ratio.

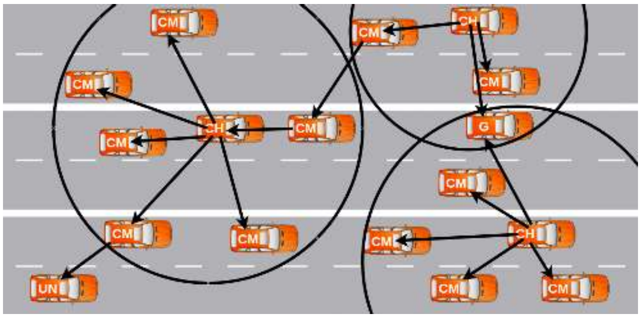

FIGURE 2. Clustering of vehicles.

III. PRELIMINARIES

The proposed technique is used for dissemination of EM in a V2V scenario. The technique is specifically designed for an urban environment. It is based on a dynamic cluster of vehicles comprising CH with its CMs as shown in Fig 2. Moreover, there are vehicles that can be a part of multiple clusters, such vehicles are termed as gateway-vehicles (G). The vehicles that are not a member of any cluster are unregistered vehicles represented as UN_{reg}. Once a vehicle becomes the CH, it starts broadcasting cluster head advertisements (CHA) message after a fixed time intervals. In response, vehicles within its range, send a cluster association request (CAR) to become a member of the cluster. On receipt of an EM, a vehicle establishes a time barrier for further broadcast. Note that every vehicle computes its own time barrier (ξ_i), which is the time a vehicle waits before broadcasting the received EM. It is computed based on the distance from the source vehicle.

Keeping generality, a vehicle is represented with id i and cluster id with $\Omega(i)$, t represents the current time of simulation. The ξ_{ij} represents the distance between two vehicles V_i and V_j. The ξ_{ij} is used to define the time barrier before broadcast. Moreover, the cluster refresh interval is represented as Δr. The CH removes the CM information from its cluster table if it does not receive any beacon during this time interval. Furthermore, a cluster is represented with $C^k_{\Omega(i)}$, where k represents the total number of CMs.

A. SYSTEM MODEL

As mentioned earlier, the proposed time barrier based EM dissemination algorithm is specifically designed for V2V communication in urban areas. Evidently, in such areas, there exist multiple paths to the same destination with vehicles remaining a part of a cluster for a very short time durations. Furthermore, there is an effect of channel fading on the underlying communication model. To model this effect for wireless signals in VANETs, we used Nakagami distribution. This particular distribution is used in other similar works [45], [46]. The transmission probability of packets between the source vehicle i and receiver vehicle j on successful communication in terms of channel fading is represented as:

$$p(x; m, \Omega) = 1 - \frac{\Gamma_{mx^2/\overline{P}_r}(m)}{\Gamma(m)} \tag{1}$$

$$= e^{-\frac{m}{\overline{P}_r}x^2} \frac{2m^m}{\Gamma(m)\overline{P}_r^m} x^{2m-1} \tag{2}$$

where $\frac{\Gamma_{mx^2/\overline{P}_r}(m)}{\Gamma(m)}$ represents the cumulative distributive function for signal reception, x^2 describes the reception threshold of the propagation signal and $\overline{P}_r$ represents the average power level of the received signal. The fading parameter m is defined based on the distance d between the vehicles i and j,

$$m = \begin{cases} 3.0 & : d < d_0 \\ 1.5 & : d_0 \le d < d_b \\ 1.0 & : \text{otherwise} \end{cases} \tag{3}$$

Here d_0 represents the initial value i.e. 50 meters, while d_b represents the upper bound value i.e. 150 meters.

Moreover, we also consider interest compatibility (IC) for each vehicle. This includes information about parking, accidents and traffic congestions. Let V_i be the vehicle with k potential interests then its interest vector v_{ti} is given as,

$$\vec{v_{ti}} = (v_{1,i}, v_{2,i}, \cdots, v_{k,i}) \tag{4}$$

In this study, we used an IC model based on cosine similarity for CH election. Classically the similarity measure is used to find the angle between two vectors not taking into regard their magnitudes. Since in the proposed approach focuses on the direction of vehicles for cluster formation, we compute mutual interest between vehicles V_i and V_j given as,

$$IC(\vec{v_{ti}}, \vec{v_{tj}}) = \cos(\theta) = \frac{\vec{v_{ti}} \cdot \vec{v_{tj}}}{\|\vec{v_{ti}}\| \|\vec{v_{tj}}\|} \tag{5}$$

$$= \frac{\sum_{\alpha=1}^{k} v_{\alpha,i} \times v_{\alpha,j}}{\sqrt{\sum_{\alpha=1}^{k} v_{\alpha,i}^2} \times \sqrt{\sum_{\alpha=1}^{k} v_{\alpha,j}^2}} \tag{6}$$

In order to improve the cluster lifetime, a CH is selected based on two factors: vehicle interest compatibility, and the probability of successful packet transmission. The former is computed using Eq. 5, while the latter uses the channel model defined in Eq. 1 to determine successful reception of packets. Both these factors define cluster head eligibility (CHE) of a vehicle i,

$$CHE_i = \frac{\overline{c}_i}{\overline{d}_i \times \overline{\upsilon}_i \times \overline{r}_i} \tag{7}$$

The average interest compatibility $\overline{c}_i$ of a vehicle i is given as,

$$\overline{c}_i = \frac{1}{N-1} \sum_{j=1, j \neq i}^{N} IC(\vec{V}_i, \vec{V}_j) \tag{8}$$

Here N represents the total number of vehicles.

The average distance $\overline{d}_i$ between vehicle V_i and its neighboring vehicles V_j is computed using,

$$\overline{d}_i = \frac{1}{N} \sum_{j=1}^{N} \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{9}$$

Similarly, the average velocity $\overline{\upsilon}_i$ between vehicle V_i and its neighboring vehicles V_j is computed using,

$$\overline{\upsilon}_i = \frac{1}{N} \sum_{j=0}^{N} |\upsilon_i - \upsilon_j| \tag{10}$$

Moreover, to find the average distance between the relative destination $\overline{r}_i$ of vehicle V_i and neighboring vehicles V_j is computed using,

$$\overline{r}_i = \frac{1}{N} \sum_{j} \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{11}$$

Using the cosine similarity matrix, vehicles can determine the interest of other vehicles. One with highest compatibility is selected as the CH. Note that relative destination between vehicles using GPS coordinates is used to determine CMs, however, if a member finds another CH with a more similar destination it changes its membership.

The location and velocity of i^{th} CH at any time interval t is denoted as $\vec{p}_i(t)$ and $\vec{v}_i(t)$, and Δt represents the packet delay in transmission [6]. The new location is computed using,

$$\vec{p}_i(t + \Delta t) = \vec{p}_i(t) + \vec{v}_i(t)\Delta t \tag{12}$$

Similarly, the location and velocity of j^{th} CM is calculated as,

$$\vec{p}_{ij}(t + \Delta t) = \vec{p}_{ij}(t) + \vec{v}_{ij}(t)\Delta t \tag{13}$$

where $j = 1, 2, \cdots, M$ and M is the total number of CMs. To check whether a CM is within the transmission range of its CH, we use,

$$|\vec{p}_{ij}(t + \Delta t) - \vec{p}_i(t + \Delta t)| \leq R \tag{14}$$

Here R represents the transmission range. The vehicles V_i and V_j are in transmission range if the magnitude of the difference is less than R.

IV. DISSEMINATION USING TIME BARRIER

The proposed technique uses dynamic cluster formation based on similar features where the CH disseminates data and EMs to other CMs. Moreover, the technique implements a clustering technique to tackle the broadcast storm problem. The problem is caused when all vehicles start broadcasting the received EM. Thus, leads to network congestion affecting the overall network performance in terms of packet loss and decreased packet delivery ratio.

Initially, with no CH and vehicles joining the network at different junctions, each vehicle broadcasts its basic information including vehicle speed and direction, road segment id and other parameters to vehicles that are present within its transmission range. Any vehicle can become a CH after a specific time interval. Note that during this interval, an unregistered vehicle can become neither a CH nor a CM. This delay in CH selection is primarily to assess vehicle neighborhood through the messages flowing within its reception range, and to find any existing clusters. In the later case when an existing cluster is found via reception of CHA, new vehicles can send affiliation requests to join the cluster. The CH adds the new vehicle to its CM list.

In case of no clusters around, the vehicle performs a self-assessment based on some parameters for the role of CH in a newly formed cluster. The parameters used are the direction and relative distance of the vehicle to other vehicles. For instance, the vehicle must have at least $q\%$ vehicles in its range and the relative distance must be less than Δg to maintain good link connectivity between the CH and its members. On the other hand, if the vehicle is ineligible for the role, the vehicle again waits for a time interval to again initiate its cluster search mechanism. If the vehicle declares itself as the CH which the vehicle remains unless it loses all its members and resigns itself as an unregistered vehicle.

A. CLUSTER FORMATION

The CH continuously monitoring all its members, as well as, handles unregistered vehicles in its neighborhood. This starts with the unregistered vehicles first locating a nearby CH and then sending a *CAR* to join it. Upon reception of the request, the CH acknowledges the request with a confirmation message and adds a *CM* entry of the new vehicle in its range to its member list. Similarly, the vehicle records a *CH* entry for the recently joined cluster. The detailed cluster formation algorithm is listed in Algorithm 1.

The CM monitors its link connectivity with the CH through periodic heartbeat messages. In case of lost connectivity and CM failing to re-establish connectivity within Δz time. The member removes the particular *CH* entry from its table, changes its status to an UN_{reg} vehicle, and initiates the rescans process. Upon reception of a *CHA* message during this interval, the vehicle associates itself to the respective cluster through a response *CAR* message. In case of no *CHA* messages received, the UN_{reg} vehicle checks its eligibility to become a *CH*. The primary responsibilities of the newly elected *CH* are: to disseminate EM, to cater association requests received from UN_{reg} vehicles and to monitor link connectivity to its members. Any disconnections are identified using multiple missed heartbeat messages. The CH resigns from its role when its member table is empty. Moreover, the resigned *CH* becomes an UN_{reg} vehicle.

B. EMERGENCY MESSAGES DISSEMINATION

The main objective of the proposed technique is to reduce time delay and to improve overall coverage for effective

Algorithm 1 Cluster Formation

while *true* **do**
  $\{k | k \in C_{\Omega(k)} \wedge d(i, k) < R\}$
  if $k = \phi$ **then**
    $\Omega(i) \leftarrow i$
    $C_{\Omega(i)} \leftarrow \{(i, T_i)\}$
    CHA($\Omega(i)$)
  else
    $n \leftarrow |C^i_{\Omega(i)}|$
    $C^{n+1}_{\Omega(k)} \leftarrow i$
    Beacon(i)
    $T^i_k \leftarrow t$
  end if
  if $|T^i_k - t| > \Delta r$ and $k = \phi$ **then**
    $C^i_{\Omega(i)} = \phi$
  end if
  if $|T^i_k - t| > \Delta r$ and $k \neq \phi$ **then**
    $C^i_{\Omega(i)} = \{k | \Omega^k_i = \Omega(i)$ and $k \neq i\}$
  end if
end while

Algorithm 2 Emergency Messages

$CH = \{k | k \in C^k_{\Omega(i)}, \Omega(k) = \Omega(i)\}$
$CM = \{k | k \in C^k_{\Omega(i)}, \Omega(k) \neq \Omega(i)\}$
if $CH \neq \phi$ **then**
  Send($\forall k \in C^k_{\Omega(i)}$)
else if $CM \neq \phi$ **then**
  $\xi_{ij} \leftarrow d(i, j)$
  if $|T_{ij} - T'_{ij}| < \xi_{ij}$ **then**
    $\xi_{ij} \leftarrow \phi$
  else
    Wait(ξij)
    Send($EM, \forall k \in C^k_{\Omega(i)}$)
  end if
else
  $\xi_{ij} \leftarrow d(i, j)$
  if $|T_{ij} - T'_{ij}| < \xi_{ij}$ **then**
    $\xi_{ij} \leftarrow \phi$
  else
    Wait(ξij)
    Broadcast(EM)
  end if
end if

EM dissemination, in contrast, non-time-critical messages can be received with a delay. Furthermore, sending *EM* through broadcast can cause network congestion degrading the overall performance of the entire network. The proposed *EM* dissemination framework presented in Algorithm 2 manages cluster formation and CH selection, as well as, it manages UN_{reg} vehicles.

On receipt of an *EM*, the vehicle first checks its status. If the vehicle is *CH*, the received *EM* is immediately disseminated to all its CMs. Upon reception, a *CM* vehicle sets a barrier to broadcast the message. This barrier is inversely dependent on the distance between the sender vehicle V_s and the receiver vehicles V_r, that is, vehicles at large distances will end up setting a small time barrier value. Therefore, only faraway vehicles broadcast the EM. This increases the overall coverage area avoiding any delays caused due to a broadcast storm, in turn, improving the packet delivery ratio. Moreover, if a nearby vehicle receives an *EM* again, it simply cancels its barrier.

In a traditional scenario, a CM forwards the received message to its CH, which disseminates the message to all its CMs. This additional hop can add a delay in disseminating the EM. To reduce this delay, in the proposed approach, any vehicle can elevate its privileges to broadcast the EM itself after its time barrier expires. Moreover, the gateway vehicle behaves similarly on receipt of EM when disseminating the EM across clusters.

Furthermore, there are no explicit acknowledgments used in the proposed technique. When an EM is received at a vehicle opposite to the direction for which it set up a time barrier, the message is taken as an implicit acknowledgment. This means a farther away vehicle has received the same message and there is no need to broadcast the message. However, if the same message is not received during the time period, the vehicle broadcasts the EM.

V. PERFORMANCE EVALUATIONS

In this section, we evaluated the proposed mechanism using OMNeT++ [43], *s*imulation of *u*rban *mo*bility (SUMO) [27] and Veins [40] platform. The proposed algorithm is compared to clustering based probabilistic broadcasting (CPB) [30], cluster-based EM dissemination proposed by Jin *et al.* (termed as Jin Model) [23] and simple flooding. In CPB, data is disseminated using probabilistic forwarding, and the CH is responsible for dissemination of messages. Whereas in Jin Model, messages are disseminated on basis of vehicle status and region of interest (ROI). Lastly, in flooding, each vehicle broadcasts the message received by all vehicles even if they already received it.

A. SIMULATION SETUP

The simulation scenario was evaluated in an urban area, where vehicles can cluster for shorter periods of time. The vehicles were added randomly at different intersections of the road to simulate an urban area. The vehicle density varied between 20 to 125 vehicles/km. The uptime of the simulation runs averaged around 500 seconds and the average of 50 simulation runs was reported. To measure the effectiveness of the proposed technique, we used metrics including information coverage, transmission delay, packet delivery ratio, and vehicle density. The simulation parameters used are listed in Table 2.

B. RESULTS AND DISCUSSIONS

1) COVERAGE AREA

The amount of area covered by EMs defines information coverage. It is an important factor when dealing with message

TABLE 2. Simulation parameters.

Parameters	Values
Simulation area	3km × 3km
Simulation time	500s
Simulation runs	50
Transmission range	250m
Transmission power	20 mW
Road type	Two-way traffic
Data transmission rate	6 Mbps
MAC protocol	IEEE 802.11p WAVE
Vehicle density (N)	20–125/km
Vehicle velocity	12–20 m/s
Maximum acceleration	2.6 m/s^2
Distribution model	Nakagami
EM packet size	170 bytes
Beacon packet size	194 bytes
Accident interval	15s
Accident duration	30s
Number of accidents	33
Road side units	None

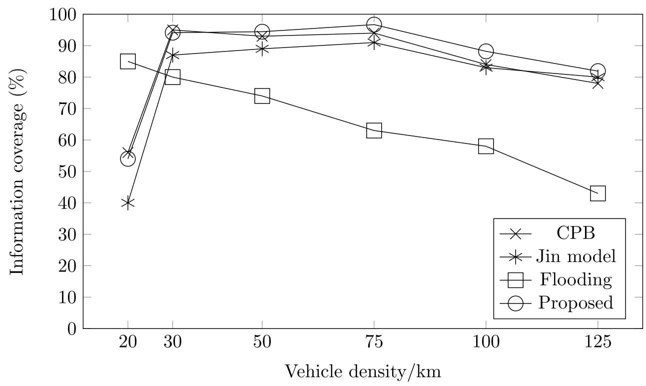

FIGURE 3. Information coverage vs. vehicle density.

dissemination as it shows reachability of EMs. Fig. 3 shows the percentage of information coverage with respect to the vehicle density. The proposed technique is compared to CPB, Jin model and traditional flooding. In lower density, the percentage of information coverage of the proposed technique is close to CPB, whereas the flooding techniques outperform the other techniques. With increase in density, the flooding is not the better option as seen in the figure. The proposed technique outperforms the flooding approach, whereas, Jin model is close to CPB technique. In low density, fewer vehicles are available to disseminate the message, therefore they cover a smaller area of the Urban environment. With the increase in the density of the vehicles, the information coverage also increases as more vehicles are covering the urban area. Moreover, for an urban area, flooding is not suitable as it affects the network and can cause congestion. Further, it has been observed that after a certain vehicle density, the information coverage become saturated. This is because of the fact that higher vehicle density causes congestion in the network.

2) TRANSMISSION DELAY

We evaluated the transmission delay between two vehicles moving at variable velocities. The transmission delay is the time required by the message to reach a destination vehicle.

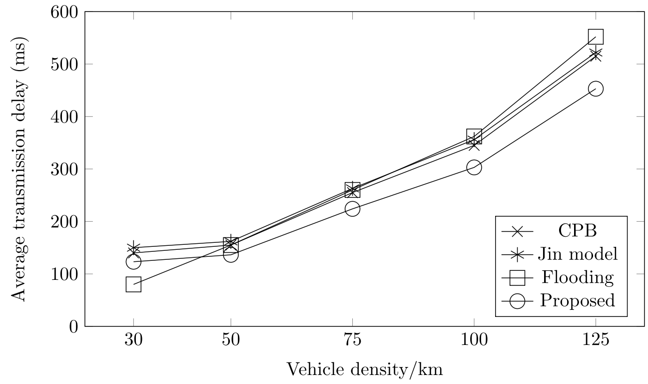

FIGURE 4. Average Transmission delay vs. vehicle density.

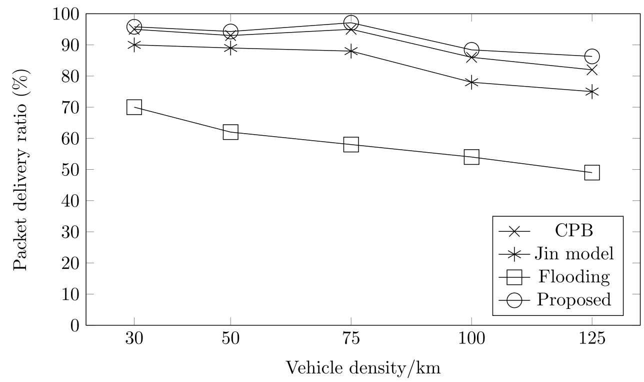

FIGURE 5. Packet delivery ratio vs. vehicle density.

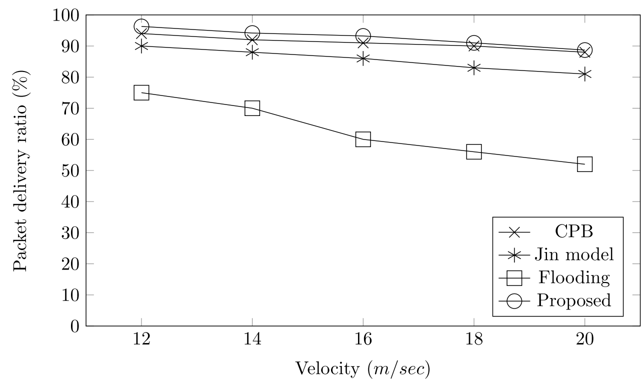

FIGURE 6. Comparison of the proposed scheme, packet delivery ratio with variation in velocity.

It is highly dependent upon the distance between vehicles and channel effects. Fig. 4 shows the average transmission delay with respect to vehicle density. The result shows that the average transmission delay comparison among the proposed technique, CPB, Jin Model, and flooding. With high and low density, the proposed technique performed well; whereas the flooding technique outperforms others with a lower density only, but with the increase in the density, a prominent change is observed. This is due to the fact that in the proposed algorithm, the EMs are handled on high priority and any vehicle can elevate its role for timely dissemination of messages. Whereas in other algorithms, EMs are sent to CH for further dissemination.

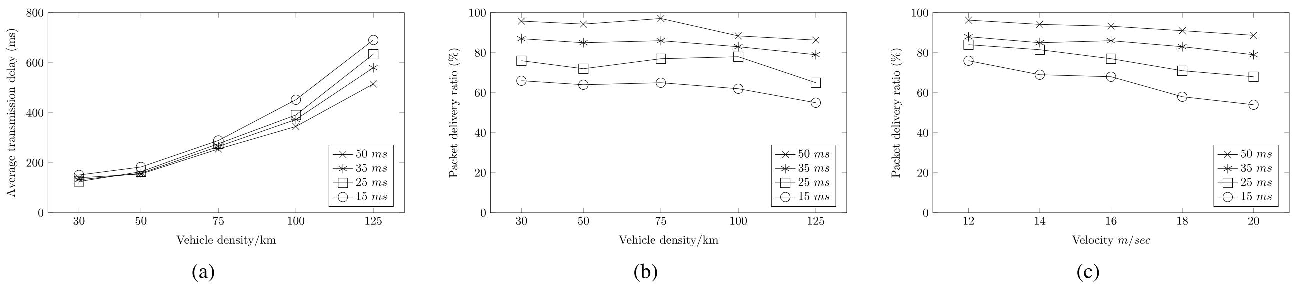

FIGURE 7. Performance evaluation of the proposed mechanism w.r.t different beacon intervals: (a) average transmission delay vs vehicle density (b) packet delivery ratio vs vehicle density and (c) packet delivery ratio vs velocity.

3) SUCCESSFUL TRANSMISSION

The packet delivery rate is the ratio between the packets successfully received at the destined vehicle to the overall packets transmitted. It plays a vital role in determining the success of the proposed technique as the frequent generation of messages can cause network congestion and affect the delivery rate. Fig. 5 shows the packet delivery ratio with respect to the vehicle density. The result shows that the packet delivery ratio of the proposed technique is performed better compared to the other techniques. This is due to the fact that in high density, vehicles can come close to one another and thus, overlaps in the transmission range with other vehicles. Thus the packet delivery ratio has increased, on the other hand, it has also been observed that after a certain point, high density have a decreasing effect over packet delivery ratio due to network congestion. The flooding technique is constantly under-performing. This is mainly because that every vehicle is broadcasting the same message when received, which causes congestion in the network, which in-turn causes packet collisions. This causes the packets to drop in the network and decrease the packet delivery ratio. Jin model and CPB are very close to each other. On high-density situation, the CPB and Jin model perform has also reduced.

In Fig. 6, the packet delivery ratio is evaluated with the velocity of the vehicles. The packet delivery ratio decreases with an increase in the velocity of the vehicles. It can be seen that the flooding mechanism performed low when it comes to packet delivery ratio with high speed. This is due to the fact that vehicles have very limited time to receive the packet. Moreover, everyone is broadcasting caused more congestion, thus, most of the vehicles left network without receiving an EM even a single time. Moreover, with high-speed vehicles, the network lifetime decreases as the fast-moving vehicles join the network for a short duration of time. Thus, all the mentioned algorithm face a decrease in packet delivery ratio as the velocity of the vehicles increases. Thus, the proposed technique and CPB has nearly the same performance.

4) IMPACT OF BEACON INTERVAL ON EMERGENCY MESSAGES

Further, the effect of beacon internal on EMs under the proposed technique has also been considered during evaluation. The beacon interval is defined as the time at which the UN_{reg}, CH and CM generate heartbeat messages to show its presence in the network. The correct selection of beacon interval is crucial as the control messages can also clot the communication channels and results in increased packet drop rate. Fig. 7a shows the affect of the beacon generation at different intervals on transmission delay. It can be seen that more frequent generation of the beacon can further cause transmission delay. As all the vehicles are generating beacon at regular interval of time and that can cause network congestion. A similar effect has been observed in packet delivery ratio with varying vehicle density and velocity as shown in Fig. 7b and Fig.7c.

C. DISCUSSION

The proposed technique has improved the coverage area, increased packet delivery ratio and reduced the transmission delay. Thus, based on the evaluation, the proposed technique has performed well compared with other techniques. The proposed technique has reduced the delay upto 12% when compared with CPB and Jin model. Thus, timely dissemination of EMs are very critical and reducing delay is beneficial in emergency situations. Moreover, the information coverage and packet delivery ratio has also increased. This is due to the fact that the proposed technique is based on a dynamic time barrier mechanism which stops all vehicle to broadcast the same message to avoid congestion in the overall network. The major hurdle in EM dissemination using vehicles is the ad-hoc nature. The vehicle can join and leave the network very frequently. Further, the high-speed vehicles reduce the lifetime of clusters. Thus, the coverage area decreases. In the future, with the advancement in technology and the inception of 5G services can overcome these issue. In 5G services, the data rate increases that can further improve the packet delivery ratio. Moreover, the use of RSU can be used to relay among clusters and increase the coverage area.

VI. CONCLUSION

In this paper, we proposed a novel technique for the dissemination of EMs which are extremely time critical. The information such as road accidents must be disseminated with minimum possible delay to inform others about the road blockage. Our proposed scheme is based on clustering technique to handle broadcast storm problem and dynamic time barrier mechanism to reduce the network congestion.

The proposed scheme has reduced the delay upto 12% compared with other well-known techniques. Moreover, the packet delivery ratio is improved with a reduction in the average transmission delay. Our proposed mechanism performs better at low speed and higher vehicle density due to increased network connection time. With the increase in vehicle speed, the network connection time decreases. Thus, it degrades the performance of the system.

ACKNOWLEDGMENT

The work of S. U. Khan is based upon work supported by (while serving at) the National Science Foundation. Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

[1] *IEEE Standard for Information technology–Local and metropolitan area networks– Specific requirements– Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments*, IEEE Standard 802.11p-2010 (Amendment to IEEE Standard 802.11-2007 as amended by IEEE Standard 802.11k-2008, IEEE Standard 802.11r-2008, IEEE Standard 802.11y-2008, IEEE Standard 802.11n-2009, and IEEE Standard 802.11w-2009), Jul. 2010, pp. 1–51..

[2] *IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-Channel Operation*, IEEE Standard 1609, Mar. 2016, pp. 1–94.

[3] A.-M. Ahmad, H. Idriss, A. E. Mouallem, and Z. E. Bazzal, "Chain-based data dissemination in vehicular ad-hoc networks (VANETs)," in *Proc. 6th Int. Conf. Digit. Inf., Netw., Wireless Commun. (DINWC)*, Apr. 2018, pp. 75–80.

[4] S. Alwakeel and A. Prasetijo, "A virtual P-persistent bandwidth partitioning manager for VANET's broadcast channel," in *Proc. Int. Conf. Multimedia Comput. Syst. (ICMCS)*, Apr. 2014, pp. 1212–1215.

[5] I.-H. Bae, "A dynamic Hi-CAST protocol for safety message dissemination in VANET," in *Proc. 5th Int. Conf. Ubiquitous Future Netw. (ICUFN)*, Jul. 2013, pp. 827–831.

[6] X. Bai, Y. Hong, Y. Du, and Z. Gao, "Efficient data dissemination scheme for the urban vehicular ad hoc networks," *Inf. Technol. J.*, vol. 12, no. 9, p. 1696, May 2013.

[7] M. M. Bhuiyan, S. M. Salim, and M. R. Hasan, "Density aware broadcasting scheme for VANET," in *Proc. 17th Asia Pacific Conf. Commun.*, Oct. 2011, pp. 467–471.

[8] S. Boumerdassi and E. Renault, "A flooding-based solution to improve location services in VANETs," in *Proc. IEEE Int. Conf. Commun. (ICC)*, May 2016, pp. 1–6.

[9] J. Costa, W. Lobato, A. M. de Souza, D. Rosário, L. A. Villas, and E. Cerqueira, "Centrality-based data dissemination protocol for vehicular ad hoc networks," in *Proc. IEEE 16th Int. Symp. Netw. Comput. Appl. (NCA)*, Nov. 2017, pp. 1–4.

[10] F. Cunha *et al.*, "Data communication in VANETs: Protocols, applications and challenges," *Ad Hoc Netw.*, vol. 44, pp. 90–103, Jul. 2016.

[11] E. Daknou, M. Thaalbi, and N. Tabbane, "Clustering enhancement for VANETs in highway scenarios," in *Proc. 5th Int. Conf. Commun. Netw. (COMNET)*, Nov. 2015, pp. 1–5.

[12] Y. Du *et al.*, "A distributed message delivery infrastructure for connected vehicle technology applications," *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 3, pp. 787–801, Mar. 2018.

[13] A. Dua, N. Kumar, and S. Bawa, "An energy efficient data dissemination and information retrieval scheme for VANET," in *Proc. IEEE Int. Conf. Data Sci. Data Intensive Syst.*, Dec. 2015, pp. 427–434.

[14] B. B. Dubey, N. Chauhan, and S. Pant, "RRDD: Reliable route based data dissemination technique in VANETs," in *Proc. Int. Conf. Commun. Syst. Netw. Technol.*, Jun. 2011, pp. 148–151.

[15] O. S. Eyobu, J. Joo, and D. S. Han, "Cooperative multi-channel dissemination of safety messages in VANETs," in *Proc. IEEE Region 10 Conf. (TENCON)*, Nov. 2016, pp. 1867–1870.

[16] O. S. Eyobu, J. Joo, and D. S. Han, "A broadcast scheme for vehicle-to-pedestrian safety message dissemination," *Int. J. Distrib. Sensor Netw.*, vol. 13, no. 11, p. 1550147717741834, Nov. 2017.

[17] M. U. Farooq, K. U. R. Khan, and S. Mohammed, "Selective flooding techniques for dissemination in VANETs," in *Proc. 2nd Int. Conf. Contemp. Comput. Inform.*, Dec. 2016, pp. 369–374.

[18] G. Farrokhi and S. Zokaei, "Improving safety message dissemination in IEEE 802.11e based VANETs using direction oriented controlled repetition technique," in *Proc. IEEE 21st Symp. Commun. Veh. Technol. Benelux (SCVT)*, Nov. 2014, pp. 100–104.

[19] Y. Guenter, B. Wiegel, and H. P. Grossmann, "Medium access concept for VANETs based on clustering," in *Proc. IEEE 66th Veh. Technol. Conf.*, Oct. 2007, pp. 2189–2193.

[20] S. Iadicicco, S. Infante, P. Salvo, A. Baiocchi, and F. Cuomo, "Multi-originator data dissemination in VANETs," in *Proc. 12th Annu. Conf. Wireless On-Demand Netw. Syst. Services (WONS)*, Jan. 2016, pp. 1–8.

[21] R. Jamgekar and S. Tapkire, "A robust multi-hop clustering algorithm for reliable VANET message dissemination," in *Proc. Int. Conf. Energy, Commun., Data Anal. Soft Comput. (ICECDS)*, Aug. 2017, pp. 2599–2604.

[22] N. Jianwen, L. Chang, and M. Jian, "Opportunistic auto-adaptive dissemination in vehicular ad-hoc networks," in *Proc. 1st Int. Conf. Netw. Commun.*, Dec. 2009 , pp. 40–45.

[23] D. Jin, F. Shi, and J. Song, "Cluster based emergency message dissemination scheme for vehicular ad hoc networks," in *Proc. 9th Int. Conf. Ubiquitous Inf. Manage. Commun.*, Jan. 2015, p. 2.

[24] F. Khan, K. Sanil, F. Elahi, and J. Copeland, "Recovering VANET safety messages in transmission holes," in *Proc. Global Inf. Infrastruct. Symp.*, Oct. 2013, pp. 1–5.

[25] S. R. Kolte and M. S. Madnkar, "A design approach of congestion control for safety critical message transmission in VANET," in *Proc. 4th Int. Conf. Commun. Syst. Netw. Technol.*, Apr. 2014, pp. 298–301.

[26] J. J. Kponyo, Y. Kuang, E. Zhang, and K. Domenic, "VANET cluster-on-demand minimum spanning tree (MST) prim clustering algorithm," in *Proc. Int. Conf. Comput. Problem-Solving (ICCP)*, Oct. 2013, pp. 101–104.

[27] D. Krajzewicz, J. Erdmann, M. Behrisch, and L. Bieker, "Recent development and applications of SUMO-simulation of urban MObility," *Int. J. Adv. Syst. Meas.*, vol. 5, pp. 3–4, Dec. 2012.

[28] A. Kumar and R. P. Nayak, "An efficient group-based safety message transmission protocol for VANET," in *Proc. Int. Conf. Commun. Signal Process.*, Apr. 2013, pp. 270–274.

[29] B. Liu, D. Jia, J. Wang, K. Lu, and L. Wu, "Cloud-assisted safety message dissemination in VANET–cellular heterogeneous wireless network," *IEEE Syst. J.*, vol. 11, no. 1, pp. 128–139, Mar. 2017.

[30] L. Liu, C. Chen, T. Qiu, M. Zhang, S. Li, and B. Zhou, "A data dissemination scheme based on clustering and probabilistic broadcasting in VANETs," *Veh. Commun.*, vol. 13, pp. 78–88, Jul. 2018.

[31] W. Liu, X. Tang, S. Jia, and J. Pu, "Safety message dissemination using edge computing in heterogeneous VANETs," in *Proc. IEEE 27th Int. Symp. Ind. Electron. (ISIE)*, Jun. 2018, pp. 1276–1281.

[32] N. Maslekar, M. Boussedjra, J. Mouzna, and L. Houda, "Direction based clustering algorithm for data dissemination in vehicular networks," in *Proc. IEEE Veh. Netw. Conf. (VNC)*, Oct. 2009, pp. 1–6.

[33] N. Maslekar, M. Boussedjra, J. Mouzna, and H. Labiod, "C-DRIVE: Clustering based on direction in vehicular environment," in *Proc. 4th IFIP Int. Conf. Technol., Mobility Secur.*, Feb. 2011, pp. 1–5.

[34] R. Mehra, R. S. Bali, and P. Kaur, "Efficient clustering based OLSR routing protocol for VANET," in *Proc. Symp. Colossal Data Anal. Netw. (CDAN)*, Mar. 2016, pp. 1–7.

[35] M. Milojevic and V. Rakocevic, "Location aware data aggregation for efficient message dissemination in vehicular ad hoc networks," *IEEE Trans. Veh. Technol.*, vol. 64, no. 12, pp. 5575–5583, Dec. 2015.

[36] Y. L. Morgan, "Notes on DSRC & WAVE standards suite: Its architecture, design, and characteristics," *IEEE Commun. Surveys Tuts.*, vol. 12, no. 4, pp. 504–518, 4th Quart., 2010.

[37] T. Qiu, R. Qiao, and D. O. Wu, "EABS: An event-aware backpressure scheduling scheme for emergency internet of things," *IEEE Trans. Mobile Comput.*, vol. 17, no. 1, pp. 72–84, Jan. 2018.

[38] N. S. Samaras, "Using basic MANET routing algorithms for data dissemination in vehicular ad hoc networks (VANETs)," in *Proc. 24th Telecommun. (TELFOR)*, Nov. 2016, pp. 1–4.

[39] C. Shi *et al.*, "A centralized clustering based hybrid vehicular networking architecture for safety data delivery," in *Proc. IEEE Global Commun. Conf.*, Dec. 2017, pp. 1–6.

[40] C. Sommer, R. German, and F. Dressler, "Bidirectionally coupled network and road traffic simulation for improved IVC analysis," *IEEE Trans. Mobile Comput.*, vol. 10, no. 1, pp. 3–15, Jan. 2010.
[41] S. Syarif *et al.*, "Proposed priority packet data dissemination scheduling mechanism," in *Proc. 4th Int. Conf. Comput. Appl. Inf. Process. Technol. (CAIPT)*, Aug. 2017, pp. 1–5.
[42] S. Ucar, S. C. Ergen, and O. Ozkasap, "Multihop-cluster-based IEEE 802.11p and LTE hybrid architecture for VANET safety message dissemination," *IEEE Trans. Veh. Technol.*, vol. 65, no. 4, pp. 2621–2636, Apr. 2016.
[43] A. Varga and R. Hornig, "An overview of the OMNeT++ simulation environment," in *Proc. 1st Int. Conf. Simul. Tools Techn. Commun., Netw. Syst. Workshops*, Los Angeles, CA, USA: ICST, 2008, p. 60.
[44] M. D. Venkata, M. M. Pai, R. M. Pai, and J. Mouzna, "Traffic monitoring and routing in VANETs—A cluster based approach," in *Proc. 11th Int. Conf. ITS Telecommun.*, Aug. 2011, pp. 27–32.
[45] W. Wang and T. Luo, "The minimum delay relay optimization based on nakagami distribution for safety message broadcasting in urban VANET," in *Proc. IEEE Wireless Commun. Netw. Conf.*, Apr. 2016, pp. 1–6.
[46] X. Zhang, X. Cao, L. Yan, and D. K. Sung, "A street-centric opportunistic routing protocol based on link correlation for urban VANETs," *IEEE Trans. Mobile Comput.*, vol. 15, no. 7, pp. 1586–1599, Jul. 2016.
[47] J. Zheng, H. Tong, and Y. Wu, "A cluster-based delay tolerant routing algorithm for vehicular ad hoc networks," in *Proc. IEEE 85th Veh. Technol. Conf. (VTC Spring)*, Jun. 2017, pp. 1–5.

SYED SARMAD SHAH received the B.Sc. degree in information technology from the IBMS, The University of Agriculture, Peshawar, Pakistan. He is currently pursuing the M.Sc. degree in information technology with the National University of Sciences and Technology, Islamabad, Pakistan. His research interests include VANETs and distributed systems.

ASAD WAQAR MALIK received the Ph.D. degree in computer software engineering from the NUST, Pakistan, where he is currently an Assistant Professor with the School of Electrical Engineering and Computer Science. His research interests include parallel and distributed simulation, cloud computing, and large-scale networks.

ANIS U. RAHMAN received the master's degree in parallel and distributed systems from Joseph Fourier University, France, and the Ph.D. degree in computer science from Grenoble University, France, in 2013. He is currently an Assistant Professor with the School of Electrical Engineering and Computer Science, National University of Sciences and Technology, Pakistan. His main research interests include modeling of visual attention by assessing the different mechanisms guiding it, salient multi-object image and video segmentation and tracking, and efficient implementations of large-scale scientific problems on commodity graphical processing units.

SOHAIL IQBAL received the M.Sc. and M.Phil. degrees in mathematics from Quaid-i-Azam University, Pakistan, in 2002 and 2004, respectively, and the Ph.D. degree in surgical robotics from the University of Paris-Est, France, in 2010. He served as a Scientific Advisor under the French Ministry of Higher Education, from 2008 to 2010. He is currently an Assistant Professor with the National University of Sciences and Technology, Islamabad. His main research interests include apply mathematical techniques to different areas of computer science and engineering with special focus on robot modeling, energy management, and fuzzy controllers.

SAMEE U. KHAN received the Ph.D. degree from The University of Texas at Arlington, Arlington, TX, USA, in 2007. He is currently the Lead Program Director (Cluster Lead) for the Computer Systems Research with the National Science Foundation. He is also a Faculty Member with North Dakota State University, Fargo, ND, USA. His work has appeared in over 400 publications. His research interests include optimization, robustness, and security of computer systems. He is an ACM Distinguished Speaker, an IEEE Distinguished Lecturer, and a Fellow of the Institution of Engineering and Technology (IET, formerly IEE) and the British Computer Society. He is on the Editorial Boards of leading journals, such as *ACM Computing Surveys*, the IEEE ACCESS, the IEEE COMMUNICATIONS SURVEYS AND TUTORIALS, *IET Wireless Sensor Systems*, *IET Cyber-Physical Systems*, and the IEEE IT PROFESSIONAL.