

# Enhanced Performance Evaluation for Broadcasting Safety Messages In VANET

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**Abstract**— The applications of VANETs falls into two categories namely safety application (event-driven applications) and non-safety application (periodic applications). These both categories coexist in the network operation mode proposed for DSRC. High priority must be given to safety messages as they contain critical information. The proper estimation of network traffic is highly important in Vehicular Ad Hoc Networks (VANETs) as they are expected to exchange high-priority critical messages. In reality, the network most of the time will handle low-priority traffic and in emergency situation will have to transfer high-priority traffic also. In this paper, performance evaluations of safety message dissemination in VANETs in Vehicle-to-Vehicle communication (V2V) are considered. The vehicles which are considered as nodes in VANET communicate or exchange messages with each other, which is referred to as V2V or Inter-Vehicle Communication (IVC). V2V communication is implemented through Dedicated Short Range Communication (DSRC) protocol. The main advantage of the V2V communication with DSRC will be decreased delay and efficient broadcasting of safety messages to far away nodes as possible. An adaptive algorithm (AMBA) is introduced to increase the system reliability in terms of the probability of packet's successful reception and delay of emergency messages in a harsh vehicular environment.

**Keywords**— VANET, V2V communication, V2I communication, DSRC, IEEE 802.11p, Safety message broadcasting, AMBA(Adaptive and Mobility Based Algorithm) algorithm.

## I. INTRODUCTION

The research and application development in vehicular ad hoc networks (VANETs) have been driven by the Dedicated Short Range Communication (DSRC) technology or IEEE 802.11p [1] designed to help drivers to travel more safely and to reduce the number of fatalities due to road accidents. The IEEE 802.11p MAC uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and some concepts from the Enhanced Distributed Channel Access (EDCA) [2]. In this technology, there are four access classes (ACs) with different Arbitration Inter Frame Space Numbers (AIFSN) to insure less waiting time for high priority packets as listed in Table I.

The DSRC is licensed at 5.9GHz with 75MHz spectrum which is divided into seven 10MHz channels and 5MHz guard band. The control channel (CCH) will be used for safety applications while the other six channels, called service channels, will be used for infotainment or commercial applications to make this technology more cost effective. Vehicles will synchronize the switching between the CCH and one or more of the service channels (SCH),

hence safety related messages will not be missed or lost. The synchronization interval (SI) contains a control channel interval (CCI) followed by a service channel interval (SCI) [3]. Increasing the CCI will enhance the reliability of safety applications and challenge the coexistence of both safety and non-safety applications on the DSRC.

VANET is a self-organizing network that works on both Inter-Vehicle Communication (IVC) and Vehicle to Infrastructure communication. In this paper, IVC is taken into consideration where vehicles will be equipped with sensors and GPS systems to collect information about their position, speed, acceleration and direction to be broadcasted to all vehicles within their range. These status messages should be broadcasted periodically in every CCI. In IEEE 802.11p, vehicles will not send any acknowledgement for the broadcasted packets. Therefore, the transmitter cannot detect the failure of the packet reception and hence will not retransmit it. This is a serious problem in collision warning applications where all vehicles behind the accident have to receive the warning message successfully in a short time to avoid chain collisions. This problem motivates us to propose an

TABLE I  
CONTENTION PARAMETERS FOR IEEE802.11P CCH [4]

AC No.	Access Class	CWmin	CWmax	AIFSN
0	Background Traffic (BK)	15	1023	9
1	Best Effort (BE)	7	15	6
2	Voice (VO)	3	7	3
3	Video (VI)	3	7	2

analytical model for assessing the DSRC reliability and delay taking into account the multipath fading channel in VANETs, vehicles high mobility, hidden terminal problem and transmission collisions. More specifically, the probability of successfully receiving the status messages from all vehicles around the tagged vehicle, the probability of receiving the safety (or emergency) messages from all vehicles up to a certain distance behind the accident scene, and the delay for that safety messages to reach their intended recipients will be studied assuming unsaturated conditions. Fig 1 Shows the channel access scheme for WAVE (Wireless Access in Vehicular Environment) access.

It is shown that the current specifications of the DSRC may lead to severe performance degradation in dense and high mobility conditions. Therefore, a new adaptive and mobility based algorithm (AMBA) is introduced to increase the system's reliability in terms of the probability of packet's successful reception and time delay of emergency messages in a harsh vehicular environment.

**II. RELATED WORK**

The MAC protocol of IEEE 802.11p [1] is based on the Distributed Coordination Function (DCF) of IEEE 802.11 which has been investigated extensively in the literature analytically and by simulations. Simulation based analysis of the IEEE 802.11p shows that as the network density increases, the system latency increases and the packet successful reception rate decreases [5]-[10]. To ensure a successful reception of emergency messages, [7] and [8] introduce an algorithm to control the load of periodic status messages. The channel access delay of the DSRC has been analyzed in [9] and compared with a self-organizing time division multiple access (STDMA) scheme which has been proved to be more suitable for VANETs’ real time applications. In [10], the authors propose a framework for sharing the DSRC between vehicular safety and non-safety applications. By assuming uniform distribution of vehicles on the road, their simulations show that non-safety applications may have to be severely restricted such that safety applications are not compromised especially in high density networks.

Many analytical models have been proposed to study the DSRC or in general the IEEE 802.11 MAC protocol. Although DSRC is based on IEEE 802.11 and EDCA, the unicast analytical models for IEEE 802.11 [11] and EDCA

Frequency (MHz)	5850	5855	5865	5875	5885	5895	5905	5915	5925
Channel number	Guard band	172	174	176	178	180	182	184	
Channel usage	Guard band	SCH	SCH	SCH	CCH	SCH	SCH	SCH	

(channel access scheme for WAVE access)

Fig 1. Channel access scheme for WAVE access

[12][13] cannot be used for broadcast communication mode in IEEE 802.11p because no ACK is communicated. Therefore, the transmitter cannot detect a collision from a successful transmission. In [14] a one dimensional Markov chain has been used to calculate the delay and reception rate in VANETs without including the delay in each stage due to busy channel. The authors in [15] analyze the DSRC based on the average delay for each access class without taking into account the backoff delay. An analytical model that accounts for the mutual influence among nodes in a multichannel environment and the broadcast message frequency has been proposed in [16]. In this model they assume static distribution of vehicles on the road with no hidden terminals. Moreover, they did not take into account how the vehicle speed affects the network density and hence there is a need to throttle the message transmission frequency in order to increase the successful reception rate. In [17], an analytical model for the performance of delivering vehicular safety messages is proposed without taking into account the mobility of vehicles. This model considers only the neighbourhood of a single Roadside Unit (RSU) operating in a non-saturation traffic regime. A two-dimensional Markov chain is used in [18] to model the impact of the differentiated AIFS on a stationary vehicular scenario in an urban intersection. They assume fixed

number of vehicles within the range of the transmitter and did not include vehicles mobility in their model. In [19] and [20], the authors study the saturation performance of the broadcast scheme in VANETs taking into account the consecutive freeze situation of the backoff counter. They assume saturation conditions, stationary distribution without considering the impact of vehicle mobility on the system performance. In [21], an analytical model for delivering safety messages within inter-vehicle communication (*IV C*) is derived. They assume a perfect channel access and have not accounted for the hidden terminal problem, collision probability and vehicle mobility. The authors in [22] study the performance of IEEE 802.11p based on the delay of status packets by modeling each vehicle as an M/G/1 queue with an infinite buffer without taking vehicle mobility into consideration. In [23], the authors analyze the effect of different sets of data rates and communication ranges on the performance of the DSRC safety applications. They derive the probability of successful reception without taking the busy channel probability in each back-off stage. They introduced a power control algorithm based only on the average channel occupancy to change only the used communication range. As the channel occupancy increases, they decrease the communication range to maintain an acceptable channel capacity.

The connectivity in VANETs has been studied in [24]-[26] based on the assumption that vehicles have a uniform stationary distribution without including VANET mobility. By assuming that vehicles positions are known by either simulation or observation, the authors in [27] present an analytical model for VANET’s multi-hop connectivity. A mobility model has been derived in [28] considering the arrival of vehicles to a service area as a Poisson distribution. The authors in [29] derive the probability of the end-to-end connectivity between clusters of vehicles distributed uniformly on the road. They introduce a new opportunistic packet relaying protocol that switches between data muling and local routing with the help of vehicles on the other direction. In contrast to our mobility model, all of these models do not consider how the speed of transmitters and receivers affect the connectivity and the packet reception rates.

In this paper we propose a new adaptive and mobility based algorithm (AMBA) for improving performance measures in VANET communication for broadcasting safety message to decrease delay.

**III. NETWORK MODEL**

In this paper, we consider a 1-D VANET model in a highway. The nodes have constant transmission ranges, and their mobility is neglected because they remain almost stationary within a message transmission time. We assume that the nodes enter the highway according to a Poisson process with the parameter  $\phi$  nodes per unit length of the highway. Thus, the location of nodes follows a uniform distribution. We will refer to nodes with or without a message to transmit as busy and idle nodes, respectively. A busy node is either transmitting a message or is in a backoff process. Two classes of message traffic are considered. The

first class is low-priority traffic, which arrives at the VANET according to a Poisson process with the parameter  $\lambda_0$  messages per vehicle per second. We assume that only idle nodes generate new messages. Thus, each node may have only a single outstanding message that waits for transmission. Let us define  $\lambda$  as the parameter of the Poisson message arrival rate per unit length of the highway, with all the nodes being in idle state. Then,  $\lambda = \phi\lambda_0$ . The second class is event-driven high-priority messages, which are generated by a randomly selected node such that at most one message of this type will propagate in the network at any given time. The arrival time of a message to the channel corresponds to the moment that it is passed to the MAC layer for transmission. The transmission time of a message for both traffic classes is exponentially distributed, and it is assumed that each node can have at most one message for transmission. At any given time, the number of concurrent transmissions may divide the network into alternating activity and inactivity regions, where in an activity region; there is at least one ongoing transmission. Let us define an interference sub region as the overlap area between the transmission ranges of two concurrent transmitting nodes in an activity region. We assume that a destination node can correctly receive a message, as long as it is not located in an interference sub region. Furthermore, if the transmitting nodes themselves are within the interference sub region, this interference is referred to as internal (otherwise, external interference), which are traditionally known as collision and hidden-terminal activities, respectively. Fig. 2 and Fig. 3 shows the hidden-terminal and collision activities.

#### IV. ADAPTIVE AND MOBILITY BASED ALGORITHM (AMBA)

There are many conflicting parameters that affect the system reliability and its success rate. Parameters like mobility model, communication range, link availability probability, Backoff process and Contention window and Probability of successful reception. Keeping these parameters with fixed values as specified in the standard [1] will result in undesired performance, especially in a harsh vehicular environment where vehicles are moving in a very high speed and their density on the road is changing very frequently. That is, in a matter of seconds, the vehicle density could change from light density to the jam scenario. Therefore, vehicles have to change their sending rate ( $\lambda_s$ ), communication range ( $R$ ) or (transmission power), carrier sense range ( $LCS$ ) and/or their minimum contention window size ( $W_s$ ) based on the situation on the road in order to increase the success rate and VANETs reliability.

Therefore, a new adaptive and mobility based algorithm (AMBA) in which vehicles change their parameters according to their density and average speed on the road, pertaining to the following assumptions, is proposed: 1) The vehicles know their current average speed ( $V_c$ ) and their maximum allowed speed  $V_{max}$  on the road. 2) The maximum communication range (or the maximum transmission power) is set to  $R_{max}$  and the minimum communication range is set to  $R_{min}$  which is used in the jam scenario. 3) The carrier sense parameter ( $\rho$ ) can take

three values  $\rho \in [1, 0.5, 0.25]$  when the average vehicle speed is [30%, 30 – 70%, 70%] of the maximum speed respectively. The values 30% and 70% are chosen here based on intensive simulations and they seem to work well as can be seen from the simulation results. 4) The vehicles status packet sending rate can take the values in the range of [1 – 10]. 5) The minimum contention window size  $W_s$  can take on values in the range [15 – 127] with a step size of 16. 6) The current used vehicle's average speed, range, carrier sense parameter, packet sending rate and the minimum contention window are denoted as  $V_c$ ,  $R_c$ ,  $\rho_c$ ,  $\lambda_{sc}$ ,  $W_{sc}$  respectively. Vehicles will execute the AMBA algorithm every  $T_{alg}$  seconds, where they sense the vehicle's density from their current average speed and compare it with the maximum speed  $V_{max}$ .

The pseudocode of the AMBA algorithm is shown as Algorithm 1 below. The smaller the current vehicle's average speed within the previous time period  $T_{alg}$ , the higher the vehicle density will be around that vehicle based on the proposed mobility model. The algorithm divides the range ( $R_{max} - R_{min}$ ) into ten steps. Each time, the vehicle speed is dropped by a tenth of its maximum speed  $V_{max}$ , it will reduce its range and set the other parameters accordingly.

The vehicle will calculate its delay ( $T_b$ ) from the time it was ready to transmit its status packet until the time the packet is transmitted. If the new value of  $T_b$  is higher than its previous one by  $\psi = 10\%$ , the vehicle will increase its minimum contention window size  $W_{sc}$ . On the other hand, if  $T_b$  is smaller than its previous value by  $\psi = 10\%$ , it will decrease its  $W_{sc}$ . Otherwise it will keep it the same. The carrier sense range is also set according to the sensed density. When the vehicle's density is high (average speed drops below  $30\%V_{max}$ ), the carrier sense range is decreased in order to decrease the waiting time for each vehicle to send its status message. Although decreasing the carrier sense range will increase the hidden terminal area, the algorithm deals with this problem by decreasing the communication range. Therefore, the AMBA algorithm allows more vehicles to send their status messages within the synchronization interval with high successful reception rate.

Algorithm 1 Adaptive and Mobile Based Algorithm (AMBA) to set VANETs parameters according to the vehicles density on the road.

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Initial setup
 $R_c \leftarrow R_{max}$ 
 $\rho_c \leftarrow 0.25$ 
 $\lambda_{sc} \leftarrow 10$ 
 $W_{sc} \leftarrow 15$ 
for Every  $T_{alg} = 10 \cdot CCI$  seconds do
if  $V_c < V_{max}$  then
 $i \leftarrow \lfloor (V_c / V_{max}) \cdot 10 \rfloor$  { $i$  represents a step from 1 to 10 in which the current speed falls in compared to the max. speed}
 $R_c \leftarrow R_{min} + i \cdot ((R_{max} - R_{min}) / 10)$  {use a new range based on the step  $i$ }
 $\lambda_{sc} \leftarrow \max(i, 1)$  {use a new sending rate based on the step  $i$ }
if  $i \leq 3$  then
 $\rho_c \leftarrow 1$  {in high density,  $LCS = R$ }
else

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if  $i \leq 7$  then
 $\rho_c \leftarrow 0.5$  {in medium density,  $R \leq LCS \leq 2R$ }
else
 $\rho_c \leftarrow 0.25$  {in low density,  $LCS \square 2R$ }
end if
end if
if  $Tb_{new} > (1 + \psi) \cdot Tb_{old}$  then
 $W_{sc} \leftarrow \min(W_{sc} + 16, 127)$  {if the time delay increases, i.e.
more contention, increase  $W_s$ }
else
if  $Tb_{new} < (1 - \psi) \cdot Tb_{old}$  then
 $W_{sc} \leftarrow \max(W_{sc} - 16, 15)$  {if the time delay decreases, i.e.
less contention, decrease  $W_s$ }
end if
end if
end if
end for
    
```

### V. CONCLUSION

Safety message broadcasting is the primary concern of VANET to improve security. Along with security other performance measures has to be considered. To increase security and performance measures a new algorithm is proposed.

The current DSRC specifications may lead to undesirable performance under harsh vehicular environments. Therefore, a new adaptive algorithm, Adaptive and Mobility Based Algorithm (AMBA), is introduced to enhance VANET's reliability. By using the AMBA algorithm, vehicles are able to estimate the vehicle density and change their transmission parameters accordingly based on their current average speed to enhance VANETs' performance.

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