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# Dynamic speed adaptive classified (D-SAC) data dissemination protocol for improving autonomous robot performance in VANETs

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## ABSTRACT

In robotics, mechanized and computer simulation for accurate and fast crash detection between general geometric models is a fundamental problem. The explanation of this problem will greatly improve driver safety and traffic efficiency, vehicular ad hoc networks (VANETs) have been employed in many scenarios to provide road safety and for convenient travel of the people. They offer self-organizing decentralized environments to disseminate traffic data, vehicle information and hazardous events. In order to avoid accidents during roadway travels, which are a major burden to the society, the data, such as traffic data, vehicle data and the road condition, play a critical role. VANET is employed for disseminating the data. Still the scalability issues occur when the communication happens under high-traffic regime where the vehicle density is high. The data redundancy and packet collisions may be high which cause broadcast storm problems. Here the traffic regime in the current state is obtained from the speed of the vehicle. Thus the data reduction is obtained. In order to suppress the redundant broadcast D-SAC data, dissemination protocol is presented in this paper. Here the data are classified according to its criticality and the probability is determined. The performance of the D-SAC protocol is verified through conventional methods with simulation.

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Robotics; VANETs; broadcast storm; probabilistic approach; dynamic speed adaptive classified (D-SAC) data dissemination protocol; data classification; critical data; non-critical data

## 1. Introduction

In recent years, vehicular ad hoc networks (VANETs) are considered by many researchers since they show wider applications in many areas like intelligent transport system (ITS), passenger safety, infotainment and emergency scenarios. VANETs are a kind of mobile ad hoc networks (MANETs), but the difference is that the nodes move over the limited places. These networks have the nodes with high mobility and the nodes of network move in the same or opposite directions. Because of the high mobility of the nodes, the network topology becomes dynamic. In VANETs, the vehicles moving on road can establish two different communications, vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) [1]. In V2V communication, the nodes (vehicles) send and receive message between them in peer-to-peer (P2P) manner, while in V2I communication the nodes communicate with the surrounding communication units which are the nearest road side unit (RSUs). RSUs also work as the routers to send various information to the moving vehicles. Though VANETs yield many benefits to the drivers and others, there are certain issues to be met by the VANETs. The nodes moving on different roads cannot sometimes establish communication between them if there are blockades. Many

VANETs employ a broadcast communication scheme to transmit the information to all nodes that come within the communication. This is known as a data dissemination process. In this scheme, the data are not preserved; the details of a certain vehicle, such as position and travel route, are publicly accessible by other vehicles. In a crash avoidance system and a traffic information system, the message must be transmitted to the vehicles travelling near to the source vehicle. However, if there are more vehicles in a region, the information from all the vehicles are shared and hence redundant data are communicated which exploits the channel radio bandwidth which is a limited constraint. Data collision also occurs when many vehicles retransmit the same data. This is referred as broadcast storm [2]. Moreover, the generated data must reach the all destination nodes within the specific time without any delay. Since the VANETs are dynamic network and the traffic patterns change frequently, the information also may vary. When the vehicle is reaching another area, the traffic pattern may vary. The information regarding accidents or obstacles should be communicated and reached to the vehicle in time critical fashion [3]. These reasons make the broadcast in VANETs as a great concern. Since the density of nodes (vehicles) varies for different times

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and on different roads, the broadcast scheme should function well in different scenarios. In a dense network, packet collisions and low packet delivery ratio problems occur. Many protocols are invented to reduce the broadcast storm concern in the traditional MANETs. However, there are only few for VANET and they are not much reliable and efficient.

The general solution to overcome these concerns is reducing the amount of redundant data. This process is accomplished by allowing only few vehicles to transmit data. However, in this process the high delivery ratio must be maintained [4]. In the existing method, the vehicles need beacons to retrieve information from the neighbouring vehicle. Conversely, beaconing has some disadvantages like bandwidth exploitation, delayed data packet and higher network congestion [5]. Even beaconing process also produce large load in the network. If it produce large load in the network, this process is referred as background traffic [6]. Hence, when using the beaconing process for VANETs, it is necessary to employ suitable data dissemination methods to keep the beacons size at a particular range, so that the bandwidth exploitation can be decreased. In VANETs, broadcasting the flooding process is the basic broadcasting approach in which the source vehicle transmits the data to all of its neighbouring vehicles. In multi-hop transmission, all the nodes receiving data from the source node will reroute the same to their one-hop neighbouring nodes. In the simple broadcast scheme, when all the vehicles in an area transmit the data simultaneously, many data are transferred and collisions may occur. This problem is more for high-density networks. Because of the transmission of many data, the utilization of bandwidth increases. In Figure 1, the broadcast storm problem is depicted where node A starts first to transmit the data and the data are received at nodes B and C. Afterward, these nodes retransmit the data if the data were not transmitted by them previously. Similarly, node D retransmits the data if no collision occurs. This process increases the cost of the communication system and the following issues will happen.

1. Redundant retransmission: This problem happens when a vehicle retransmits data to its neighbouring vehicle when those nodes have already obtained the data from other nodes. In this figure vehicle A is a neighbouring vehicle to nodes B and C. Hence it receives the same data from both B and C. Thus redundant transmission occurs.
2. Packet collisions: This problem causes packet loss or corrupted messages. In this figure, if nodes B and C transmit the data at the same time, the data collision occurs at vehicle D.

Many protocols are proposed for solving broadcast storm problems in MANETs and they give efficient results. However, they do not provide better results

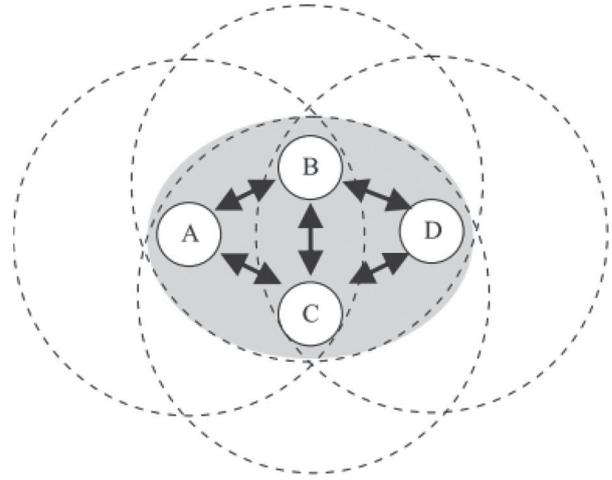


Figure 1. Broadcast storm problem [7].

for VANETs since they have the mobility features. In Section 2, the existing protocols for mitigating broadcast storm issues are described. The aim of this work is to mitigate the broadcast storm problem in multi-hop VANETs. We presented the dynamic speed adaptive classified (D-SAC) data dissemination protocol. In this work, the traffic flow theory presented in [8,9] is employed to determine the traffic details. This theory states that the negative correlation exists between the speed and the traffic density. In employing vehicle density to determine the traffic condition in an area, the details of nearby vehicles are required, whereas the employment of speed in determining the traffic does not require the details of other vehicles. Based on this concept, the probability of data transmission in VANET is determined by considering four different factors, namely, the speed of the vehicle, source vehicle distance, label of message or type of message and time of occurrence of an event. The proposed work and the advantages of the proposed method compared with the existing works are described in Section 3. Section 4 explains the results obtained from the proposed work.

The contribution of proposed work is as follows.

- Since a vehicle obtains the current traffic scenario from its speed, the transmitted bytes are reduced.
- Broadcast overhead (BO) is reduced through broadcast suppression, which is achieved by fixing probability for forwarding data according to the message type, message occurrence time, vehicle and distance. Thus the unnecessary data broadcast occurring even after the event are vanished or can be reduced.
- The packet collisions are avoided through time-based dissemination since the time-based method allots a different time for each vehicle to relay the received data. Moreover, the data are discarded if it is forwarded previously. Thus the performance of the network is improved.

The work is organized as follows. Section 2 describes the previous works related to the mitigation of broadcast storm problem. The proposed protocol and the relevant computations are explained in Section 3. Section 4 describes the simulation process and the results obtained from simulation.

## 2. Related works

Many protocols were presented in literatures to reduce the broadcast storm problem in a high-density network. These protocols can be typified into sender-oriented protocols and receiver-oriented protocols. In sender-oriented protocols, a sender node detects the relay nodes for broadcasting packets, whereas in receiver-based protocols, the receiver node takes decision whether to transmit the packets or not. In works [10–13], receiver-based broadcast protocols have been explained. In these types of protocols, all of the redundant broadcasts are not eliminated. In addition, as these protocols employ a probabilistic method, the reliability of the network is not ensured, particularly in the case of sparse network. Hence the receiver-based broadcast protocols do not suit well for VANET applications where reliability is momentous. In [14], a multipoint relay (MPR) broadcast protocol was presented. In [15], connected dominating set-based broadcast protocol is presented. In both of these works, the authors did not consider the node mobility while selecting the relay node. Therefore, the relay node selection process becomes sub-optimal and packet loss will occur due to the moving nodes. In work [16], the authors presented enhanced MPR broadcast protocol that allows only several relay nodes to rebroadcast a message. This protocol employs an acknowledgement method to note whether the message is received by all the selected receivers and retransmitted on the occurrence of packet loss. The strength of received signal is not taken into account in selecting the relay nodes. The performance of this protocol is reduced when fading happens. In addition, the receiving node should transmit acknowledgement signal to the source node. This problem leads to increased overhead in the high-density network. Sahoo et al. [17] presented a protocol in which the node located far away in the selected direction is chosen to rebroadcast the message. But in a fading channel, packet loss happens when this method is used. Hence many factors, such as inter-vehicle distance, mobility and signal strength, must be taken into account for selecting relay node. In a VANET broadcast, retransmission process is necessary due to some factors such as the moving vehicles, data collisions and random loss occurring in fading channel. In enhanced MPR broadcast protocol, a source node retransmits a message if a receiver node did not receive the message in a fixed time period. This state can be checked by the protocol with the help of explicit ACK

messages. Hence, the overhead problem increases particularly in the case of high-density network. Hence, the MAC layer contention time at every node increases. Thus, more delay occurs and a message becomes useless though it is received after some time. Hence, a lightweight retransmission method is considered.

The protocols presented for obtaining lightweight solutions in VANETs are classified into types, probabilistic approach and the Delay-based approach. In the probabilistic approach, rebroadcast probability set to the different receiving vehicle is different. Hence, in this only some vehicles broadcast data and so data redundancy, overhead and data collisions are reduced. The major challenge of the probabilistic approaches is to find out an optimal probability assignment function to keep the delivery ratio high. Simple probabilistic broadcasting approaches assign a fixed probability to the vehicles, whereas complex probabilistic approaches assign dynamic probability values. In [10], weighted p-persistence probabilistic broadcast protocol is presented in which distance of the node from the source node is selected as a factor to compute probability of packet broadcast. In this method, the vehicles located far away are given higher probability. However, in this work, the traffic density details are not taken into account and hence the data redundancy issue happens when network density is high. In paper [18], another probabilistic broadcast protocol is presented in which traffic density is considered. In this method, the traffic density is determined by counting the number of one-hop and two-hop neighbouring vehicles. Mylonas et al. [13] first presented speed adaptive probabilistic flooding (SAPF) technique of utilizing the speed of vehicles in the network for probabilistic broadcast approach. Linear approximation of data is used to map the speed of the vehicle to the broadcasting probability. The authors compared the probability function with typical flooding method and a valid comparative analysis was not performed. Besides this, the broadcasting overhead was not considered. Conversely, in delay-based broadcast, various waiting delays were set to the receiving vehicles in the VANET. In this method, the vehicles with less delay would rebroadcast first. Delay-based broadcast protocol is also known as broadcast suppression approaches. In this method, when a vehicle received a duplicate copy of message, it stopped rebroadcasting the same message since it indicates that the other vehicle was involved in the job. Therefore, redundant rebroadcasts are reduced. In [18], slotted 1-persistence is presented where the vehicles are allotted to different time slots according to the distance to the source vehicle. Here the farther vehicles are assigned to the slot having less delay for broadcasting. In this method also, the traffic density is not taken into account. Hence scalability issue will happen when the network density is high because of redundant data. In some works, the probabilistic and delay-based approaches are combined

and assign the farthest vehicles with shortest delay with a fixed probability to rebroadcast. In [10], slotted p-persistence approach is given, where messages are rebroadcasted based on a pre-computed probability and a waiting delay. This method also did not consider the traffic density. Distributed optimized time (DOT) [19] is delay-based rebroadcasting approach in which timeslot density control is involved. But this work did not consider the actual traffic in the network. The density of timeslots assigns the number of vehicles in each slot. DOT needs beacons to collect the information regarding the nearest vehicles. The increase in beacon size yields high bandwidth exploitation. In [20], an efficient data dissemination protocol is presented without beaconing overhead. In this scheme, a sweet spot is defined in an area of interest (AoI) and the vehicle in the sweet spot started to disseminate the message. The transmission region is considered as a circle shape area and it is partitioned into four quadrants. For every quadrant, one sub-region is assigned which is termed as sweet spot. If no vehicle presents in the sweet spot, the next vehicle located away from the sweet spot will broadcast the data. This method can give high delivery ratio, but the high communication overhead still exists. Maia et al. [21] presented HyDiAck protocol for dense and sparse networks. This method cannot reduce the redundant data, but it gives high delivery ratio. Another disadvantage is the requirement of one-hop neighbour data. In [22], Adaptive Forwarding message and Cooperative Safe driving (AFCS) approach are presented in which traffic density is considered. The traffic details are found through exchanging information among the vehicles through beacons or through RSUs. In [23], autonomic dissemination method (ADM) is proposed where the vehicles are allowed to dynamically change its broadcasting according to the network density and based on the priority level of packet to be sent. The advantages of this method are that the latency and radio interferences are reduced. However, the shortcoming is that the method did not reduce the redundant data. In [24], advanced diffusion of classified data (ADCD) protocol is presented to manage data dissemination in VANETs. In this method, the received message as the input message and compute the time of reception in receiver end. The authors used Markov chain to obtain the optimal number of broadcasting nodes. The advantage of this method is that the overhead is maintained as constant even the vehicle density varies. The conventional schemes for data dissemination in VANETs produce communication overhead, scalability issues when the vehicle density is more. Though the methods presented in [10,20,21] yield high data delivery ratio, they cause high dissemination overhead. In literatures [19,21,22,23,25], though redundant data are reduced through beacons some problems, such as bandwidth exploitation and increased congestion, may occur. When beacons are used, the congestion will

occur in high density since the beacons broadcast the message many times. Thus beaconing produces high load on the VANET.

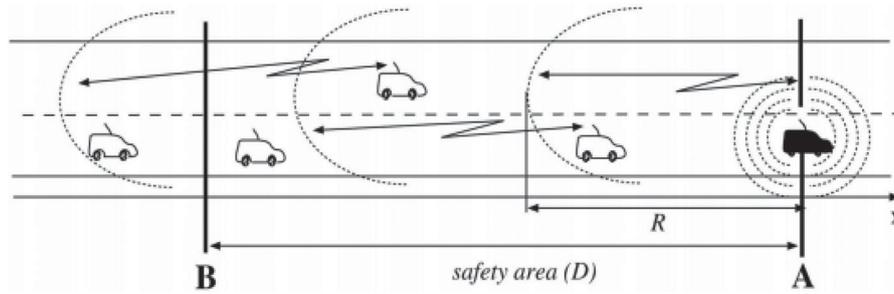
### 3. Proposed method

In the proposed method, when an incident occurs and it is required to be transmitted to the participating vehicles in the network, the source vehicle sends the event occurrence along with some other information. On receiving the information from the source vehicle, the subsequent vehicle will assign a probability for rebroadcasting the message according to the four factors, which are described later. Since in this work speed adaptive broadcast technique is utilized as in [7], the traffic regime can be retrieved using the speed of the source vehicle only and hence the vehicle no need to gather message from more vehicles to determine the traffic regime.

#### 3.1. Materials and methods

Autonomous robots like a VANET consider three different models: road layout, mobility and communication. Linear road topology of multiple lanes is assumed as the road layout in this model, which contains highways and straightway roads. For mobility modelling, a simple macroscopic model is taken for mathematical analysis. In this model, the activities of one parameter of traffic flow alter according to the activities of another. The Green shields model presented in [9] explains the traffic flow using the speed-density relationship as road traffic as the traffic in a region always depends on certain features like flow rate, the traffic density and the average speed. For analysing the performance of the proposed method using simulation, the traffic scenarios are generated using SUMO [26]. In establishing vehicular communication, an on board unit (OBU) is interfaced with each vehicle. Each OBU contains physical layer, MAC layer, networking layer and application unit. The vehicle can establish communication through its OBU with vehicles in its communication range. In this work, V2V communication is considered and the communication with RSUs does not occur in this work. The global positioning system (GPS) is employed to obtain the information regarding vehicle location. In vehicular networks, the disseminated data are the type of WAVE short messages (WSM) [26] containing the information like position, speed and acceleration of vehicle. The message has eight fields and the total size of the message is computed by adding the bytes consumed by each field. The information reported along with the message are listed as follows.

- The position of the place where the event has occurred.



**Figure 2.** Example model for data dissemination.

- The time when the source vehicle starts to transmit the message.
- A sequence number (known as message ID) fixed to the message generated by the source vehicle.
- ID of source vehicle (source ID) which is denoted by the MAC address of the respective vehicle. The message ID and the source ID jointly help the other vehicles to discriminate the various messages.
- ID of the relaying vehicle (sender ID) which is the MAC address of the vehicle.
- The geographical position of the source vehicle known as source's coordinates.
- The geographical position of the forwarding vehicle known as sender's coordinates.
- Speed of the vehicle, which is employed to determine the traffic regime.
- Number of hops transmitted.

### 3.2. Data dissemination model

Consider a highway road lane shown in Figure 2, where the vehicles detect a hazardous incident and transmits the message to alert the following vehicles through multi-hop ad hoc communications. This is to alert all of the following vehicles travelling in the area near to the location A. The number of vehicles in the dissemination area is taken as  $\nu$ . Whenever a vehicle in the area collects a message, a probability is determined by the vehicle to decide whether the message is to be forwarded or not. The probability is determined based on four factors. They are speed of the vehicle, source vehicle distance, label of message or type of message and time of occurrence of an event.

In this section, the average number of informed nodes is determined by using the analysis made in [27] for single a broadcast cycle. The probability that a node rebroadcasts a message is denoted using  $\alpha$  which is less than one always. The vehicle density is represented as  $\gamma$  which denotes the average number of vehicles in an area. The distance between two neighbouring vehicles is exponentially distributed with  $\gamma$ . The probability that the number of informed nodes in an area is denoted by  $S(n)$ . Similarly, the probability that the number of connected forwarding nodes equal to  $n$  is denoted as  $P_r(n)$ . The length of the area is denoted as  $D$  and the

transmission range of all vehicles in the area is equal and denoted by  $R$ . In this analysis, the number of nodes in an area is denoted as  $n^*$  which is equal to  $\gamma D$ .  $P_r(n)$  is expressed as

$$P_r(n) = \begin{cases} (1 - e^{-\alpha R})^n e^{-\alpha R}, & n < n^* \\ (1 - e^{-\alpha R})^{n^*}, & n = n^* \\ 0 & n > n^* \end{cases} \quad (1)$$

The average number of informed nodes  $S(n)$  is obtained by using the following equation:

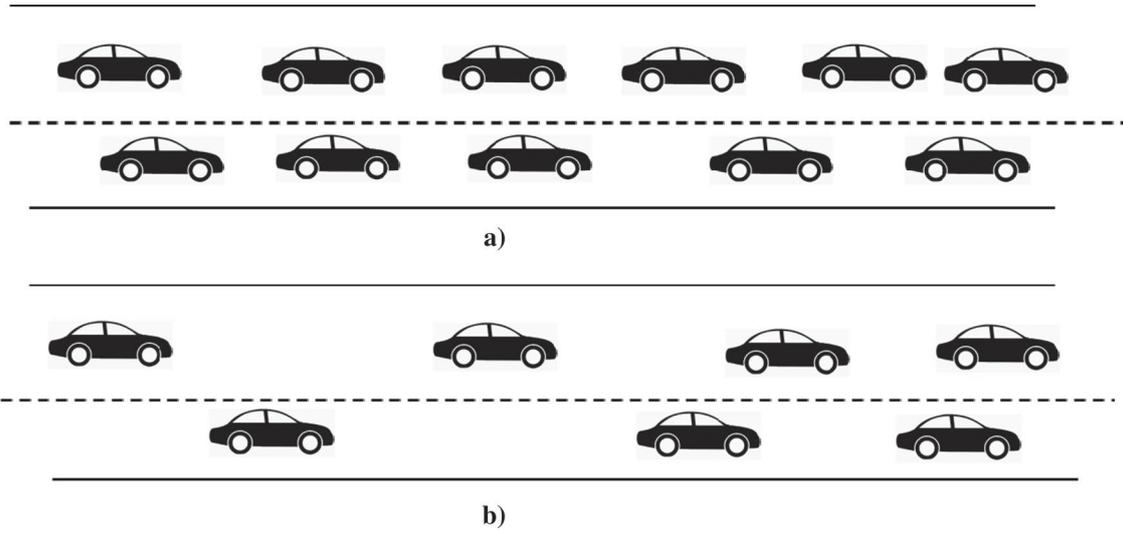
$$\bar{S} = (1 - e^{-\gamma R})^{n^*} (1 - e^{\gamma R}) + e^{\gamma R} - 1 \quad (2)$$

The probability that a vehicle is informed irrespective of the position can be obtained as shown in (3), where  $\bar{S}$  denotes the average number of informed nodes and  $\gamma D$  denotes the average number of nodes in the area:

$$P_I = \frac{\bar{S}}{\gamma D} \quad (3)$$

### 3.3. Traffic regime detection

Since the data dissemination overhead happens when all the nodes forward the received data, only some selected nodes must forward the data. In this work to select the nodes, the probability is assigned to every node based on the several factors. In a high-density area where there are more number of vehicles, the dissemination overhead is high. Hence it is essential to allow very few vehicles to relay the message. To achieve this the probability is assigned by considering the speed such that the probability for a vehicle to forward the message is computed as a fraction of the vehicle density. As provided in [7], the traffic density is obtained from the own speed of a vehicle. Thus using this model the traffic in an area can be determined without the knowledge of the number of nearby travelling vehicle. In high-density roads, the vehicles must be driven in low speeds whereas in the low-density roads the converse will happen. Taking this notion, the speed-density relationship is presented in [9]. Thus using this model, since the speed of the own vehicle can provide the traffic information, the message retrieval from the neighbouring vehicle to get the traffic regime is avoided which in turn



**Figure 3.** Traffic regime (a) denotes high traffic where the speed of the vehicles approaches zero and (b) denotes low traffic where the speed of the vehicles approaches maximum speed (free flow speed).

reduces the dissemination overhead. In addition, the probability for a vehicle to forward the message is computed. The fundamental traffic flow equation is given as

$$Q = V \times TD \quad (4)$$

where  $Q$  is the traffic flow,  $V$  is the average speed and  $TD$  is the traffic density.

The traffic condition of a road can be found by analysing the speed ratio given in the following equation:

$$V_r = \frac{V}{V_f} \quad (5)$$

where  $V_r$  is the speed ratio,  $V$  is the current average speed on the road and  $V_f$  is the free flow speed (maximum allowable speed).

In [9], the speed and density relationship is given as

$$V = V_f - \frac{V_f}{d_j} d \quad (6)$$

$$\frac{V}{V_f} = 1 - \frac{d}{d_j} \quad (7)$$

where  $d$  denotes the current traffic density and  $d_j$  denotes the density when traffic jam occurs.

Thus it is inferred that when  $V_r$  reaches zero, the traffic jam occurs, while on reaching value 1, the traffic density is low and the vehicles move with the free flow speed. The traffic organization as shown in Figure 3.

### 3.4. D-SAC data dissemination protocol

The proposed D-SAC data dissemination method assigned a probability at the receiving node based on the four factors as described above. The speed of the sender vehicle is received along with the message. From the speed, the current traffic density on the road is

determined using the relationship shown in (6). In determining, whether the received data to be forwarded by the receiving vehicle, the first and foremost factor must be considered is the message type. Based on the type of received message the dissemination is divided into three kinds, namely critical data dissemination, semi-critical data dissemination and non-critical data dissemination. After classifying the messages, the probability is assigned based on the class.

#### 3.4.1. Critical data dissemination method

For critical data dissemination, the forwarding probability is determined similar to the dynamic speed adaptive broadcast (D-SAB) method. The critical data are the events that are lasting for long time, such as damage on the road, road extension works, and landslides. The probability of a receiving vehicle  $i$  to forward data at time  $t$  is given by the speed ratio as shown in the following equation:

$$P(i, t) = \frac{V(i, t)}{V_f} \quad (8)$$

where  $V(i, t)$  is the current speed of receiving vehicle  $i$  at time  $t$ .

Based on the speed, the probability is determined for the critical data dissemination. Equation (8) implies that the probability to forward the data is low when the road is congested while the probability is high on the free road. Thus the redundant communication occurred by many vehicles where the forwarding message is reduced. The critical data should necessarily reach to the subsequent vehicles to avoid the hazardous events. Upon receiving the message, the received vehicle forwards the data after some delay. In this dissemination method, each vehicle is assigned to a timeslot which is computed at each hop based on the speed ratio. Timeslot is the time period for which a vehicle must

wait before deciding to forward the received message or discard the message. From the speed of the neighbouring vehicles, the received vehicle set the total number of slots. Each time slot is assigned with certain waiting delay. In addition, the delay is assigned by considering the type of the road area. In rural area roads, less delay is given since they are less congested, whereas in city roads, more delay is given to each timeslot to avoid transmission overhead since the traffic is more in city roads. Since the forwarded message transmits the message along with its current speed, the receiving vehicle can able to detect the current traffic state of the road. When a message is received by a vehicle, it checks whether it receives the message before, using the message ID. If the message is already scheduled in the slot to be forwarded by this vehicle, it suppresses the broadcast. Adding to this the received vehicle computes the total number of timeslots and detects its suitable timeslot based on its location. Then it fixes delay according to the road area to schedule the retransmission. In this D-SAC, the nearest vehicle is assigned with less delay and given high priority to forward the message. Hence, since the other vehicles have more delay, they will suppress (cancel) the broadcast on receiving duplicate message. Thus the redundant transmissions are reduced. The timeslots are allocated with enough time to the timeslots for obtaining efficient broadcast suppression and hence it can have enough time to decide either to forward the message or to discard the message. The total number of timeslots is obtained by using the following equation:

$$n = \left[ (-m + 1) \times \frac{V_i}{V_f} + m \right] \quad (9)$$

where  $m = R/w$  and denotes the maximum number of timeslots.  $R$  and  $w$  denote the transmission radio range and the minimum size of a single timeslot which is set by summing the length of vehicle with the safety distance between two vehicles. Thus under high-traffic regime, more number of slots are obtained from Equation (9) and hence only few vehicles forward message. Conversely, the number of slots is less in low traffic regime. In this method, it is assumed that the speed of the vehicles in the single hop transmission is the same whereas it changed in next-hop transmission. The current speed of the vehicles is obtained from the data received from the sender vehicle (i.e. speed of the source vehicle in the first hop and relaying vehicle in the subsequent hop). The width of timeslots is allocated to be equal over the transmission range for all vehicles and the corresponding timeslot of a receiving vehicle is detected based on the location information of the vehicle. The time delay at each time slot is computed using (10) such that the nearest vehicles are allocated to less delay:

$$d_k = (S_k \times \tau) + \beta \quad (10)$$

where  $d_k$  is the delay at a timeslot  $k$ ,  $S_k$  is the slot number,  $\tau$  is the minimum one-hop delay that depends on the propagation delay,  $\beta$  is 0.5 for rural roads and 0.8 for city roads:

$$S_k = \left[ \left( \frac{\min(\text{dist}, \text{range})}{\text{range}} \right) \times n \right] \quad (11)$$

where  $\text{range}$  denotes the distance covered by the forwarding vehicle and  $\text{dist}$  denotes distance between two vehicles.

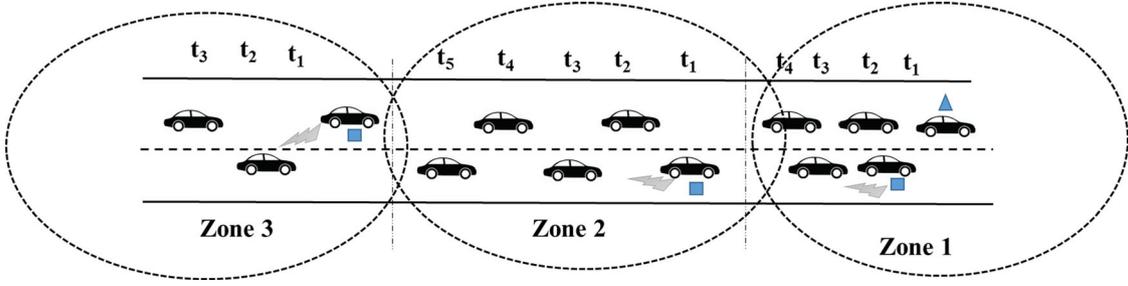
Thus in computing delay to allocate for each timeslot, the parameter  $\beta$  is given with two different values according to the type of road. Figure 4 shows the D-SAC-based critical data dissemination, where the source node transmits the message on the occurrence of an event to its one-hop neighbours. Then, based on D-SAC protocol, the vehicles determine whether to forward the message or suppress the message. Each vehicle in a zone is allotted to the corresponding time slot with delay according to the traffic regime. The nearest vehicle to the source vehicle in zone 1 forwards the message to its next-hop vehicles. The other vehicles check whether the data are scheduled to be forwarded and discard the message because of the broadcast by forwarding vehicle. In zone 2, the nearest vehicle to the forwarding vehicle forwards the message to its next-hop vehicles. Thus the message reaches all the vehicles travelling in the area. Algorithm 1 shows the D-SAC data dissemination protocol.

### 3.4.2. Semi-critical data dissemination method

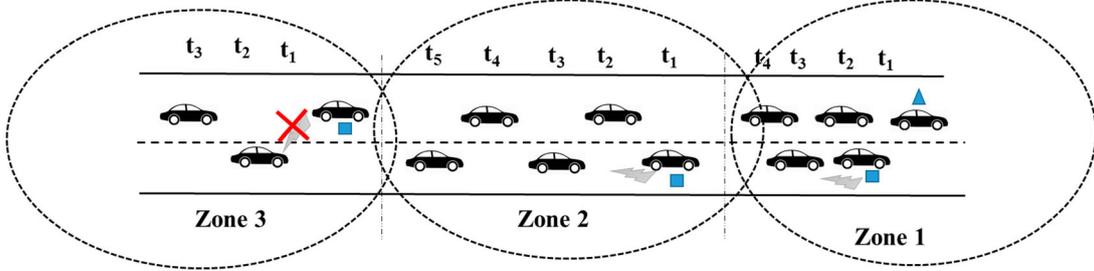
For semi-critical data dissemination, the time of occurrence of event is considered in computing the probability. The events classified under semi-critical case are the events that may disappear or cleared off within some time period. Example for semi-critical data is the accidents, vehicle collision, traffic due to breakdown vehicle, traffic light failure. The probability of a receiving vehicle  $i$  to forward data at time  $t$  is given by the following equation:

$$P(i, t) = \frac{V(i, t)}{V_f \times (\text{message received time} - \text{message occurred time})} \quad (12)$$

Equation (12) denotes that the probability to forward the data is more if the difference between the times is less. The more difference between message received time and message occurred time denotes that the message is occurred long time ago. This in turn implies that the event may be vanished. Hence the probability is less. Thus the vehicle discards the message if the event is vanished and suppresses the broadcast. After computing the probability, as in the case of critical data dissemination, D-SAB technique is employed. The timeslots are allocated based on the speed of the sender vehicle and the delay time for each slot is computed dynamically at each hop using Equation (10). Thus the vehicle



**Figure 4.** D-SAC-based critical data dissemination.



**Figure 5.** D-SAC-based semi-critical data dissemination where the cross mark indicates broadcast suppression since the occurred event exists for the time duration equal to two-hop propagation delay.

suppress the broadcast of semi-critical data if the data occurred long time ago. If the occurred event lasts for the time duration equal to two-hop propagation delay, then two relaying vehicles forward the message and the next vehicle suppresses the message, which is shown in Figure 5. Figure 5 shows the D-SAC-based semi-critical data dissemination where the source node transmits the message on the occurrence of an event to its one-hop neighbours. Then, based on D-SAC protocol, the vehicles determine whether to forward the message or suppress the message. Each vehicle in a zone is allotted to the corresponding time slot with delay according to the traffic regime. The nearest vehicle to the source vehicle in zone 1 forwards the message to its next-hop vehicles. The other vehicles check whether the data are scheduled to be forwarded and discard the message because of the broadcast by forwarding vehicle. In zone 2, the nearest vehicle to the forwarding vehicle forwards the message to its next-hop vehicles. Thus the message reaches all the vehicles travelling in the area. On each broadcast, the forwarding vehicle checks whether the event exists or vanished. Based on this, the probability is assigned to each vehicle as in (12). If the event is vanished, the forwarding vehicle suppresses the broadcast.

### 3.4.3. Non-critical data dissemination method

In non-critical data dissemination method, the probability of a receiving vehicle  $i$  to forward data at time  $t$  is given by the following equation:

$$P(i, t) = \frac{V(i, t)}{V_f \times \tau^h} \quad (13)$$

where  $h$  represents the current hop number. Thus, the forwarding probability of farthest vehicle from the source vehicle reduces. After computing the probability, as in the case of critical data dissemination, D-SAB technique is employed. The timeslots are allocated based on the speed of the sender vehicle and the delay time for each slot is computed dynamically at each hop using Equation (10). Thus the vehicle suppresses the broadcast of semi-critical data if the data are forwarded by other vehicles. Since the message is not critically to be forwarded, it does not necessarily reach to a long distance. Hence, only the vehicles near to the location of the event forward the data. Thus, the probability decreases when the number of communication hops increases. In addition, if the one-hop propagation delay is more the probability is less. Thus, the message is forwarded in at least two to three hops of communication.

## 4. Result and discussion

In this section, the proposed approach is implemented and validated by simulating autonomous robot system in VANETs environment with NS2. The simulation parameters are given in Table 1. In simulation settings, 3-lanes highway of 5 km distance is chosen. The MAC layer and physical layer settings are arranged as per IEEE 802.11p.

The traffic at various time intervals is monitored to determine the status of traffic in different time durations. To represent traffic scenario in simulation four different vehicle densities are taken. The vehicle density is measured in vehicle per km. The vehicle density of 10 denotes free-flow. The values 30 and 50 denote medium

Algorithm 1: Dynamic speed adaptive classified (D-SAC) data dissemination algorithm

```

1. Input: message, message id, GPS location of all source
   vehicles and receiving vehicles, sender id, speed of the
   vehicles.
2. On receiving a message, vehicle  $i$  classifies the mes-
   sage.
3. // slot computation
4. Compute number of slots using (9)
5. Compute distance between the source and receiving
   nodes
6. Determine its slot number ( $S_i$ ) using (11)
7. Check road type
8. If (road = = rural)
9.  $d_k = (S_k \times \tau) + 0.5$ 
10. end
11. If (road = = city roads)
12.  $d_k = (S_k \times \tau) + 0.8$ 
13. end
14. return ()
15. If (message id ( $i$ ) = = 1) // checks if message is already
   scheduled by vehicle  $i$ .
16. Discard () //broadcast suppression.
17. else if (message = = critical) // critical data dissemi-
   nation.
18. Compute probability using (8)
19. Go to step 4
20. broadcast () // transmit data after  $d_k$ 
21. else if (message = = semi-critical)
22. Compute probability using (12)
23. Go to step 4
24. Compute total propagation delay using  $pow(\tau, h)$ 
25. If  $pow(\tau, h) < (message\ received\ time - message\ occurred\ time)$ 
26. broadcast () // transmit data after  $d_k$ 
27. else
28. discard () //broadcast suppression.
29. end
30. else if (message = = critical)
31. Compute probability using (13)
32. Go to step 4
33. If  $pow(\tau, h) < thresholddelay$ 
34. broadcast () // transmit data after  $d_k$ 
35. else
36. discard () //broadcast suppression
37. end
38. end

```

**Table 1.** Simulation settings.

Physical layer	Frequency band	5.8 GHz
	Bandwidth	12 MHz
MAC layer	Transmission range (R)	~ 362 m
	MAC bit rate	7 Mbps
Scenario	Data frequency	4.8 Hz
	Highway length	4.7 km
	Lane max. speed	80 kmph
	Message size	100 byte
	Number of messages	50
	Minimum slot width	9 m
	Simulation time	898 s
	Number of runs	5
	Confidence level	96%

traffic state whereas 70 denotes heavy traffic. In simulation, the messages are generated and the proposed broadcast protocol is applied to measure the performance parameters. In the proposed protocol, the data redundancy, average delay and the number of propagated hops are reduced. Data delivery ratio represents the successfully received messages over the VANET. It is computed as the ratio of the number of successfully received messages ( $M_{received}$ ) to the number of expected

messages ( $M_{expected}$ ):

$$DDR = \frac{M_{received}}{M_{expected}} \quad (14)$$

$M_{expected}$  is computed from total number of messages sent:

$$M_{expected} = N \times M_{sent} \quad (15)$$

BO is measured as the ratio of the total number of duplicate messages to the number of received messages:

$$BO = \frac{M_{duplicate}}{M_{received}} \quad (16)$$

Average dissemination delay is computed by measuring delay at every vehicle and then averaging it over the network. The simulation results give the performance of the proposed method over the existing methods such as P-SAB, slotted 1-persistence, G-SAB weighted-p persistence method [7]. Figures 6–9 show the comparative analysis of the performance parameters such as data delivery ratio, average dissemination delay, BO and number of hops. In Figure 6 data delivery ratio in various traffic scenarios is plotted for different methods. It is observed that all the methods almost provide the maximum delivery ratio. It is also inferred that the delivery ratio is less in congested scenarios while it is high in low traffic scenarios. Here in the weighted-p persistence method, the delivery ratio is less. Figure 7 shows the comparative analysis of average number of hops propagated. The number of propagation hops should be minimum for the improved performance. In the weighted-p persistence method, the average number of hops is more. In the proposed scheme, the data are delivered to less number of hops. On an average, the data are delivered for 2–4 hops, from the sender side to the receiver side in the proposed scheme. In addition, it is found from the graph that the number of hops is reduced when the vehicle density increases, which implies that the data are transmitted for only two hops in high-traffic scenarios.

Figure 8 depicts BO. When compared with the P-SAB, weighted p-persistence, slotted 1-persistence, G-SAB reduces BO. In the proposed scheme, since high level of broadcast suppression is obtained, the BO is reduced significantly. The impact of the classification of message in BO reduction is shown in Figure 10. From Figure 10, it is observed that the BO is more in critical data dissemination compared with the other two types, since the critical data must be forwarded with higher probability. For lower traffic regime, overhead is low since the number of vehicles is less. In contrast, overhead is large in medium traffic. All at once, it should be observed that the overhead is constant in semi-critical type and non-critical type, irrespective of the traffic regime.

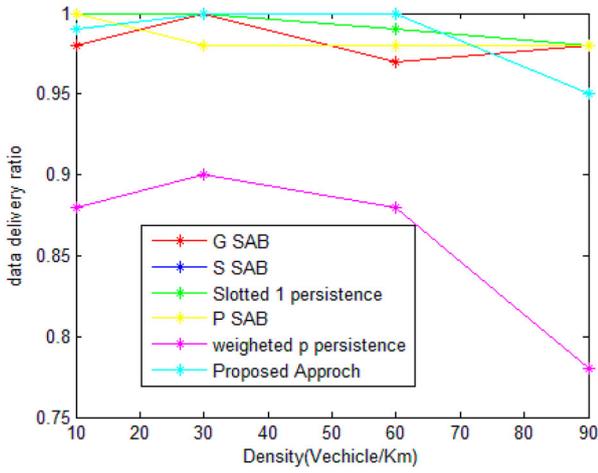


Figure 6. Comparison of data delivery ratio.

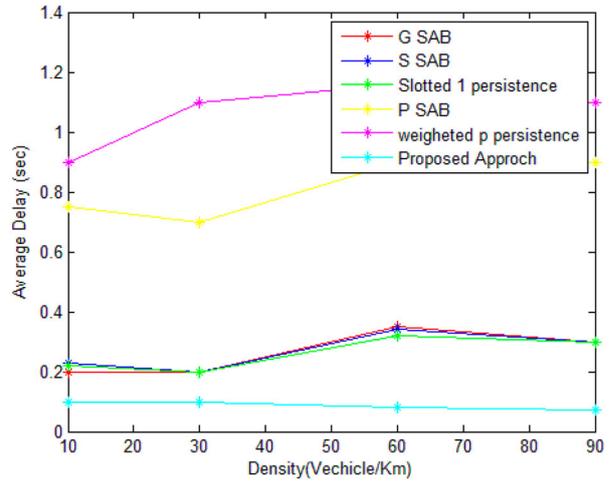


Figure 9. Comparison of average delay.

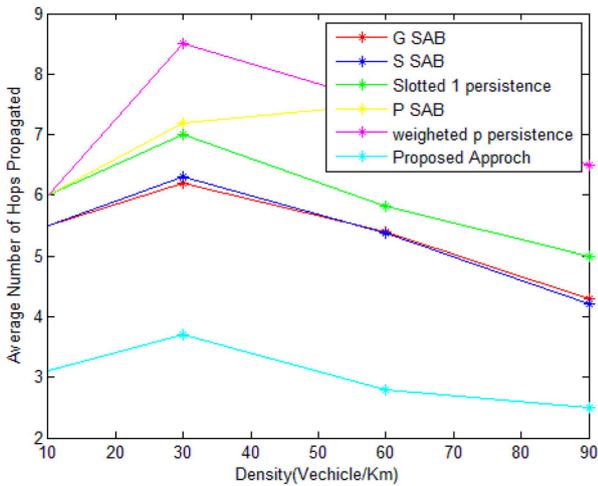


Figure 7. Average number of hops propagated.

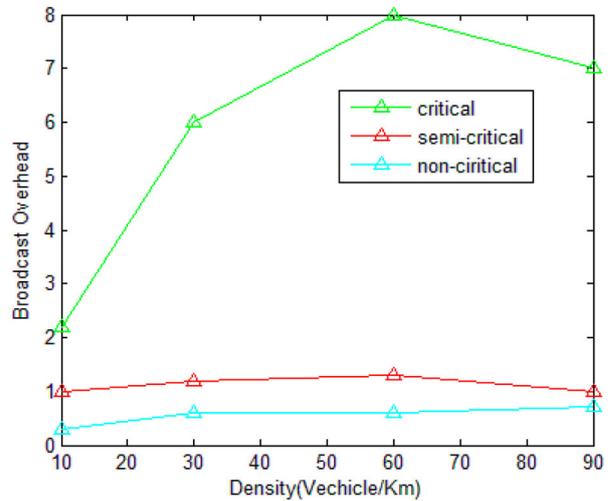


Figure 10. Comparison of BO for different kinds of messages.

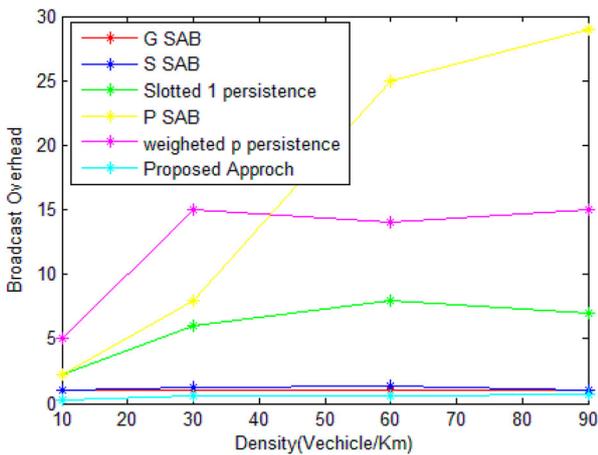


Figure 8. Comparison of BO.

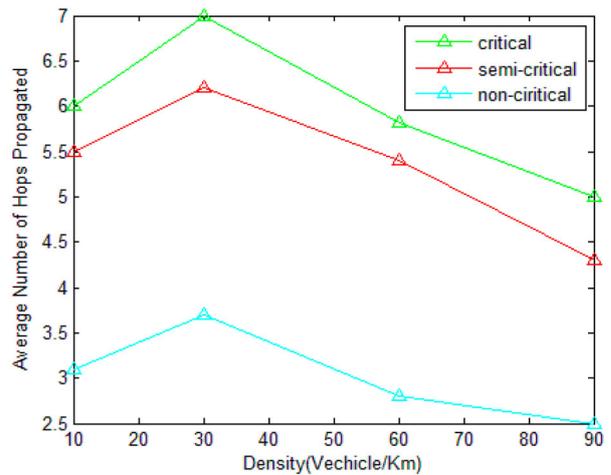


Figure 11. Comparison of BO for different kinds of messages.

Figure 9 compares the average delay over the entire network, for different methods. In the weighted p-persistence method, the delay is more. Though considerable reduction is achieved in the exiting methods like slotted 1-persistence, G-SAB and S-SAB, in the proposed method, the performance is still improved by achieving very small delay of 50–100 ms on average.

Average of number of hops for the proposed scheme is analysed and compared for various classes of message. The graph in Figure 11 shows the comparison,

where the number of hops is more in critical data dissemination. With respect to the traffic regime, the number of hops for critical data dissemination is more for medium traffic regime and less for higher traffic regime. The number of hops is slightly reduced in semi-critical data dissemination since it depends on the time occurrence of the event. Similar to the case of critical data, the number of hops is more for medium traffic regime and less for higher traffic regime. For non-critical data dissemination, the average number of hops is 3 for low-traffic regime and it nearly approaches 2 for high-traffic conditions. Thus in the proposed scheme, the BO, average delay and average number of hops are reduced considerably compared with the previous methods.

## 5. Conclusion

Autonomous robot in VANETs the broadcast storm is considered as a significant concern which disrupts the performance of the network. Concerning VANETs, it is essential that the BO issue should be minimum along with the assurance of improved data delivery ratio. It is hard to attain high delivery ratio along with the maintenance of small delay. To achieve the objectives we presented D-SAC data dissemination protocol, which forwards the data according to different factors. The proposed protocol is implemented and the simulation results verified that the proposed technique decreases the end-end dissemination delay and BO. It is also proved that the delivery ratio is high. In addition, by classifying the data based on their criticality, the data redundancy is still reduced. In semi-critical data, the probability for rebroadcast is computed based on the time of event occurred. Thus, the data are discarded after certain hops. Therefore, the number of hops also reduced. From the results, it is observed that the BO does not increase under high-density scenarios, which proves that the broadcast suppression is improved. The impact of data classification is analysed through the number of hops. For critical message it should be forwarded to more vehicles hence it is propagated over more number of hops. In semi-critical data, the number of hops is proportional to the time of event occurrence and the propagation delay.

## Compliance with ethical standards

**Disclosure of potential conflicts of interest:** Author 1 & 2 declares that they have no conflict of interest.

**Research involving human participants and/or animals:** All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

**Informed consent:** Informed consent was obtained from all patients for being included in the study

## References

- [1] Dua A, Kumar N, Bawa S. A systematic review on routing protocols for vehicular ad hoc networks. *Veh Commun.* 2014;1(1):33–52.
- [2] Sherin BT, Newton PC. RBCAST: an efficient data dissemination technique to reduce broadcast storm problem in vehicular ad hoc network. *Int J Comput Sci Eng.* 2016;4(2):1294–1300.
- [3] Dua A, Kumar N, Bawa S, et al. An intelligent context-aware congestion resolution protocol for data dissemination in vehicular ad hoc networks. *Mobile Netw Appl.* 2015;20(2):181–200.
- [4] Wu C, Ohzahata S, Kato T. VANET broadcast protocol based on fuzzy logic and lightweight retransmission mechanism. *IEICE Trans Commun.* 2012;95(2):415–425.
- [5] Cao Z, Shi K, Song Q, et al. Analysis of correlation between vehicle density and network congestion in VANETs. 2017 7th IEEE International Conference on Electronics Information and Emergency Communication (ICEIEC). IEEE; 2017.
- [6] Bouk SH, Kim G, Ahmed SH, et al. Hybrid adaptive beaconing in vehicular ad hoc networks: a survey. *Int J Distrib Sens Netw.* 2015;11(5):390360.
- [7] Chaqfeh M, Lakas A. A novel approach for scalable multi-hop data dissemination in vehicular ad hoc networks. *Ad Hoc Netw.* 2016;37:228–239.
- [8] Wu C, Kumekawa K, Kato T. A novel multi-hop broadcast protocol for vehicular safety applications. *Inf Media Technol.* 2010;5(2):798–812.
- [9] Kühne R, Gartner N. Years of the fundamental diagram for traffic flow theory. *Greenshields Symposium*, vol. E-C149 of Transportation Research Circular, Traffic Flow Theory and Characteristics Committee. *Transp Res Board Natl Acad.* 2011; 46(75).
- [10] 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.
- [11] Suriyapaiboonwattana K, Pornavalai C, Chakraborty G. An adaptive alert message dissemination protocol for VANET to improve road safety. *IEEE International Conference on Fuzzy Systems, 2009, FUZZ-IEEE 2009.* IEEE; 2009.
- [12] Slavik M, Mahgoub I. Statistical broadcast protocol design for unreliable channels in wireless ad-hoc networks. *Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE.* IEEE; 2010.
- [13] Mylonas Y, Lestas M, Pitsillides A. Speed adaptive probabilistic flooding in cooperative emergency warning. *Proceedings of the 4th Annual International Conference on Wireless Internet. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering);* 2008.
- [14] Qayyum A, Viennot L, Laouiti A. Multipoint relaying for flooding broadcast messages in mobile wireless networks. *Proceedings of the 35th Annual Hawaii International Conference on System Sciences, 2002, HICSS.* IEEE; 2002.
- [15] Wu C, Kumekawa K, Kato T. A novel multi-hop broadcast protocol for vehicular safety applications. *Inf Media Technol.* 2010;5(2):798–812.
- [16] Lagraa N, Yagoubi M, Tahari K. Adaptation of the MCDS broadcasting protocol to VANET safety applications. *International Conference on Innovations in Information Technology, 2008, IIT 2008, IEEE;* 2008.

- [17] Sahoo J, Wu EH, Sahu PK, et al. BPAB: binary partition assisted emergency broadcast protocol for vehicular ad hoc networks. Proceedings of 18th International Conference on Computer Communications and Networks, 2009. ICCCN 2009. IEEE; 2009.
- [18] ALshaer H, Horlait E. An optimized adaptive broadcast scheme for inter-vehicle communication. Vehicular Technology Conference, 2005, VTC 2005-Spring, 2005 IEEE 61st, Vol. 5. IEEE; 2005.
- [19] Schwartz RS, Das K, Scholten H, et al. Exploiting beacons for scalable broadcast data dissemination in VANETs. Proceedings of the Ninth ACM International Workshop on Vehicular Inter-networking, Systems, and Applications. ACM; 2012.
- [20] Villas LA, Boukerche A, Maia G, et al. Drive: an efficient and robust data dissemination protocol for highway and urban vehicular ad hoc networks. Comput Netw. 2014;75:381–394.
- [21] Maia G, Villas LA, Boukerche A, et al. Data dissemination in urban vehicular ad hoc networks with diverse traffic conditions. 2013 IEEE Symposium on Computers and Communications (ISCC). IEEE; 2013.
- [22] Chang B-J, Liang Y-H, Huang Y-D. Adaptive message forwarding for avoiding broadcast storm and guaranteeing delay in active safe driving VANET. Wirel Netw. 2015;21(3):739–756.
- [23] Abdou W, Darties B, Mbarek N. Priority levels based multi-hop broadcasting method for vehicular ad hoc networks. Ann Telecommun – Ann Télécommun. 2015;70(7–8):359–368.
- [24] Haddadou N, Rachedi A, Ghamri-Doudane Y. Modeling and performance evaluation of advanced diffusion with classified data in vehicular sensor networks. Wirel Commun Mob Comput. 2011;11(12):1689–1701.
- [25] 1609.0-2013 – IEEE Guide for Wireless Access in Vehicular Environments (WAVE) – Architecture. IEEE Standards Association. IEEE Vehicular Technology Society, 2013. Web. 9 April 2015.
- [26] Behrisch M, Bieker L, Erdmann J, et al. SUMO – simulation of urban mobility: an overview. Proceedings of SIMUL 2011, The Third International Conference on Advances in System Simulation. ThinkMind; 2011.
- [27] Fracchia R, Meo M. Analysis and design of warning delivery service in intervehicular networks. IEEE Trans Mob Comput. 2008;7(7):832–845.