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Position-based emergency message dissemination for Internet of vehicles

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Abstract
With the advancement in communication technologies, Internet of vehicles presents a new set of opportunities to efficiently manage transportation problems using vehicle-to-vehicle communication. However, high mobility in vehicular networks causes frequent changes in network topology, which leads to network instability. This frequently results in emergency messages failing to reach the target vehicles. To overcome this problem, we propose a data dissemination scheme for such messages in vehicular networks, based on clustering and position-based broadcast techniques. The vehicles are dynamically clustered to handle the broadcast storm problem, and a position-based technique is proposed to reduce communication delays, resulting in timely dissemination of emergency messages. The simulation results show that the transmission delay, information coverage, and packet delivery ratios improved up to 14%, 9.7%, and 5.5%, respectively. These results indicate that the proposed scheme is promising as it outperforms existing techniques.

Keywords
IoV, VANET, emergency messages, clustering, position-based dissemination

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Introduction

The emerging domain of Internet of things (IoT) has transformed many fields, among them, the traditional vehicular ad hoc networks (VANETs) have transformed into a new paradigm of connected vehicles known as Internet of vehicles (IoV). IoV plays an important role in building a dynamic network of vehicles for improving the intelligent transport system (ITS), focusing on efficient information exchange among vehicles. It provides support for new applications such as road safety, entertainment, and traffic management, which were previously difficult to realize. With IoV, this revolution in VANETs can easily be seen now as vehicles can share data and information with other vehicles and road side units (RSUs). IoV essentially extends structure by improving stability of VANETs to enhance ease of travel and improve driver awareness of traffic conditions, particularly, to help avoid road accidents, find less congested routes, and reduce fuel consumption and air pollution.[1] An

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illustration of a high-level IoV communication model is shown in Figure 1. This model improves the stability of vehicular networks and supports an application to facilitate drivers in avoiding congested routes.[2]

A steady increase in the number of vehicles on highways, owing to a reduction in initial ownership cost, has led to more congested roads and increased risk of accidents. In addition, weather conditions such as fog can also contribute to road congestion and inhibit driver response, leading to serious accidents. According to the reports published in 2011, in the United States, \$121 billion is wasted in 498 urban areas, and 56 billion pounds of additional CO_2 is produced due to congestion. The concept of connected vehicles is a promising approach to reduce road congestion via intelligent traffic control and management.[3] In traditional VANETs, information is exchanged directly or indirectly through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. Unlike mobile ad hoc networks (MANETs), the challenge in VANETs is handling high mobility and rapid topology changes that cause frequent network disconnections.[4,5] Moreover, these factors lead to excessive transmission delays, packet loss, and spectrum scarcity, leading to lower overall network performance. Vehicles rely on multi-hop mechanisms for message forwarding to other vehicles because of limited wireless communication range. Inherently, the radio signals used for such communication are likely to interfere with each other as vehicle density on roads increase. In such situations, a simple approach like broadcasting via flooding is costly and results in redundancy, contention, and collisions in the underlying network. This phenomenon is known as the broadcast storm problem, and it wastes significant spectrum resources, leading to spectrum scarcity.[6] From a public interest point, efficient dissemination of information among vehicles is desirable, as drivers are often interested in getting real-time traffic-related information.[7] Without any central control, the dynamic positioning of vehicles on roads causes network instability and broadcast issues, resulting in overall performance degradation. One possible solution is to install RSUs, which would be responsible for scheduling and managing dynamic networks. However, these access points add additional deployment and maintenance costs. Another possible solution is to dynamically build clusters based on parameters common to a set of vehicles on the road. These clusters can help to increase connection lifetime by grouping together vehicles with similar attributes, such as speed, physical location, and direction of travel. In such clusters, the vehicles send messages to the cluster head (CH), which in turn broadcasts them to other cluster members (CM). In this solution, however, certain issues, such as cluster stability, need to be addressed to enhance the network lifetime and channel fading affects.[8,9]

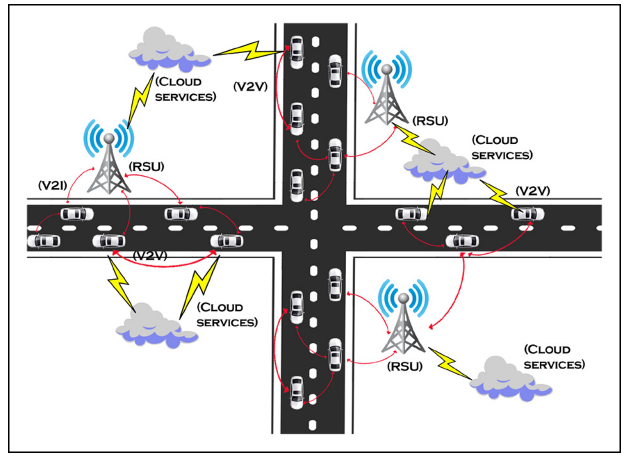

Figure 1. Internet of vehicles—communication paradigm.

In this article, we propose an emergency message (EM) dissemination scheme using dynamic clustering and position-based cross-cluster communication. The clusters are formed primarily on interest compatibility (IC) and destination similarity among vehicles, that is, vehicles sharing EMs based on the position of the target vehicle. In this approach, the position of a vehicle is known through beacon messages, and the optimum candidate for EM sharing is the vehicle moving in the opposite direction on the road. This is optimum because the opposite vehicle can spread information much faster. However, communication with such vehicles suffers because of reduced connection times, adversely affecting the data sharing rates. Though this can reduce the success rate, a successful communication decreases the delay and increases the coverage significantly as compared to other schemes. The rest of the article is organized as follows: section "Literature review" presents an overview of existing research on dissemination of EMs. Section "Methodology" covers the system model where the proposed position-based dissemination scheme is presented and evaluated. Section "Discussion" discusses the results and limitations of the proposed model. Finally, section "Conclusion" concludes the article.

Literature review

The dissemination of EMs, especially in VANETs, is an active area of research, with many techniques proposed for efficient data dissemination. However, many of these techniques are application dependent, generate a large number of messages to increase the coverage area, and add significant delays to find a suitable candidate for forwarding. Owing to their ad hoc nature, the main challenge of VANETs is their network lifetime.[10] Besides these, reliability, latency, and lack of device compatibility are other factors with serious implications on VANETs.[11]

With the inception of IoT, conventional VANETs have transformed into IoV, promising an improvement in road safety and traffic-related issues. In this regard, many protocols have been proposed for effective data dissemination among vehicles. In Dua et al.,[12] a protocol with the objective of quality-of-service (QoS) is proposed, where data packets are sent to a destination using the best possible routes. In addition, weights are assigned to different routes based on the information received from other vehicles. An improved approach in Wahab et al.[13] introduces a cluster-based data dissemination protocol, which makes a trade-off between QoS and mobility in order to form stable clusters for effective data dissemination.

A delay-based data dissemination technique proposed in Akamatsu et al.[14] deals with the broadcast storm problem. The technique selects relay nodes in a distributed manner that are used to broadcast messages based on the distance from the source vehicle. A similar work involves selection of relay nodes for EM dissemination in VANETs in Rehman and Ould-Khaoua.[15] The ad hoc mechanism results in improved performance while reducing network congestion.

For broadcast communication, different dissemination techniques are proposed to suppress the undesired broadcast problem in dense networks. In Schwartz et al.,[16] a carryforward model is proposed to address the broadcast problem as well as to present a solution for frequent network disconnections. The solution works for both dense and sparse networks. In Salvo et al.,[17] a protocol for efficient and robust data dissemination is introduced to address the issue of spurious dissemination, which generally occurs in such time-based dissemination schemes. Here, the information obtained from the received packet headers is used to make forwarding decisions. Similarly, Baiocchi et al.[18] have discussed the impact of spurious message forwarding on available bandwidth in timer-based VANET protocol. The spurious message forwarding affects the overall achievable throughput rate and degrades the network performance.

Other techniques use probabilistic and timer-based broadcasting techniques to control packet loss and network congestion while maintaining a reasonable end-to-end delay, as demontrated in Wisitpongphan et al.[19] A similar study in Tonguz et al.[20] proposes the distributed vehicular broadcast (DV-CAST) protocol for both dense and sparse traffic scenarios. The protocol works in a distributed manner, with messages sent on the basis of local topology and success measured in terms of packet delivery ratio (PDR). In Panichpapiboon and Cheng,[21] a technique to reduce the number of redundant packets using inter-vehicle spacing distribution in real traffic scenarios is introduced, whereas Mostafa et al.[22] proposed a probabilistic rebroadcasting scheme for packet forwarding with reduced number of collisions. Factors affecting the rebroadcast probability are derived from the vehicle's environment such as the vehicle density, the distance from source to destination, and its transmission range. The resulting probability determines whether a particular vehicle receives a rebroadcast successfully or not. Further to this, in Zhang et al.,[23] a smart geo-cast algorithm is proposed, which reduces redundant messages at the receiver end without compromising the important information.

A protocol with an emphasis on road safety in Liu and Chigan[24] implements a directional greedy broadcast routing technique to reduce the delay in the EM dissemination. Moreover, the technique allows vehicles to disseminate data as response to data requests. However, such techniques add an additional delay, as discussed in Mondal and Mitra.[25] More recent works, for instance, in Shah et al.,[26] propose a data dissemination approach that defines a time barrier based on the distance from source vehicle. The objective is to reduce message overhead, which can congest the network and affect the overall performance. Other studies in Ata et al.[27] and Shumayla et al.[28] explore the possibility of using fog computing for congestion avoidance in VANETs and IoVs.

The aforementioned key issues in VANETs such as mobility, connection lifetime, and network stability affect EM dissemination. To overcome these issues, some techniques have been proposed, but these fail to adequately address all these problems. This article attempts to fill this gap in the literature by proposing a position-based EM dissemination technique. Specifically, the approach shares information with vehicles moving in the opposite direction. This is an attempt to improve dissemination performance of incident-related information (e.g. accident or congestion) to every vehicle passing through the incident zone.

Methodology

The proposed methodology focuses on V2V communication without requiring any additional assistance such as RSUs. Vehicles moving in the same direction, with similar speed, and in the vicinity are dynamically grouped as clusters. Each cluster is lead by a CH, and all other vehicles in the cluster are referred to as CM. Interest compatibility (IC) matrices are calculated to the CM suitable for CH. It is also possible for vehicles to be left out of clusters if they fail to meet the cluster membership criterion. Such vehicles are referred to as inferior nodes (IN). Besides vehicles, every road is assigned a unique $road_{id}$ that is included in every EM, later used to select the most suitable vehicle for EM

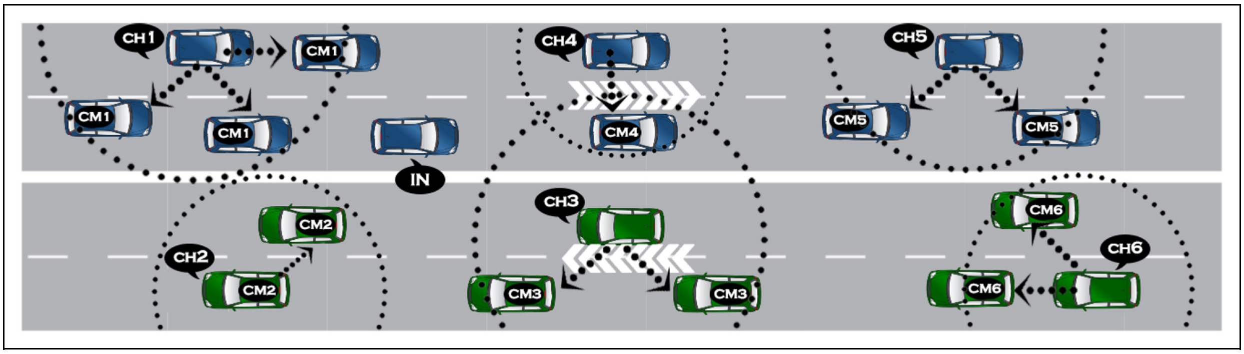

Figure 2. Dynamic cluster formation illustrating cluster head, cluster members, and inferior nodes in a realistic scenario.

dissemination. Generally, vehicles within a cluster communicate with each other; however, in some scenarios such as road congestion and accidents, EMs may move within or across multiple clusters.

System model

This section describes the system model used by the proposed technique. For this model, we assumed that all vehicles are equipped with wireless communication and they periodically exchange information with each other. The information includes vehicle location, current speed, and direction of travel. Moreover, destinations are known and shared among the vehicles.[29] Notably, the proposed scheme does not require any RSUs to relay this information. The symbols/notations used in the system model are listed in Table 1.

The proposed technique is designed for urban areas where traffic density is usually high and many of the roads have multiple lanes and support two-way traffic, as shown in Figure 2. Vehicles can join an existing cluster based on their parameters such as speed and direction of travel. Thereby, multiple clusters may exist on a road segment at any given time, and each cluster comprises a designated CH with its CMs. For EM dissemination, a vehicle (usually the CH) would transmit the messages to other clusters to enhance the overall coverage area and reduce communication delay. In fast-moving vehicles, the packet drop rate increases due to the wireless fading channel, affecting the probability of successful transmissions. This probability between vehicles i and j is modeled using the Nakagami-m distribution[30] represented as

$$Pr_{ij}^{f}(d_{ij}) = 1 - F_d(r_T, l, \Phi) = e^{-lr_T/\Phi} \sum_{i=1}^{l} \frac{((lr_T)/\Phi)^{i-1}}{(i-1)!} \tag{1}$$

where $F_d(r_T, l, \Phi)$ shows the cumulative distribution function of receiving signal strength. The parameter r_T defines the threshold value of the receiving signal, l is the fading parameter, and Φ indicates the average strength of the received signal.

The model uses configurable fading parameter l to represent channel conditions.[31] The parameter depends on the distance d_{ij} between vehicles i and j and is computed as

$$l = \begin{cases} 3, & d_{ij} < 50 \text{ m} \\ 1.5, & 50 \text{ m} \leqslant d_{ij} < 150 \text{ m} \\ 1, & d_{ij} \geqslant 150 \text{ m} \end{cases} \tag{2}$$

We consider three different values for the fading parameter depending on the distance between vehicles, such as distance below 50 m, between 50 and 150 m, and above 150 m. These fading values are assumed based on the Nakagami-m distribution.

We also take into account the interests of a vehicle, that is, interest in parking, accidents, or traffic congestion information. Let X_i be the interest vector comprising K different interests for a vehicle i

$$X_i = \left(x_i^1, x_i^2, \ldots, x_i^K\right) \tag{3}$$

An IC model is used for CH election based on compatibility among vehicle interests. For instance, the compatibility IC between vehicles i and j with interest vectors X_i and X_j is given as

$$\mathrm{IC}\left(X_i, X_j\right) = \frac{\sum_{k=1}^{K} \left(x_i^k x_j^k\right)}{\sqrt{\sum_{k=1}^{K} \left(x_i^k\right)^2} \sqrt{\sum_{k=1}^{K} \left(x_i^k\right)^2}} \tag{4}$$

To improve the network lifetime, a CH is selected using the cluster head eligibility score ξ. The score is computed using equation (5). The score is based on two factors: the compatibility among vehicles in a cluster (equation (4)) and the probability of successful packet transmissions for a vehicle in a channel fading environment (equation (1)). The eligibility ξ of vehicle i with respect to its neighboring vehicles j is calculated as

$$\xi_i = \frac{IC_i^{average}}{d_i^{average} \times \upsilon_i^{average} \times \rho_i^{average}} \tag{5}$$

The average compatibility $IC_i^{average}$ between vehicle i and its neighboring vehicles j is computed as

$$IC_i^{average} = \frac{1}{N-1} N \sum_{j=0, j \neq i} IC(X_i, X_j) \tag{6}$$

The average distance $d_i^{average}$ between vehicle i and its neighboring vehicles j is computed as

$$d_i^{average} = \frac{1}{N} \sum_{j=0}^{N} \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{7}$$

The average velocity $\upsilon_i^{average}$ between vehicle i and its neighboring vehicles j is computed as

$$\upsilon_i^{average} = \frac{1}{N} \sum_{j=0}^{N} |\upsilon_i - \upsilon_j| \tag{8}$$

Here, N shows the total number of vehicles. Moreover, the average relative distance between the destinations of vehicle i and its neighboring vehicles j is computed using

$$\rho_i^{average} = \frac{1}{N} \sum_{j=0}^{N} \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \tag{9}$$

In summary, the election step involves using the cosine similarity matrix to determine a vehicle's interests to other vehicles, which is used to compute the IC weighted matrix.[32] The vehicle having the highest IC is selected as the CH. Furthermore, as the relative destination information is shared among vehicles (both intra- and inter-cluster), a CM can change its cluster membership to another cluster, in case it finds a CH with better destination similarity.

Table 1. List of notations.

Notation	Description
l	Fading parameter
r_T	Received signal strength
Φ	Average strength of received signal
d_{ij}	Distance between vehicle i and j
υ_i	Velocity of vehicle i
X_i	Interest of vehicle i
$IC(X_i, X_j)$	Interest compatibility between interest vectors of vehicles i and j
$IC_i^{average}$	Average interest compatibility of i with its neighbors
$d_i^{average}$	Average distance between vehicle i and its neighbors
$\upsilon_i^{average}$	Average velocity of vehicle i and its neighbors
$\rho_i^{average}$	Average relative distance between destinations of vehicles
t_{max}	Maximum connection time
R_i	Transmission range of vehicle i
N	Total number of vehicles

Position-based data dissemination

The section details the proposed EM dissemination scheme using cluster and position-based target vehicle selection. In the scheme, vehicles traveling on the road are grouped using parameters including vehicle direction, speed, and relative location. The clustering technique is adapted to handle the broadcast storm problem while enhancing the vehicular network lifetime achieved through network stability. This is difficult to attain unless vehicles with similar interests are grouped. Furthermore, in contrast to MANETs, the mobility of vehicles is high owing to frequent connection timeouts in vehicular networks.

A typical approach for vehicles in a network is to broadcast the received EMs. However, due to spectrum scarcity of the vehicular network, these redundant messages can cause network congestion, thereby affecting the performance of EM dissemination. This is because the messages, being time-critical, need to be sent out as soon as possible to alert other vehicles. The traditional probability-based techniques cause additional delays that are unacceptable in emergency situations. In the proposed technique, EMs are disseminated based on the position of vehicles; that is, a target vehicle for EM dissemination is identified based on its position and direction, especially a vehicle moving in opposite direction. This choice can help quick dissemination of emergency information to other vehicles as compared to sending the message in the backward direction. The goal is to provide early warning, for instance, receiving vehicles can take alternative routes to avoid traffic congestion or emergent situations.

In the proposed scheme, when the CH receives an EM, it first verifies the sender. There are four cases: first, if the message is received from a CM, the CH disseminates the EM among its CMs, any neighboring clusters (if within reach), and any vehicles outside the cluster moving in a suitable direction for dissemination. Second, if the message is received from a neighboring cluster, the CH checks $road_{id}$ in the EM to determine the source cluster direction. In case of same directions, the CH finds a vehicle moving in the opposite direction or having a different $road_{id}$. Third, when a CM receives an EM from a vehicle outside of its own cluster, it simply forwards it to the respective CH. Last, if an EM is received by a vehicle not a part of any cluster, it simply broadcasts the EM with its $road_{id}$.

In addition to sending EMs, all vehicles periodically broadcast beacon messages (M_b) to exchange information. This information is used to determine common interests for stable cluster formation and CH election. Each beacon message from a vehicle contains information such as its speed, location, destination, $node_{id}$, and $road_{id}$. Moreover, every vehicle maintains an information table for neighboring vehicles.

In vehicular networks, maintaining a stable cluster is a challenging task due to frequent network topology changes owing to the high mobility of vehicles. In order to overcome this issue, we propose to build a cluster of vehicles with similar destinations as detailed in Algorithm 1. The destination-based clustering provides benefits of cluster stability and improved network lifetime. We assume that vehicles are installed with Global Positioning System (GPS), which is used to identify destination similarity and traveling direction. Vehicles can join clusters by responding to cluster head advertisement (CHA) messages. On receipt of a cluster membership request (CMR), the CH checks the destination and direction of the vehicle before accepting the request. Thereafter, the CH sends its location, speed, and direction through beacon messages at regular intervals. If any CM fails to receive a beacon message from its CH during a Δt time interval, the vehicle changes its status and becomes an IN (not a member of any cluster).

Following cluster formation, Algorithm 2 is used for CH election. Each vehicle i starts by computing its IC value using the equation (4) and broadcasts it to all of its neighboring vehicles j through beacon messages. Each vehicle then sets a timer to a predefined Δt and a flag to true. Upon receiving an IC value from a neighboring vehicle j, it checks if the IC_j is higher than its value or if the received message is a CHA. In either case, the vehicle i sets the flag to false and invokes Algorithm 1 for cluster formation. In case the timer expires with the flag still set true, the vehicle i declares itself as the CH and starts broadcasting CHA.

The proposed EM dissemination scheme is described in Algorithm 3. In this scheme, every CH maintains a list of neighboring CHs, including clusters on the opposite side of the road. If it receives an EM with the same $road_{id}$ as its own, it sends the message to all its CMs and all neighboring CHs (within transmission range R). Note that EMs are only sent to CHs on the opposite side, to reduce the dissemination delay and to quickly spread the message. Each EM contains information about the emergency situation, for instance, information including accident location, the direction of the crashed vehicle, $road_{id}$, and its cluster association as a CH or CM. This information is used to take appropriate actions and decide on the direction of further message dissemination. The EM is only forwarded to a target vehicle or cluster, to reduce the dissemination delay and improve message delivery rates without broadcasting it, and hence, avoiding the broadcast storm problem. Similarly, a CM upon receiving an EM

Algorithm 1– Cluster formation

```
Input
dst_i: destination of vehicle i
dir_i: direction of vehicle i
Output
cluster formed
if CHA ← Recv() then                      ▷IN receives CHA from CH
    Send(CMR)                             ▷Send CMR to CH
end if
if CMR ← Recv() then                      ▷CH receives CMR
    if dst_CH = dst_IN and dir_CH = dir_IN then
        Send(M_confirm)                   ▷Send confirmation to IN
    else
        Discard()
    end if
end if
```

Algorithm 2 – Cluster head election based on interest compatibility

```
Input
IC_i: interest compatibility for vehicle i
Δt: wait time to find vehicle j with higher IC
Output
cluster head elected
Broadcast(IC_i)
t ← Δt                                    ▷Start timer
f ← 1                                     ▷Cluster search status
while t > 0 do
    if IC_i < IC_j or CHA ← Recv() then
        f ← 0
        Invoke Algorithm 1
    end if
end while
if f = 1 then
    Broadcast(M_adv)                      ▷Declare oneself as CH
    Send(CHA)                             ▷Start sending CHA
end if
```

Algorithm 3– Emergency message dissemination

```
Input
n: current node
L_CH: position-based list of cluster heads
Output
message disseminated
m ← Recv()                                ▷Message received
if m IS EM then
    if n IS CH then
        Send(m)
  ▷Send message to CMs and neighboring CHs
    else if n IS CM then
        Send(m)                           ▷Send to CH for dissemination
    else if n IS IN then
        Broadcast (m)
    end if
end if
```

simply forwards it to its CH. Finally, an IN receiving the EM broadcasts it so that it reaches the nearest CH or CM.

The maximum connection time t_{max} between CHs moving in the opposite direction is calculated using

$$t_{max} = \frac{R_i}{v_i + v_j} \tag{10}$$

where R_i is the transmission range of vehicle i, v_i is the speed of vehicle i, and v_j is the speed of vehicle j.

It is pertinent to note that the maximum connection time is inversely proportional to the sum of vehicle speeds. However, in emergency scenarios, either side of the road may get congested, resulting in increased connection times between CHs and better dissemination performance using the proposed technique.

Performance evaluation

For evaluation, we used OMNeT ++, VEINS,[33] and SUMO[34] to design the simulation. SUMO was used to illustrate traffic movement on roads connected to VEINS via Transmission Control Protocol (TCP) socket, while the movement of vehicles was reflected in OMNeT ++ (https://omnetpp.org/). VEINS includes implementations of IEEE 1609.4 and IEEE 802.11p communication standards. The other parameters used for the simulation are shown in Table 2.

In the simulation scenario, we used custom maps imported through the open street map (OSM). The vehicle movements were scheduled from source to destination via different edges, and the routes of vehicles were designed to last at least 500 s. The number of vehicles per kilometer was kept between 25 and 125. The vehicle speed varied from 12 to 20 m/s, and the transmission range of each vehicle was set at 250 m. The simulation was repeated 50 times, and the averages were reported. The results were compared with three techniques: clustering and probabilistic broadcasting (CPB),[29] DV-CAST,[20] and traditional flooding.[35] First, CPB is based on directional clustering and probabilistic broadcasting techniques. It calculates the probability of packet forwarding using the count of identical messages received within a specific time interval. Second, DV-CAST uses a distributed vehicular broadcast protocol to overcome re-transmissions using local topology information. Last, in the traditional flooding technique, each vehicle rebroadcasts the messages it receives.

Information coverage

Information coverage is defined as the number of vehicles receiving an EM in a vehicular network comprising N vehicles. In other words, it is the total geographical area covered by an EM. Figure 3(a) illustrates a comparison of EM coverage area between our proposed technique and existing approaches. For the proposed technique, the coverage area initially increases with increasing vehicle density but starts decreasing as the vehicle density reaches 125 vehicles per km. This is due to the fact that with increasing vehicle density, more delays are incurred because of congestion. In comparison to CPB, DV-CAST, and flooding, the proposed technique performs better in a dense environment. With vehicle density between 75 and 125 per km, the proposed technique exhibits more coverage area compared to CPB. As an indicative measure, at 100 vehicles per km, we observe 9.7% more coverage area compared to CPB.

Table 2. Simulation parameters.

Parameters	Values
Transmission range	250 m
Simulation time	500 s
Data transmission rate	6 Mbps
MAC model	IEEE 802.11p WAVE
Packet interval	50, 40, 30, 20 m/s
Simulation area	3 km × 3 km
Simulation runs	50 times
Beacon size	194 bytes
EM packet size	170 bytes
Vehicle density	25–125/km
Vehicle velocity	12–20 m/s
Maximum acceleration	3.1 m/s^2
Accident interval	10 s
Road side units (RSU)	No
Accident duration	10 s
Number of accidents	50
Vehicle length	2.5 m
Minimum vehicle gap	2.5 m
Road type	Two-way

MAC: medium access control; EM: emergency message.

Transmission delay

Transmission delay is the amount of time required to send an entire EM to other vehicles. Figure 3(b) shows the average transmission delay with respect to vehicle density. CPB requires computation on every node due to its probabilistic forwarding approach, and hence, suffers from additional delay. This delay increases with increasing vehicle density. Moreover, CPB requires CMs to send packets to their CH, causing congestion in a dense network, high packet loss, and frequent retransmissions. In the case of DV-CAST, vehicles disseminate EMs with high probability to vehicles farther apart. Thus, this probability to forward a message increases linearly with increasing distance, leading to the broadcast storm problem because of the number of redundant messages. The proposed technique results in reduced transmission delays by 14%, 25.7%, and 4.4%

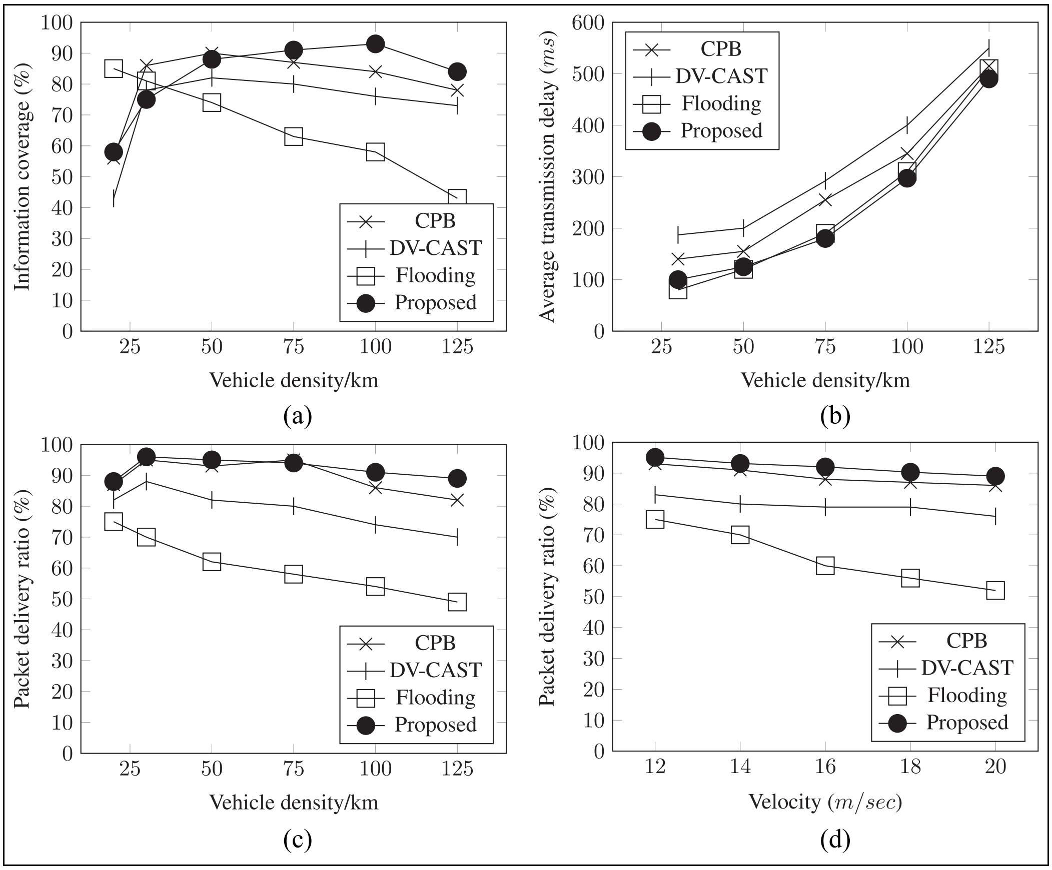

Figure 3. (a) Information coverage versus vehicle density, (b) average transmission delay versus vehicle density, (c) packet delivery ratio versus vehicle density, and (d) packet delivery ratio versus velocity.

compared to CPB, DV-CAST, and flooding, respectively.

PDR

PDR is the ratio of the number of packets sent by the source vehicle to the number of packets received at the next hop destination vehicle. Figure 3(c) shows the effect of increasing vehicle density on PDR. In the proposed technique, initially, when the network coverage is low, some messages fail to deliver. However, with increasing vehicle density, PDRs are improved. The result shows flooding with the lowest PDR followed by DV-CAST and CPB. Overall, the proposed technique shows 5.5%, 19%, and 41% improvement in PDRs compared to CPB, DV-CAST, and flooding, respectively.

Figure 3(d) shows the impact of velocity on PDR. The ratio is good at lower speeds, but declines as the vehicles accelerate. This decline is due to the fact that high mobility reduces network lifetime. In comparison to CPB, DV-CAST, and flooding, the proposed technique performs well at all reported velocities. As discussed earlier, the proposed technique disseminates messages based on the position of vehicles when they are moving in the opposite directions, further reducing the connection times and therefore lowering the PDRs at higher speeds. The results indicate that flooding has the lowest performance, DV-CAST is better than flooding, and CPB and the proposed technique are comparable. To summarize, the proposed technique shows improved PDR by 3.3%, 12.6%, and 38% compared to CPB, DV-CAST, and flooding techniques, respectively.

Impact of beacon messages

Figure 4(a) shows the average transmission delay with respect to vehicle density at different beacon intervals. With shorter beacon intervals, more messages are generated on the network, which increases the network congestion and adversely impacts the EM transmission delay. Figure 4(b) and (c) show the impact on PDR with varying vehicle density and velocity, respectively. In both cases, the PDRs are lowered when beacons are

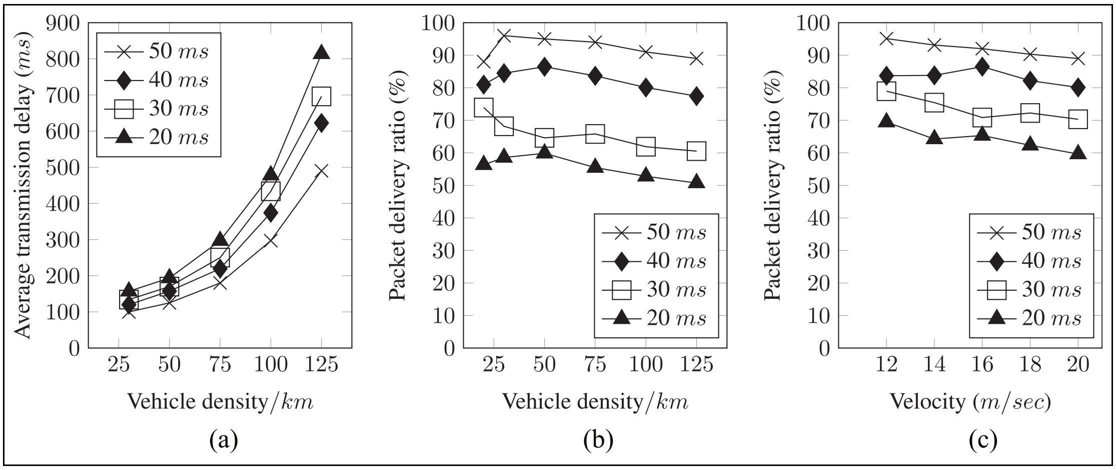

Figure 4. (a) Average transmission delay versus vehicle density/km at different beacon intervals, (b) packet delivery ratio versus vehicle density/km at different beacon intervals, and (c) packet delivery ratio versus velocity (m/s) at different beacon intervals.

generated more frequently. Thus, the beaconing rate needs to be carefully tuned to avoid unnecessary network congestion.

In all of the evaluation parameters, the proposed solution performs better as compared to existing techniques. With the increase in vehicle density, the proposed technique performs much better, as it is able to avoid network congestion that would be caused if every vehicle broadcasts the packets it had received. Moreover, the proposed scheme reduces the transmission delay as compared to traditional techniques, where vehicles send messages to CH and it is always the responsibility of CH to further disseminate the message. In the proposed position-based data dissemination technique, it is possible to identify suitable vehicles moving in the opposite direction for carrying EMs. This choice is more effective in reducing the dissemination delay for EM delivery to the desired vehicles, as opposed to sending messages in the backward direction using hoping mechanism.

Discussion

Table 3 summarizes the current techniques used in comparison to the proposed model. As mentioned earlier, the main issues faced when designing a data dissemination approach are information coverage and the broadcast storm problem. Notably, as illustrated in the summary table, most of the existing works focus on PDR, delay, and broadcast problem; however, limited works cover information coverage. Moreover, many works focus on low density scenarios (e.g. highways), reducing the effects of the broadcast storm problem. The result is an improved PDR but low coverage due to low number of vehicles serving as relay nodes. In contrast, the issues become more challenging in an urban environment. With high vehicle density, a large number of concurrent transmissions, the vehicular network is more prone to get choked.

In the proposed technique, we observed significant improvements in terms of coverage area, PDR, and average transmission delays in comparison to the state-of-the-art solutions including CPB, DV-CAST, and traditional flooding. Since EMs are time-critical and need to be disseminated as soon as possible, the proposed solution improves the PDR and information coverage, addressing the problem of EM dissemination effectively.

The proposed technique works fine at lower speed and in high density environments. However, high mobility and transmission delay of vehicles can limit its effectiveness. For instance, the coverage area of EMs is reduced with increasing vehicle speeds due to reduced contact times among vehicles moving in opposite directions on the road. This further deteriorates for sparse environments, where transmission range limits the information coverage. To resolve this, we need the connection times to be enhanced between vehicles moving in opposite directions at high speeds, for instance, using cloud services.

The major limitation of the proposed work is efficient transmission between fast-moving vehicles. At the moment, with increasing vehicle speeds, the packet error rate also increases, thus affecting the performance of the entire system that involves forwarding of regular position updates to and from clusters. We presume that widespread adoption of 5G technologies can improve device-to-device communication, in turn, high data rates. Furthermore, enhancing the stability of clusters can improve the performance of the proposed system. Note that for this study, we consider vehicle speed, direction, and relative distance for cluster formation.

Table 3. Data dissemination schemes.

	Broadcast storm problem	PDR	Delay	Information coverage	Scenario	Simulation environment	Density
Fogue et al.[36]	✓	✓	×	×	Urban	NS-2	High
Fogue et al.[37]	✓	✓	×	×	Urban	NS-2	Low
Sommer et al.[38]	✓	✓	×	✓	Urban	OMNET ++ / Veins/SUMO	High
Zhu et al.[39]	×	✓	✓	×	Highway	OMNET ++ / Veins/SUMO	Low
Liu et al.[40]	×	×	✓	×	Urban	OMNET ++ / Veins/SUMO	High
Bousbaa et al.[41]	×	✓	✓	×	Urban	NS-2	High
Gupta et al.[42]	✓	✓	✓	×	Highway	NS-2	Low
Oliveria et al.[43]	✓	✓	×	✓	Highway	OMNET ++ / Veins/SUMO	Low
Zhu et al.[44]	×	✓	✓	×	Urban	Not specified	High
Wu et al.[45]	×	×	✓	✓	Urban	OMNET ++ / Veins/SUMO	High
Lee et al.[46]	×	✓	✓	×	Highway	NS-2	Low
Kapileswar et al.[47]	×	✓	✓	×	Urban	NS-2	High
Sebastian et al.[48]	×	✓	✓	✓	Not specified	Not specified	Low
Suriyapaiboonwattana et al.[49]	✓	×	×	×	Highway	Groovenet	Low
Bai et al.[50]	✓	✓	✓	×	Highway	Qualnet 4.0	Low
Suriyapaiboonwattana et al.[51]	✓	✓	✓	×	Highway/urban	Groovenet	Low/high
Sahoo et al.[52]	✓	✓	✓	×	Highway	NS-2	Low
Proposed scheme	✓	✓	✓	✓	Urban	OMNET ++ / Veins/SUMO	High

PDR: packet delivery ratio.

These clusters can be further strengthened by the addition of more attributes. In the future, apart from the aforementioned limitations, security is a major concern for EMs dissemination. In this work, we left this aspect open for resolution through the use of techniques like blockchain and artificial intelligence, that is, to identify the credibility of the source vehicles.

Conclusion

In this article, we propose a novel EM dissemination scheme. In IoV context, it is a challenging task to disseminate data in high mobility conditions with frequently changing topologies. We used a clustering scheme based on IC metrics to form clusters and elect the CHs. This resulted in more stable clusters with reduced packet loss, enhancing the connection lifetime in vehicular networks. With the goal to disseminate EMs with minimum possible delay to a large number of vehicles on the same route, we proposed dissemination via vehicles traveling in the opposite direction on the same road. Our simulation results show better results for both normal and emergency data dissemination. The transmission delay, information coverage, and PDR improved up to 14%, 9.7%, and 5.5%, respectively.

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References

1. Cheng J, Cheng J, Zhou M, et al. Routing in Internet of vehicles: a review. *IEEE T Intell Transp Syst* 2015; 16(5): 2339–2352.
2. Abbasi HI, Voicu RC, Copeland JA, et al. Performance optimization of a contention based broadcasting algorithm in VANETs. In: *Global communications conference (GLOBECOM)*, San Diego, CA, 6–10 December 2015, pp.1–7. New York: IEEE.
3. Schrank D, Eisele B and Lomax T. Tti's 2012 urban mobility report. Report, Texas A&M Transportation

Institute, The Texas A&M University System, College Station, TX, December 2012.
4. Chen C, Pei Q and Li X. A GTS allocation scheme to improve multiple-access performance in vehicular sensor networks. *IEEE T Veh Technol* 2016; 65(3): 1549–1563.
5. Chen C, Jin Y, Pei Q, et al. A connectivity-aware intersection-based routing in VANETs. *EURASIP J Wirel Comm* 2014; 2014(1): 42.
6. Chen C, Qiu T, Hu J, et al. A congestion avoidance game for information exchange on intersections in heterogeneous vehicular networks. *J Netw Comput Appl* 2017; 85: 116–126.
7. Qiu T, Qiao R and Wu DO. EABS: an event-aware backpressure scheduling scheme for emergency Internet of things. *IEEE T Mobile Comput* 2018; 17(1): 72–84.
8. Sharma V, Song F, You I, et al. Energy efficient device discovery for reliable communication in 5G-based IoT and BSNs using unmanned aerial vehicles. *J Netw Comput Appl* 2017; 97: 79–95.
9. Aparecido L. Data dissemination in vehicular networks: challenges, solutions, and future perspectives. In: *2015 7th international conference on new technologies, mobility and security (NTMS)*, Paris, 27–29 July 2015, pp.1–5. New York: IEEE.
10. Saini M, Alelaiwi A and Saddik AE. How close are we to realizing a pragmatic VANET solution? A meta-survey. *ACM Comput Surv* 2015; 48(2): 29.
11. Toutouh J and Alba E. Light commodity devices for building vehicular ad hoc networks: an experimental study. *Ad Hoc Netw* 2016; 37: 499–511.
12. Dua A, Kumar N and Bawa S. QoS-aware data dissemination for dense urban regions in vehicular ad hoc networks. *Mobile Netw Appl* 2015; 20(6): 773–780.
13. Wahab OA, Otrok H and Mourad A. VANET QoS-olsr: QoS-based clustering protocol for vehicular Ad hoc networks. *Comput Commun* 2013; 36(13): 1422–1435.
14. Akamatsu R, Suzuki M, Okamoto T, et al. Adaptive delay-based geocast protocol for data dissemination in urban VANET. In: *2014 seventh international conference on mobile computing and ubiquitous networking (ICMU)*, Singapore, 6–8 January 2014, pp.141–146. New York: IEEE.
15. Rehman O and Ould-Khaoua M. A hybrid relay node selection scheme for message dissemination in VANETs. *Future Gener Comp Sy* 2019; 93: 1–17.
16. Schwartz RS, Barbosa RR, Meratnia N, et al. A directional data dissemination protocol for vehicular environments. *Comput Commun* 2011; 34(17): 2057–2071.
17. Salvo P, De Felice M, Baiocchi A, et al. Timer-based distributed dissemination protocols for VANETs and their interaction with MAC layer. In: *2013 IEEE 77th vehicular technology conference (VTC Spring)*, Dresden, 2–5 June 2013, pp.1–6. New York: IEEE.
18. Baiocchi A, Salvo P, Cuomo F, et al. Understanding spurious message forwarding in VANET beaconless dissemination protocols: an analytical approach. *IEEE T Veh Technol* 2016; 65(4): 2243–2258.
19. Wisitpongphan N, Tonguz OK, Parikh JS, et al. Broadcast storm mitigation techniques in vehicular Ad hoc networks. *IEEE Wireless Commun* 2007; 14(6): 84–94.
20. Tonguz OK, Wisitpongphan N and Bai F. DV-CAST: a distributed vehicular broadcast protocol for vehicular ad hoc networks. *IEEE Wireless Commun* 2010; 17(2): 47–57.
21. Panichpapiboon S and Cheng L. Irresponsible forwarding under real intervehicle spacing distributions. *IEEE T Veh Technol* 2013; 62(5): 2264–2272.
22. Mostafa A, Vegni AM and Agrawal DP. A probabilistic routing by using multi-hop retransmission forecast with packet collision-aware constraints in vehicular networks. *Ad Hoc Netw* 2014; 14: 118–129.
23. Zhang L, Gao D, Gao S, et al. SmartGeocast: dynamic abnormal traffic information dissemination to multiple regions in VANET. In: *2013 9th international wireless communications and mobile computing conference (IWCMC)*, Sardinia, 1–5 July 2013, pp.1750–1755. New York: IEEE.
24. Liu C and Chigan C. RPB-MD: providing robust message dissemination for vehicular ad hoc networks. *Ad Hoc Netw* 2012; 10(3): 497–511.
25. Mondal A and Mitra S. Secure data dissemination in VANET-a pull based approach. In: *2015 IEEE international conference on communication, networks and satellite (COMNESTAT)*, Bandung, Indonesia, 10–12 December 2015, pp.60–67. New York: IEEE.
26. Shah SS, Malik AW, Rahman AU, et al. Time barrier-based emergency message dissemination in vehicular ad-hoc networks. *IEEE Access* 2019; 7: 16494–16503.
27. Ata U, Shumayla Y, Muhammad I, et al. Emergency message dissemination schemes based on congestion avoidance in VANET and vehicular FoG computing. *IEEE Access* 2019; 7: 1570–1585.
28. Shumayla Y, Ata U, Muhammad A, et al. Congestion avoidance through fog computing in Internet of vehicles. *J Amb Intel Hum Comp*. Epub ahead of print 21 February 2019. DOI: 10.1007/s12652-019-01253-x.
29. Liu L, Chen C, Qiu T, et al. A data dissemination scheme based on clustering and probabilistic broadcasting in VANETs. *Veh Commun* 2018; 13: 78–88.
30. Zhang X, Cao X, Yan L, et al. A street-centric opportunistic routing protocol based on link correlation for urban VANETs. *IEEE T Mobile Comput* 2016; 15: 1586–1599.
31. Ma X, Yin X, Wilson M, et al. MAC and application-level broadcast reliability in VANETs with channel fading. In: *2013 international conference on computing, networking and communications (ICNC)*, San Diego, CA, 28–31 January 2013, pp.756–761. New York: IEEE.
32. Sethi V and Chand N. A destination based routing protocol for context based clusters in VANET. *Commun Netw* 2017; 9(3): 179–191.
33. Sommer C, German R and Dressler F. Bidirectionally coupled network and road traffic simulation for improved IVC analysis. *IEEE Trans Mobile Comput* 2011; 10(1): 3–15.
34. Krajzewicz D, Erdmann J, Behrisch M, et al. Recent development and applications of SUMO-Simulation of Urban MObility. *International Journal on Advances in Systems and Measurements* 2012; 5(3&4).
35. Ciccarese G, De Blasi M, Marra P, et al. On the use of control packets for intelligent flooding in VANETs. In:

2009 IEEE wireless communications and networking conference (WCNC 2009), Budapest, 5–8 April 2009, pp.1–6. New York: IEEE.
36. Fogue M, Garrido P, Martinez FJ, et al. An adaptive system based on roadmap profiling to enhance warning message dissemination in VANETs. *IEEE/ACM T Netw* 2013; 21(3): 883–895.
37. Fogue M, Garrido P, Martinez FJ, et al. Analysis of the most representative factors affecting Warning Message Dissemination in VANETs under real roadmaps. In: *2011 IEEE 19th international symposium on modeling analysis & simulation of computer and telecommunication systems (MASCOTS)*, Singapore, 25–27 July 2011, pp.197–204. New York: IEEE.
38. Sommer C, Tonguz OK and Dressler F. Traffic information systems: efficient message dissemination via adaptive beaconing. *IEEE Commun M* 2011; 49(5): 173–179.
39. Zhu X, Chen C, Pan Z, et al. Fast and reliable warning message dissemination mechanism in urban expressway VANETs. In: *2016 IEEE/CIC international conference on communications in China (ICCC)*, Chengdu, China, 27–29 July 2016, pp.1–6. New York: IEEE.
40. Liu B, Jia D, Wang J, et al. Cloud-assisted safety message dissemination in VANET-cellular heterogeneous wireless network. *IEEE Syst J* 2017; 11(1): 128–139.
41. Bousbaa FZ, Zhou F, Lagraa N, et al. Reducing transmission interferences for safety message dissemination in VANETs. In: *2015 international on wireless communications and mobile computing conference (IWCMC)*, Dubrovnik, 24–28 August 2015, pp.1205–1210. New York: IEEE.
42. Gupta N, Prakash A and Tripathi R. Clustering-based enhanced safety message dissemination medium access control protocol for vehicular ad hoc network. *Int J Ad Hoc Ubiq Co* 2016; 24(1–2): 76–89.
43. Oliveira R, Montez C, Boukerche A, et al. Reliable data dissemination protocol for VANET traffic safety applications. *Ad Hoc Netw* 2017; 63: 30–44.
44. Zhu W, Gao D, Foh CH, et al. Reliable emergency message dissemination protocol for urban Internet of vehicles. *IET Commun* 2017; 11(8): 1275–1281.
45. Wu L, Nie L, Fan J, et al. An efficient multi-hop broadcast protocol for emergency messages dissemination in VANETs. *Chinese J Electron* 2017; 26(3): 614–623.
46. Lee JF, Wang CS and Chuang MC. Fast and reliable emergency message dissemination mechanism in vehicular ad hoc networks. In: *2010 IEEE wireless communications and networking conference (WCNC)*, Sydney, NSW, Australia, 18–21 April 2010, pp.1–6. New York: IEEE.
47. Kapileswar N, Santhi PV, Chenchela VK, et al. A fast information dissemination system for emergency services over vehicular ad hoc networks. In: *2017 international conference on energy communication data analytics and soft computing (ICECDS)*, Chennai, India, 1–2 August 2017, pp.236–241. New York: IEEE.
48. Sebastian A, Tang M, Feng Y, et al. A multicast routing scheme for efficient safety message dissemination in VANET. In: *2010 IEEE wireless communications and networking conference (WCNC)*, Sydney, NSW, Australia, 18–21 April 2010, pp.1–6. New York: IEEE.
49. Suriyapaiboonwattana K, Pornavalai C and Chakraborty G. An adaptive alert message dissemination protocol for VANET to improve road safety. In: *2009 IEEE international conference on fuzzy systems*, Jeju, South Korea, 20–24 August 2009, pp.1639–1644. New York: IEEE.
50. Bai S, Huang Z, Kwak D, et al. Vehicular multi-hop broadcasting protocol for safety message dissemination in VANETs. In: *2009 IEEE 70th vehicular technology conference fall (VTC 2009-Fall)*, Anchorage, AK, 20–23 September 2009, pp.1–5. New York: IEEE.
51. Suriyapaiboonwattana K and Pomavalai C. An effective safety alert broadcast algorithm for VANET. In: *2008 international symposium on communications and information technologies (ISCIT 2008)*, Lao, China, 21–23 October 2008, pp.247–250. New York: IEEE.
52. Sahoo J, Wu EHK, Sahu PK, et al. Congestion-controlled-coordinator-based MAC for safety-critical message transmission in VANETs. *IEEE T Intell Transp* 2013; 14(3): 1423–1437.