Design and Evaluation of a Hybrid Intelligent Broadcast Algorithm for Alert Message Dissemination in VANETs

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Abstract

Vehicular ad hoc network is an emerging new technology and a promising platform for the intelligent transportation system. The most important application of VANET is disseminating emergency messages to warn drivers in case of dangerous events. The core technique relies on the design of a broadcast scheme. In this paper, we propose a hybrid intelligent broadcast algorithm for alert message dissemination in VANETs that is called Hi-CAST. To deliver alert message effectively, the proposed Hi-CAST algorithm uses delay and probabilistic broadcast protocols together with token protocol. The performance of the Hi-CAST is evaluated through simulation and compared with that of other alert message dissemination algorithms.

Keywords: *Alert message dissemination, delay broadcast, probabilistic broadcast, token protocol, vehicular ad hoc networks.*

1. Introduction

Vehicular ad hoc networks (VANETs) are more and more popular today. Due to the advanced technologies, such as the global position system (GPS), power-saving embedded computer, and wireless communication system, people can enjoy many convenience services while they are driving in cars. Safety and comfort messages are main kinds of messages transmitted in VANETs. With the safety messages, the drivers can be aware the car accidents happened in front of the vehicle even if the line of sight is bad. Then, the drivers can change their road lanes or something else to avoiding hitting the abnormal cars. Or they can change their route to destination in time and thus avoid getting into a traffic jam. The comfort messages are used for other applications, such as the shopping, parking lot or the weather information. In this paper, we focus on the dissemination of the safety/emergency messages in VANETs [1].

Most applications targeting VANETs rely heavily on broadcast transmission to disseminate traffic related information to all reachable nodes within a certain geographical area rather than a query for a route to a certain host. Because of the shared wireless medium, blindly broadcasting packets may lead to frequent contention and collisions in transmission among neighboring nodes. This problem is sometimes referred to as the broadcast storm problem. While multiple solutions exist to alleviate the broadcast storm in the usual MANET environment, only a few solutions have been proposed to resolve this issue in the VANET context [2].

In this paper, we present a hybrid intelligent broadcast (Hi-CAST) algorithm for alert message dissemination to deliver efficiently alert message effectively in VANETs. In the proposed Hi-CAST algorithm, when a vehicle receives an alert message for the first time, the vehicle determines rebroadcast degree from fuzzy logic rules, where the rebroadcast degree depends on the current traffic density of road and the distance between source vehicle and destination vehicle. The rebroadcast probability and rebroadcast delay are dependent on computed rebroadcast degree. If the vehicle does not receive the rebroadcasted alert message from another vehicle until the delay time is expired, the vehicle rebroadcasts the alert message with the rebroadcast probability to all vehicles. Also, the Hi-CAST uses delay broadcast protocol together with token protocol to improve the success rate of alert message propagation.

The remainder of this paper is organized as follows. Section 2 reviews the related works. Section 3 describes the proposed Hi-CAST algorithm. Section 4 presents the performance evaluation of Hi-CAST algorithm through simulation. Section 5 concludes the paper and discusses future works.

2. Related Works

In VANET, broadcast is the most effective means to disseminate the collision warning messages in traffic accidents. However, because of the unique features of VANET, applying the traditional broadcast algorithms for ad hoc networks to VANET directly would make algorithm performances degraded or cannot even work correctly. Up to now, researchers have been proposed a lot of broadcast algorithms for message dissemination, mainly including the following categories: flooding-based category, probability-based category and location-based category.

Simple broadcast [3, 4] is the simplest protocol used in V2V Safety alert applications for VANET. When there is an accident, safety alert application will send alert messages to all vehicles approaching towards accident site. When a vehicle receives a broadcast message for the first time, it retransmits the message. The vehicle then ignores all subsequent broadcast messages (with same ID) it receives, from other vehicles rebroadcasting the same message. There are two main problems in this simple broadcast method. First, there are many redundant rebroadcast messages because of flooding. Thus, when a *n* hosts for the first time, *n* replications will there is a high probability that a message will be received by many hosts located in a close proximity. Each host will severely contend with one another for access to medium. As show in Fig. 1, when accident is occur *B*, *C*, *D*, *E* and *F*, which are in transmission receive alert message and rebroadcast it. It will then give rise to broadcast storm, and collision will occur, which lead to retransmission and further collision.

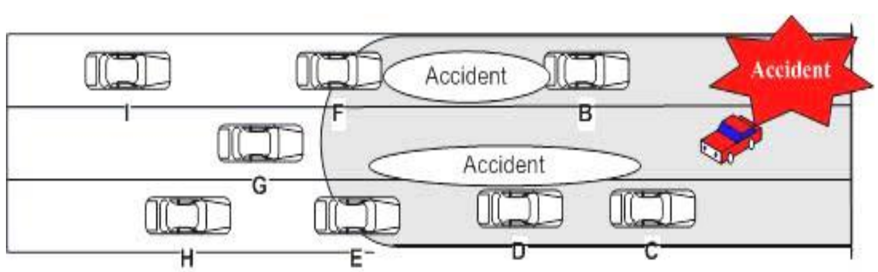


Fig. 1. Situation of an Accident and Nearby Vehicles on the Road

p-Persistence [4, 5] tries to reduce the broadcast storm problem by using a stochastic selection method to decide the vehicles that will rebroadcast the alert message. When a vehicle receives a broadcast message for the first time, the vehicle will rebroadcast the alert message with a random probability p. This method will help to reduce number of rebroadcasting vehicles and thereby broadcast storm problem. However failures to extend the alert message decide not to, which will cause the loss of alert message. For example, if all vehicles *B*, *C*, *D*, *E* and *F* decide not to rebroadcast the message, no car behind them will receive the alarm message. This approach is sometimes referred to as Gossip-based flooding [6].

Upon receiving a packet from node *i*, node *j* checks the packet ID and rebroadcasts with probability $P_{i\,j}$ if it receives the packet for the first time; otherwise, it discards the packet. Denoting the relative distance between nodes *i* and *j* by D_{ij} and the average transmission range by *R*, the forwarding probability, P_{ij}, can be calculated on a per packet basis using the following simple expression:

$$P_{ij} = \frac{D_{ij}}{R}. \quad (1)$$

Unlike the p-persistence or gossip-based scheme, weighted p-persistence [7] assigns higher probability to nodes that are located farther away from the broadcaster given that GPS information is available and accessible from the packet header.

Li et al. [8] proposed a novel broadcast protocol called Efficient Directional Broadcast (EDB) for urban VANET using directional antennas. When a vehicle broadcasts on the road, only the furthest away receiver is responsible to forward the message just in the opposite direction where the packet arrives. Due to the topology of VANET changed rapidly, EDB makes receiver-based decisions to forward the packet with the help of the GPS information. The receiver only needs to forward the packet in the opposite direction where the packet arrives. After a vehicle receives a packet successfully, it waits for a time before taking a decision whether to forward the packet or not. During this time, the vehicle listens to other relay of the same packet. The waiting time can be calculated using the following formula:

$$\mathrm{WaitingTime} = \left(1 - \frac{\mathrm{D}}{\mathrm{R}}\right) \times \mathrm{maxWT}. \quad (2)$$

Where *D* is the distance from the sender which can be obtained using the sender's location information added in the packet and its own, and *R* is the transmission range. The *maxWT* is a configurable parameter which can be adjusted according to the density of the vehicle.

3. Hi-CAST Design

In this paper, we present hybrid intelligent broadcast (Hi-CAST) algorithm to improve performance of road safety alert application in VANET. Upon receiving a packet from vehicle *i*, vehicle *j* rebroadcasts it with some waiting time and some probability if it receives the packet for the first time; otherwise, it discards the packet. The waiting time is depended on the current velocity of destination vehicle, where VANETs characteristic varies from sparse networks with highly mobile nodes to a traffic jam with very high node density and low node velocities. The probability is depended on the distance between source vehicle and destination vehicle.

In the design of Hi-CAST, we assume the following:

- Here, before transmitting alert message, GPS is used to calculate the distance between source vehicle *i* and destination vehicle *j*.
- Also, GPS is used to calculate current it's velocity of the destination vehicle.
- All vehicles are equipped with a directional antenna that is an antenna which radiates greater power in one or more directions allowing for increased performance on transmit and receive and reduced interference from unwanted sources

Fig. 2 and Fig. 3 shows the example of computation of waiting time and rebroadcast probability, respectively. From Fig. 2 and Fig. 3, we know that the waiting time of destination vehicle decreases with its distance *d* from the source, but the rebroadcast probability of the destination vehicle increases with its velocity *v*.

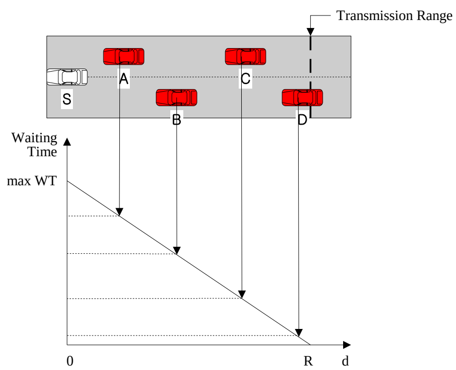


Fig. 2. Example of Computation of *Waiting Time*(*d*).

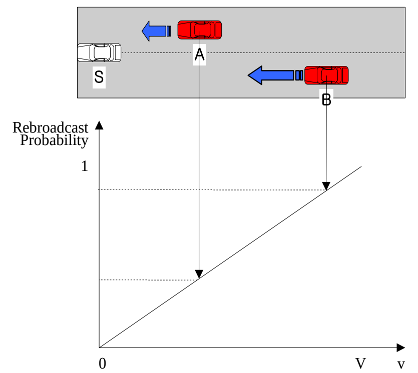


Fig. 3. Example of Computation of *Rebroadcast Probability*(*v*).

In Hi-CAST, when a vehicle receives an alert message for the first time, the vehicle rebroadcasts the alert message according to the fuzzy control rules for rebroadcast degree, where the rebroadcast degree depends on the current velocity of the destination vehicle and the distance between source vehicle and destination vehicle. Also, the proposed algorithm is a hybrid algorithm that uses delay and probabilistic broadcast protocols together with token protocol to achieve higher success rate of alert message propagation.

We map the current velocity of destination vehicle (*v*) to the five basic fuzzy sets: VF (very fast), F (fast), M (medium), S (slow), VS (very slow) using the fuzzy function as shown in Fig. 4. Membership function of *v* represents fuzzy sets of *v*. The membership function which represents a fuzzy set *v* is usually denoted by $\mu_{VD}(v)$, where V represents the maximum velocity of the destination vehicle.

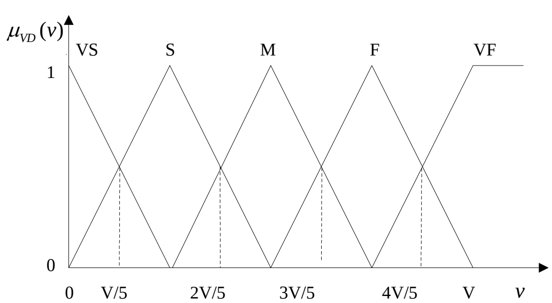
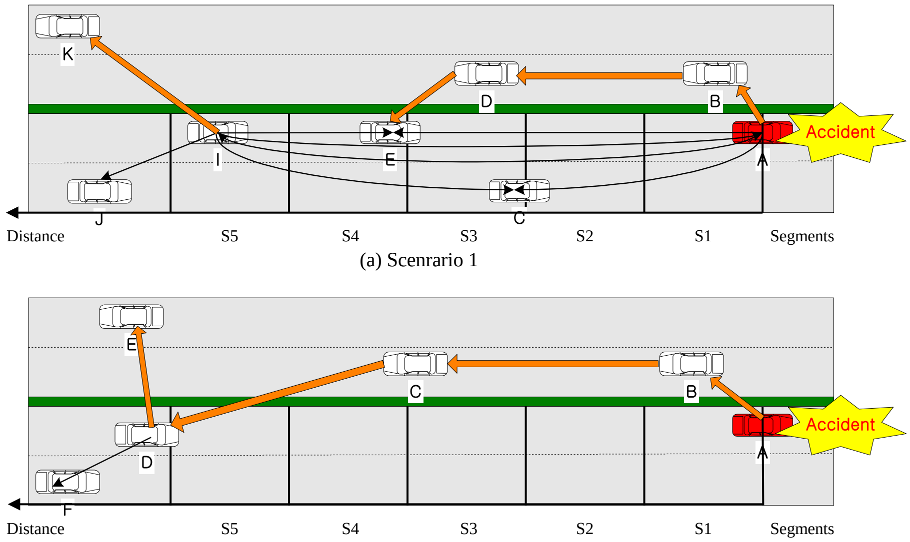


Fig. 4. Membership Function for the Current Velocity.

Fig. 5 shows a few examples of proposed Hi-CAST, where S1, S2, S3, S4 and S5 represents the segments that divide the transmission range into the same size blocks, respectively. S1 and S4 represent the nearest and the farthest segments from a vehicle accident point, respectively.



(a) Scenrario 1

(b) Scenrario 2

Fig. 5. Example of Hi-CAST.

First, consider the scenario depicted in Fig. 5(a) where the vehicles exist in transmission range. The vehicle A which detects car accident broadcasts an alert message to all vehicles in transmission range and passes an alert token to the nearest vehicle traveling in opposite direction. The vehicle I which is traveling in S5 has very short waiting time, but the vehicle C which is traveling in S3 has moderate waiting time. If the current velocity of vehicle I is medium, the vehicle I has moderate rebroadcast probability. The vehicle I rebroadcasts with moderate probability if the vehicle I receives the alert message for the first time and has not received any duplicates before its waiting time; otherwise, it discards the alert message. Also, vehicle B receives the alert token, then passes the alert token to vehicle D ahead traveling. The vehicle D passes the alert token to the vehicle E traveling in opposite direction, and the vehicle E discards the alert token.

Second, consider the scenario depicted in Fig. 5(b) where the vehicles don't exist in transmission range. The vehicle B receives the alert token from the vehicle A which detects car accident, then passes the alert token to the vehicle C just behind traveling. The vehicle C passes the alert token to the vehicle D traveling in opposite direction, and the vehicle D broadcasts the alert message to all vehicles in transmission range and passes an alert token to the nearest vehicle traveling in opposite direction.

The control rules for rebroadcast degree which consider the current velocity of destination vehicle and the distance between source vehicle and destination vehicle are shown in Table 1.

Table 1. The Control Rules for Rebroadcast Degree

		VD				
		VS	S	M	F	VF
Segment	S1	VL	VL	L	L	M
	S2	VL	L	L	M	M
	S3	L	L	M	M	H
	S4	L	M	M	H	VH
	S5	M	M	H	VH	VH

(input variables) VD: VF (very fast), F (fast), M (medium), S (slow), VS (very slow)
(output variables) rebroadcast degree: VH (very high), H (high), M (medium), L (low), VL (very low)

Upon receiving a alert message from vehicle i, vehicle j calculates *segWT*(*i*, *j*) and *Rebroadcast_Probability*(*i*, *j*) through equation (3) and equation (4). The vehicle j rebroadcasts with *Rebroadcast_Probability*(*i*, *j*) if the vehicle j receives the alert message for the first time and has not received any duplicates before *segWT*(*i*, *j*); otherwise, it discards the alert message.

$$\text{Rebroadcast\_Probability(i, j)} = \text{defuzzifier}\begin{pmatrix}\text{a linguistic weighted}\\ \text{factor for rebroadcasting}\end{pmatrix}. \quad \textbf{(3)}$$

$$\text{defuzzifier}\left(\begin{Bmatrix}\text{VH}\\ \text{H}\\ \text{M}\\ \text{L}\\ \text{VL}\end{Bmatrix}\right) = \begin{Bmatrix}0.8\\ 0.65\\ 0.5\\ 0.35\\ 0.2\end{Bmatrix}$$

$$\text{segWT(i, j)} = \left(1 - \frac{\text{Segment(j)}}{\text{n}}\right) \times \text{maxsegWT}. \quad \textbf{(4)}$$

Where, *Segment*(*j*) represents segment number which destination vehicle j is traveling, *n* is the number of segments and *maxsegWT* represents the maximum segment waiting time which is determined by considering the number of segments and the transmission delay of a VANET.

4. Performance Evaluation

The primary objective of our algorithm is to improve success rate of safety alert message which means the percentage of vehicles that receive the safety alert message. We also aimed to reduce the broadcast storm problem that occurs in most of the VANET's safety alert protocols. We use three metrics to evaluate different protocols.

- Collision: The number of alert message collisions that occur during the period of simulation.
- Success rate: Percentage of vehicles that received alert message.
- Time: Time delay from accident occurred till last vehicle received alert message.

The parameters and values of the performance evaluation for Hi-CAST are shown in Table 2.

Table 2. Simulation Parameters

Parameter	Value
Distance of alert region	2~10 *Km*
Transmission range (*R*)	250 *m*
Traffic density	0~200 vehicles/*Km*
Maximum vehicle speed	100 *Km*
Lane	2
The broadcast probability in p-Persistence	0.5
Transmission delay	20 *ms*/hop
Maximum waiting time	120 *ms*
Maximum segment waiting time	110 *ms*

The current velocity of vehicles depends on the traffic density of roads. Thus, the higher traffic density is, the slower vehicle velocity is, and the lower traffic density is, the faster vehicle velocity is. Accordingly, the current velocity of a vehicle is computed from equation (5).

$$\mathrm{v_{now}} = \mathrm{v_{max}} \times \left(1 - \frac{\rho_{\mathrm{now}}}{\rho_{\mathrm{max}}}\right). \tag{5}$$

Where, $\mathrm{v_{max}}$ represents the maximum allowable speed of the road, ρ_{max} represents the traffic density that the vehicle speed is zero when traffic jam is occurred, and ρ_{now} represents the current traffic density of the road.

We have evaluated the performance of Hi-CAST in the MATLAB 7.0 [9]. Fig. 6 shows the number of alert message collisions that occurred accordingly to the distance of alert region. We can see that Hi-CAST has lowest number of collision because Hi-CAST uses the fuzzy control rules for rebroadcast degree that considers the current velocity of a received vehicle and the distance segment between source vehicle and received vehicle.

The most important result, the success rate for different algorithms, is shown in Fig. 7. Loss of alert message causes low success rate. The success rate of Hi-CAST is higher than that of Simple and p-Persistence algorithms, and the success rate of Hi-CAST equals to that of EDB algorithm that achieves perfect success rate through broadcasting an alert message every $10 \times maxWT$ until the sender receives ACK packet from a receiver in $maxWT$.

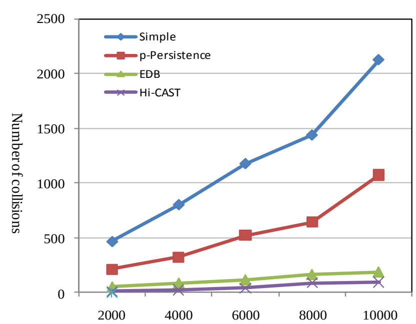


Fig. 6. Number of Collisions with Alert Region Distance

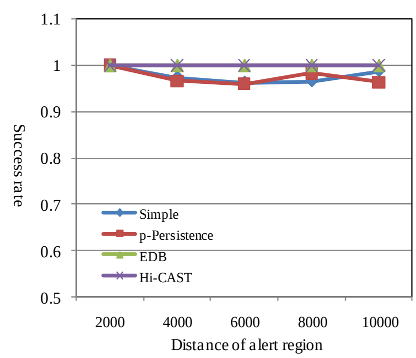


Fig. 7. Success Rate with Alert Region Distance

Message dissemination delay is shown in Fig. 8. The delay time of Hi-CAST algorithm is longer than Simple and p-Persistence algorithms because Hi-CAST uses the delay protocol with different waiting time on distance segments and the sender passes an alert token to a next hop neighbor just behind in opposite direction, the delay time of Hi-CAST is better than that of EDB, and EDB has the worst delay time because that multiple *maxWT* delays are continued until a next hop neighbor appears.

Fig. 8 shows the number of occurrences of the fuzzy sets for rebroadcast in Hi-CAST in case that the distance of alert region is 10 *Km*. The number of occurrences of fuzzy set M (medium) is greater than other fuzzy sets because the number of control rules that the fuzzy set for rebroadcast degree is M is greater of that of other fuzzy sets.

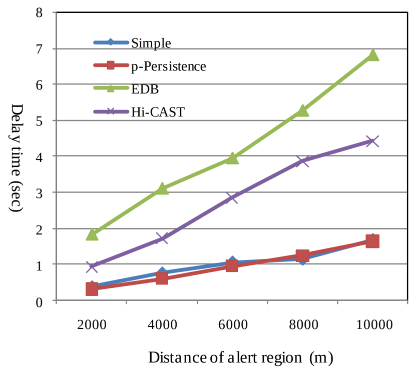


Fig. 8. Delay Time with Alert Region Distance.

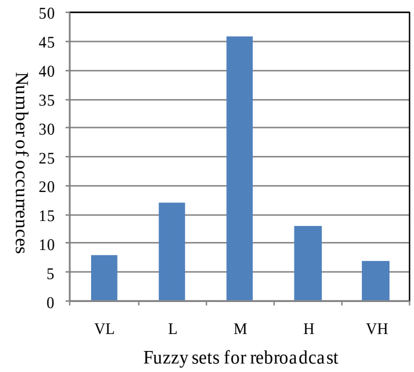


Fig. 9. The Number of Occurrences of Fuzzy Sets in Hi-CAST.

Table 2 shows the items for rebroadcast probability computation in Hi-CAST. The rebroadcast probability is computed by the number of messages over total number of vehicles. Therefore, the rebroadcast probability of Hi-CAST is 186/1,504≒0.124.

Table 3. Analysis results for rebroadcast probability of Hi-CAST.

Items for rebroadcast probability computation	Value
Number of rebroadcast messages	91
Number of collisions	95
Total number of messages	186
Total number of vehicles	1,504
Rebroadcast probability	0.124

From simulation results, we know that the rebroadcast probability of EDB is 256/1668≒0.16. Therefore, the rebroadcast probability of Hi-CAST is smaller than that of p-Persistence and EDB, so the number of alert message collisions of Hi-CAST is lower than that of p-Persistence and EDB.

5. Conclusions

Since most applications in VANETs favor broadcast transmission as opposed to point-to-point routing, routing protocols should be designed to address the broadcast storm problem to avoid unnecessary loss of important safety related packets during message propagation.

In the proposed algorithm that is called Hi-CAST, when a vehicle receives an alert message for the first time, the vehicle rebroadcasts the alert message according to the fuzzy control rules for rebroadcast degree, where the rebroadcast degree depends on the current velocity of the destination vehicle and the distance between source vehicle and destination vehicle. Also, the proposed algorithm is a hybrid algorithm that uses delay and probabilistic broadcast protocols together with token protocol to achieve higher success rate of alert message propagation. The performance of the Hi-CAST is evaluated through simulation and compared with that of other alert message dissemination algorithms. Our simulation results show that the Hi-CAST is superior to other algorithms in collision and success, but the Hi-

CAST is longer than Simple and p-Persistence algorithms in time because of using delay broadcast protocol.

Our future work includes studying on an adaptive alert message dissemination algorithm which considers the conditions of road shapes and the number of lanes.

References

[1] Lee, J-F., Wang, C-S., Chuang, M.-C.: Fast and Reliable Emergency Message Dissemination Mechanism in Vehicular Ad Hoc Networks. IEEE Wireless Communications and Networking Conference, pp. 1-6 (2010)

[2] Wisitpongphan, N., Tonguz, O. K., Parikh, J. S., Mudalige, P., Bai, F., Sadekar, V.; Broadcast Storm Mitigation Techniques in Vehicular Ad Hoc Networks. IEEE Wireless Communications, Vol. 14, Issue 6, pp. 84-94 (2007)

[3] Tonguz, O., Wisitpongphan, N., Bait, F., Mudaliget, P., Sadekart, V.: Broadcasting VANET. Proceeding ACM VANET, pp. 1-6 (2007)

[4] Suriyapaibonwattana, K., Pomavalai, C.: An Effective Safety Alert Broadcast Algorithm for VANET. International Symposium on Communications and Information Technologies, pp. 247–250 (2008)

[5] Suriyapaibonwattana, K., Pornavalai, C., Chakraborty, G.: An Adaptive Alert Message Dissemination Protocol for VANET to Improve Road Safety. In: FUZZ-IEEE, pp. 20-24 (2009)

[6] Haas, Z. J., Halpern, J. Y., Li, L.: Gossip-based Ad Hoc Routing. IEEE/ACM Transactions on Networking, vol. 14, pp. 479-491 (2006)

[7] Tonguz, O. K., Wisitpongphan, N., Parikh, J. S., Bai, F., Mudalige, P., Sadekar, V. K.: On the Broadcast Storm Problem in Ad hoc Wireless Networks. In: 3rd International Conference on Broadband Communications, Networks and Systems, pp. 1-11 (2006)

[8] Li, D., Huang, H., Li, X., Li, M., Tang, F.: A Distance-Based Directional Broadcast Protocol for Urban Vehicular Ad Hoc Network. International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1520–1523 (2007)

[9] Kay, M. G.: Basic Concepts in Matlab. Dept. of Industrial and System Engineering, North Carolina State University, http://www.ise.ncsu.edu/kay/Basic_Concepts_in_Matlab.pdf