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Performance Analysis and Enhancement of Short Range Communication For Dense Vehicular Environment

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Abstract

In this paper an analytical model for the short range communication for safety application in vehicular network is proposed. The performance of short range communication will be affected due to the increased number of vehicles and high mobility. Therefore, an adaptive mobility algorithm (AMA) is introduced for increase the probability of successful reception thereby increases the reliability of the system. In this model, the receiver which is present in the vehicle enables the probability of receiving signal status, safety information, and the coverage distance are taken in to account. The mobility model includes the safety rules to follow-on the vehicle, density of the vehicle, various safety zones, and the speed of vehicle. We also consider the impact of increased number of vehicles moving around the transmitter, channel fading, transmitted packet collision by neighbouring vehicles, etc. The proposed algorithm is validated by simulation using real environment and the results shows that the performance of AMA is greater compared to other algorithms.

Keywords: adaptive mobility algorithm, system reliability, short range communication, mobility model, road side unit (RSU), vehicular communication

Introduction

In recent cases accidents are occurring frequently due to reckless driving. The vehicles are important in our day- to- day life. Most of the people will drive the vehicle very fast so rash driving affect the other people who use the road side .Rash driving is also said to be dangerous because a little slip may endanger the life .This increases the chance of accidents .The research provides a description on development of a vision sensor for detecting shock waves. This is considered to be the main factor for the accident occurring in highways. Analysing the experiment with image sensor detects that an error may occur in the arrival time information which is provided to the driver. To solve this problem, propagation of arrival time is determined by using prediction technique. By using this technique, the error is reduced and the prediction rate is increased by5% [1]. In order to avoid the frontal collision in the urban highways wireless sensor network is proposed for allowing the vehicle to track any activity that creates an electrical signal. A small low-cost sensor is used for the traffic safety solution and therefore it replaces the infrastructure based system in the urban and suburban areas. It can also serve as an alternative solution for the vehicle which is not well equipped with aboard computers [2]. To monitor toxic gases such as CO, LPG, and alcohol inside the vehicle and to indicate alerts during critical situation, using GSM an alert message is sent to the authorized person. This system also detects the obstacles present in front of the vehicle using IR sensor and stops the vehicle if any obstacle is detected [3]. A smart display controller is implemented to reduce vehicle speed and crash alert which works on embedded system. It also alerts driver with an alarm in speed unit zone and if speed is not controlled, it automatically sends the information about the vehicle through a message to traffic police system even if a vehicle meets with an accident.

A GPS receiver is used to identify the latitude and longitude location and sends this information to police system through GSM [4]. A real time visual tracking system with a novel feature based on vehicle tracking algorithm is designed for the vehicle safety applications. This algorithm is capable of detecting the multiple moving objects automatically. Thus the experiment successfully tracks the front vehicles and provides the information on collision warning [5]. In India, since 2011 a whole of 4, 97,686 road accidents were reported due to lack of speed control in vehicle. Accidents may also be prevented by improving quality of road infrastructure and safer vehicles. In this paper Intelligent Speed Adaptation has been implemented to prevent the road accidents. This proposed system works based on colour strips which is marked on highway road and also in road where speed limit is required [6]. Accidents are occurring day to day due to poor indication of signboard, drowsy state and drunken state of drivers. This method is also implemented to decrease the fatality rate. Different types of sensors like eye blink sensors, alcohol sensors; heart beat sensor has been used to monitor the activities of drivers [7]. The advancement in technology and microcontroller has been designed to prevent accidents occurred due to negligence of drivers. To grab the attention of the drivers while driving near safety zones is done by using RFID. An electronic display controller is placed to view the zones which work on embedded system. It is also designed to fit into the vehicle dashboard. This system also reduces number of road accidents at speed breakers and also driver’s negligence towards traffic signals [8].

Table 1: Various safety zones and corresponding coded signals

Safety Zones	School	Hospital	Market Places	Temple	Industrial Areas
Allotted Coded Signal	0001	0101	1010	0111	1001
Speed Limit (km)	10	10	15	15	20

The fuel efficiency is achieved by smart driving aids with no increase in the journey time or reduction in average speed. This result is obtained by limiting the use of lower gears (facilitated by planning ahead to avoid unnecessary stops) and an increase in the use of the fifth gear (as advised by the in-vehicle system). Changes in driving patterns were also observed such as, an increase in mean headway to 2.3 s and an almost threefold reduction in time spent travelling closer than 1.5 s to the vehicle in front. It shows that there could be a significant improvement in driving behaviour in real world on real road with real users by keeping the driver's requirement in mind [12].

A discussion on the state of the art, detail common performance metrics and benchmarks, and provide perspective on future research directions in the field of on-road vision-based vehicle detection, tracking, and behaviour understanding. There has been a vast development in the field of real time vehicle detection and tracking from its infancy to maturity. Monocular and stereo-vision domains filter analysis, estimation, and dynamical models are discussed. A novice model of vision based vehicular detection is developed using spatiotemporal measurements, trajectories, and various features to characterize on-road behaviour [13]. A robust method is implemented for lane-detection in real world environment. A navigation filter which corroborates various guidance technologies such as Global Positioning System(GPS), inertial measurement unit(IMU), camera, and light detection and ranging for achieving lane-level positioning in environments where standalone GPS can suffer or fail. The advantage of this filter over the GPS/INS system is that it greatly enhances the robustness of the integrated system. Measurements from the camera and lidar are used in two lane-detection systems, and the calculated lateral distance (to the lane markings) estimates of both lane detection systems are compared with centimetre -level truth to show decimetre -level accuracy. Parameters such as satellite geometry, number of satellites, and loss of lateral distance measurements from the camera and lidar systems are taken into consideration for designing the filter [14]. SmartRevoc, a novel revocation architecture which is advancement to the present certificate revocation list (CRLs). SmartRevoc especially solves the main challenges of CRL distribution in vehicular networks: CRL size, dissemination speed, and preservation of location privacy. Basically security and privacy requirements in vehicular networks are typically addressed using a Public Key Infrastructure (PKI) and pools of pseudonymous certificates for each vehicle. Messages are signed with these certificates, so that misbehaving vehicles can be excluded from the network by disseminating Certificate Revocation Lists (CRLs). Two hash chains method is used to compute CRLs on vehicles, substantially reducing communication overhead [15].

If both the transmitter and receivers are under moving condition then the collision will increase and the successful reception of information will decrease so that the RSU is included for reducing such problems. In this paper, various parameters like dense vehicle environment, collision probability, and hidden terminal problems etc are taken into account. The remainder of this paper is organized as follows: section 2 describes the proposed system model; section 3 describes the parameter estimation; section 4 explains the simulation results and validation; and finally, conclusion is discussed in section 5.

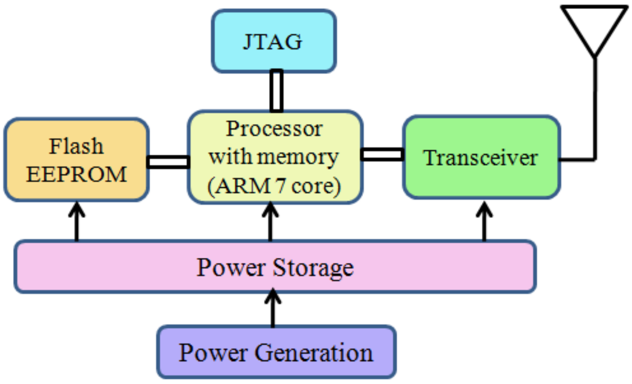

Figure 1: Bock diagram of a RSU

Proposed System Model

The proposed vehicle model consists of three important units: 1) road side unit (RSU) and 2) vehicle control unit (VCO) and 3) master control unit (MCU) for safe driving in various speed limit zones and traffic junctions. This system is also designed to avoid the accidents due to reckless drivers and also provides safety to the people using the road side unit. The vehicle control unit which is present inside the vehicle receives the information from the road side unit and provides the control information to the vehicle. The VCO also get connected to various zones (refer table I) according to the movement of vehicles in the various zones. A display system has been interfaced with the system which also provides information about different kinds of zones (school, hospital, market, temple, industrial areas, etc). The VCO is active only whenever it is getting connected to the RSU and other time it is sensing other signals for safety. The road side unit computes and provides the next hop to the vehicle. The block diagram of RSU is shown in fig. 3.

The proposed system is mainly focussed in order to avoid accidents in road side so that the RSU is also placed in the various zones to limit the speed of the vehicle. The received signal is processed by VCO and works according to the type of zone and avoids reckless driving. The micro controller, ARM 7 core is placed in both the units which also identify the type of zone where the vehicle passes through. The controller also commands to display the status of the zone through display system as well as an alert will be enabled for driver's attention. The road side unit passes a RF beam for understanding various speed limit zones.

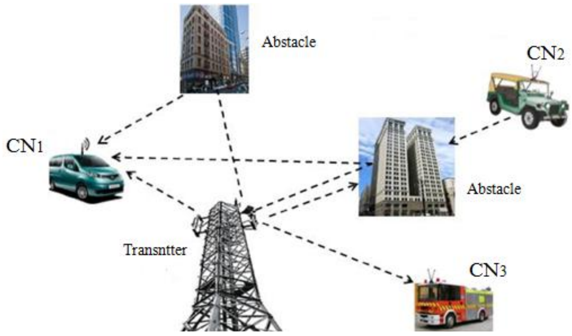

Figure 2: Communication with moving vehicles

Different unreliable phenomenon such as multipath, shadowing, and path loss are shown in fig. 5. The node CR1 is receiving the signals from multipath and affects short term Rayleigh fading. The fluctuations present in the received signal leads unreliable communication. The node CR2 is moving behind gigantic buildings present inside the city and it will be affected by long term fading. The node CR3 is present outside the coverage area of the primary transmitter. Due to long distance between the CR to the transmitter, the power level of the signal is very low and it will produce interference. These practical difficulties reveal that the communication nodes should be highly robust and reliable to channel impairment and it should be capable of detecting low power level. These parameters produce lot of challenges and problems to cooperate multi user channel to deployment of new algorithms.

Table 2: Various access classes and its parameters [9]

Access Class	Access Number (AN)	CWmin	CWmax
Background traffic	0	15	1025
Best effort	1	7	16
Voice	2	3	7
Video	3	3	7

In real road travel the above phenomenon are present and a huge number of vehicles will move at peak hours. The safety and status information are always broadcasted by the RSU. The above information is sometimes lost due to path loss, synchronization problem, and the mobility of receivers. Based on IEEE 802.11p, no acknowledgement will be transmitted from the vehicle after receiving the broadcasted packet by the RSU. The RSU can't able to detect the failure packet for retransmission. To overcome these problems we propose a new analytical model for increasing the reliability of short range communication. Here we are considering multipath fading channel for communicating the vehicle to RSU and RSU to MCU. The probability of successful reception from RSU to vehicle, the probability of safety messages or emergency information, and delay to reach the destination are studied. The performance of short range communication is not up to the mark under high mobility condition. Therefore, a new AMA is introduced to increase the reliability of communication under dense vehicular environment.

Parameter Estimation

A. Calculation of Communication Range

There are two types of messages that a vehicle develops for the safety applications: 1) warning message (event driven) and 2) status messages. Warning messages contain safety information and status message contains vehicle's state information such as speed, direction, acceleration, and position of vehicle. Four different access classes and its priority based on IEEE 802.11p is presented in table 2. From the table 2, No3 is used by emergency messages as it has the highest priority while the status messages use No1. In this model, the status messages are sent at a rate of δr. Therefore the length of the synchronization interval (SI) is SI=1/δr [10]. Each vehicle will randomly choose a slot within the SI to transmit its status packet, whereas emergency packets are sent only during emergency situations. We assume that the transmitter emits a power Pt, and receives the signals if its power is higher than the threshold P_{th}. The communication range is also a random variable because fading is a major characteristic in huge vehicle movements. The mobility model and the communication range are derived to study the distribution of vehicles on the road that will affect the available link and time to hold the link. It also determines the population size (number of vehicles) of vehicles within the coverage area transmitter's range and the number of vehicles in the two link areas.

Vehicular network have many moving and stationary objects that can block scatter or reflect the signal. The Probability density function of the received signal with power p(x) of a Nakagami channel mode [20] as

$$P(x) = \left(\frac{d}{P_r}\right)\frac{x^{d-1}}{\lceil(d)} ee^{-dx/P_r}, for\ x \geq 0 \tag{1}$$

Where $P_r = P_t$ (k/r^{α}) is the average received power, Γ (.) is the gamma function,α is the path loss exponent, r is the distance. k=$G_tG_r(v/4\pi f_c)^2$, V is the velocity of light, f_c is the carrier frequency, G_t and G_r is the gain of the transmitter and receiver respectively.

The Cumulative Distribution Function (CDF) of the communication range can be calculated where the received power is greater than the threshold P_{th} as

$$F(r) = 1 - \frac{1}{\Gamma(\mathrm{d})}\int_{P_{th}}^{\infty} p(x)\mathrm{dx}\ =\ 1 - \mathrm{p}(\mathrm{x} \geq \mathrm{P_{th}}) \tag{2}$$

Substitute (1) in (2) and the CDF can be written as

$$F(r) = 1 - \frac{1}{\Gamma(\mathrm{d})} \int_{\frac{d\mathrm{P_{th}}}{P_r}}^{\infty} u^{d-1}\ e^{-u}\ \mathrm{d} \tag{3}$$

Now CDF can be written as

$$F(r) = 1 - \frac{1}{\Gamma(\mathrm{d})} \sum_{j=0}^{d-1} \frac{(d-1)}{(d-1-j)!} \left(\frac{d\mathrm{P_{th}}}{P_r}\right)^{\mathrm{d}-1-\mathrm{j}} e^{-\frac{d\mathrm{P_{th}}}{P_r}} \tag{4}$$

The average value of communication range C_R can be written as

$$C_R = \int_0^{\infty} \big(1 - f(x)\big) dx \tag{5}$$

Substitute (4)in (5)and integrate

$$C_R = \frac{1}{\alpha\Gamma(\mathrm{d})} \sum_{j=0}^{d-1} \frac{(d-1)}{(d-1-j)!} * \Gamma\left(\mathrm{m} - 1 - \mathrm{j} + \frac{1}{\alpha}\right)\left(\frac{m\mathrm{P_{th}}}{P_t}\right)^{-(1/\alpha)} \tag{6}$$

B. Mobility Based Algorithm

Since assuming fixed values to many conflicting parameters, it affects the performance and reliability of the system, particularly in harsh vehicular environment where vehicles are moving in a very high speed and their density of vehicle is changing very frequently. In peak hours, the density of vehicle could change from lesser density to greater density. Vehicles must constantly change their sending rate δ_s, communication range R_c or transmission power, carrier sense range CSR, and/or their minimum contention window size W_s based on the situation on the road to increase the success rate and reliability.

Considering all the parameters and assumptions, the MBA is proposed for short range vehicular communication.

1) Each vehicle must know their current speed Sc and maximum speed for a specific road.
2) The status packet-sending rate of the vehicle in range of (1-10) and the contention window size in the range 15-18.
3) The minimum communication range S_{min} and maximum communication range S_{max} are used in the dense environment.
4) The average speed Sa, carrier sense parameter ρ_c, range R_c, packet-sending rate δ_s and the minimum contention window W_{cm} are used.
5) There are three values assigned for carrier sense parameter, such as 0.25 for the vehicle speed of 70%, 0.5 for the vehicle speed of 30-70%, and 1 for the vehicle speed of 30%.

For every't' seconds the MBA algorithm is executed by the vehicle in real world situation, where they sense the vehicle's density from their current average speed and compare it with the maximum speed.

C. Vehicle Mobility Model

The speed of a vehicle will affect the quality of received signal. In the real environment, a vehicle will move in and out of the communication range. The accidents can be prevented within a fraction of second enough to stop the vehicle. The proposed mobility model is created by using one-way high road segment [21]. The speed of the vehicle is uniformly distributed between the values S_{min} and S_{max} with mean $m = \frac{\text{Smin+ Smax}}{2}$and variance $\sigma^2 = (\text{S max} - \text{S min})2/12$. The total number of vehicles around the transmitter is N_t , the vehicle which are present in the interference region is Ni, the number of lanes are present in the road is N_l , and the total number of vehicle V_t , that crosses the particular point of a lane can be modelled by Poisson process, $V = \sum_{i=0}^{Nl} Vt$. The Probability of j_{th} vehicle (Ne_j = n) within the communication range by Poisson distribution as,

$$P_{CR}(N_{ej} = n) = \left(\frac{2V_i C_R}{n!}\right) e^{-\frac{2V_i C_R}{m}} \tag{7}$$

The server busy time can be calculated as

$$\text{SBT} = \text{E(T)} + \sum_{j=1}^{M(s)} C\, P_i \tag{8}$$

The random variable Y $=\frac{u_i}{u_k}$ is the ratio distribution, then the value is

$$\text{E(T)} = \text{E}[\frac{u_i}{u_k}]t_s - \frac{1}{v_i} \tag{9}$$

The Random variable has the value within the range between$\left({S_{min}}/{S_{max}}, {S_{max}}/{S_{min}}\right)$,

Therefore the PDF can be written as,

$$\text{F(Z)} = \begin{cases} \frac{1}{2(S_{max}-S_{min})^2}\left(S_{max}{}^2 - \frac{S_{min}{}^2}{Z^2}\right), \frac{S_{min}}{S_{max}} \le z \le 1 \\ \frac{1}{2(S_{max}-S_{min})^2}\left(\frac{S_{max}{}^2}{Z^2} - S_{min}{}^2\right), 1 \le z \le \frac{S_{min}}{S_{max}} \\ 0\ otherwise \end{cases} \tag{10}$$

D. Emergency Condition

When emergency vehicles such as ambulance, Fire services, etc are arriving or emergency situations such as an accident takes place in a particular lane, lane change has been analysed. If this type of vehicle is entering into the coverage area, it will send an emergency packet to the RSU and the RSU will broadcast the information to all the vehicles which are present within the coverage area. The emergency message packet is continuously transmitted until it reaches a particular distance which will be mentioned in the program itself. The emergency vehicle and its priority is given in table 3.

Table 3: Emergency vehicles and its priority

Emergency Vehicle	Ambulance	Fire Service	Police Vehicles	VIP Cars
Priority	1	2	3	4
Coded Signal	1000	1001	1011	1110

The probability of receiving message will be P_{tr}, the average waiting time is T_w. Therefore the emergency message to reach the particular distance D is (D/d). The average travel time for the emergency message is

$$T_{EM} = \left\lfloor \frac{D}{d} \right\rfloor \left(E[T_e] + \frac{T_w}{P_{tr}} \right) \tag{11}$$

Where $E(T_e)$ is the average delay for the emergency packet to be transmitted.

Model Simulation and Validation

To simulate the proposed model, the Nakagami-m propagation model has been used and the average power P_v, and fading factor k has been considered. The same approach is performed by Torrent-Moreno et. al [23] using maximum-likelihood estimation for road vehicle communication. They analysed different vehicle scenario and found that if distance of the receiver increases, then P_v get reduced. On the other hand fading factor k=1,k=1.5,k=3 is selected for long, medium and short distance between the transmitter and receiver respectively.

Table 4: Various parameters and its values used in simulation

Parameters	Value
Number of road lane N_L	2
vehicle's speed	80-100Km/h
vehicle arriving rate V_i	1 vehicle/sec
Communication range C_R	400 m
Modulation technique	BPSK
Data rate	2 Mbps
Header and message size	64 , 512 bytes
Status packets rate	10 packets/sec
Slot time	12 micro sec
Received power threshold P_{th}	3.13exp(-13) W
Transmission power P_t	20 mW
Propagation delay	1 micro sec
Antenna height	1 m

To validate the model, ns2 simulator [24] with real time mobility model has been used. The vehicle speed from 80-100km|h and a four lane one-way directional highway of length 2km is considered for simulation. The receiver of NS_2 simulator can receive the signal only if the level is greater than the threshold P^{th}, so the transmitter power is set according to equation (6). Different parameters used for simulation is shown in Table 4.

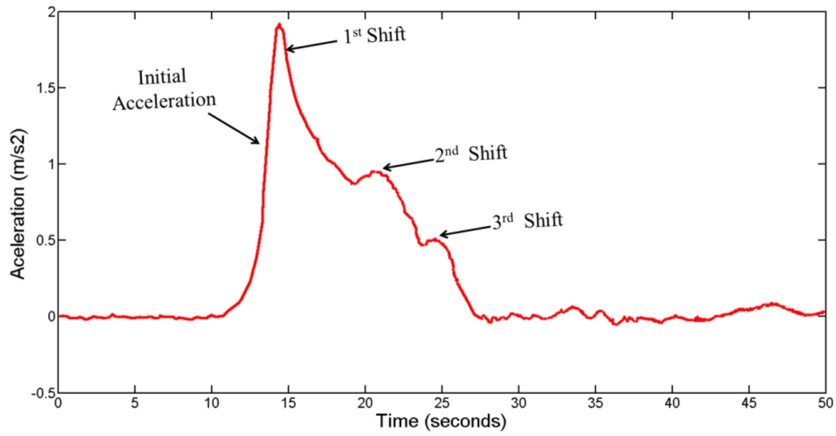

Figure 3: Vehicle gear shift analysis

Frequent change of gear in and out will lead to engine problems. The gear shifts can be easily recognized by using smart phones to avoid rash driving in dense or safety zones. The vehicle gear shift analysis is shown in fig. 3. From fig. 3 one can easily calculate the velocity by integrating the values of graph. After calculating the velocity, the speed of vehicle can be calculated for each shift.

The drivers should know the behaviour of vehicle and it provides benefit for road users. The other drivers habitually follow the other vehicles movement and it leads to unforeseen road accident. The safe acceleration and deceleration and sudden acceleration and deceleration are shown in fig. 4. The driver's direct control of the vehicle can be easily estimated from the measured x-axis and y-axis data of the accelerometer. Fig. 4(a) shows the safe acceleration and deceleration mode and the total slop in this case is less compared to sudden acceleration mode in fig. 4(b). On comparing both the safe and sudden acceleration modes, sudden acceleration and deceleration approach 5.5 m/s^2 higher acceleration than safe acceleration mode.

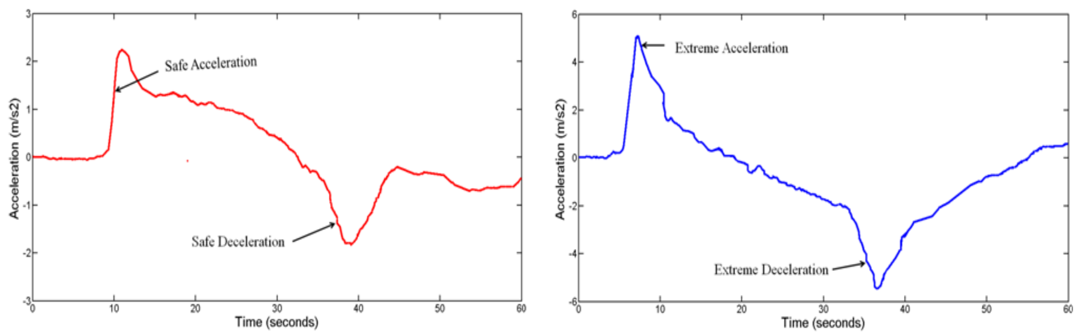

Figure 4: Acceleration and deceleration performed by two cases (a) normal acceleration and deceleration (b) Sudden acceleration and deceleration.

To compare the mobility model of the proposed system, the Poisson distribution mobility model is taken and follow-on safety rules are not considered. The comparison between vehicle arrival rate and the average number of vehicles present in the transmitters range is shown in Fig. 5. From Fig. 5, we can observe that the proposed mobility model accurately predicts the number of vehicles present in the coverage area of the transmitter than other models which is only used in Poisson distribution.

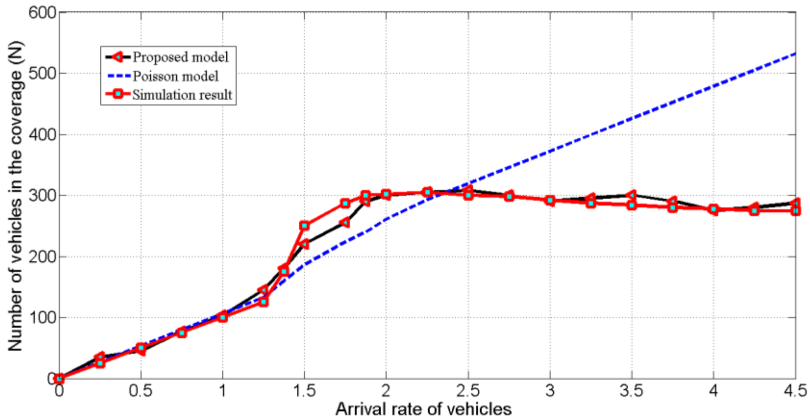

Figure 5: Number of vehicles present in the coverage area of the transmitter.

The density of vehicles and its success rate of three different scenarios are shown in Fig. 6. It can be seen that, the success rate decreases if vehicle density increases. It shows that all the vehicles cannot be able to access the channel at the same time.

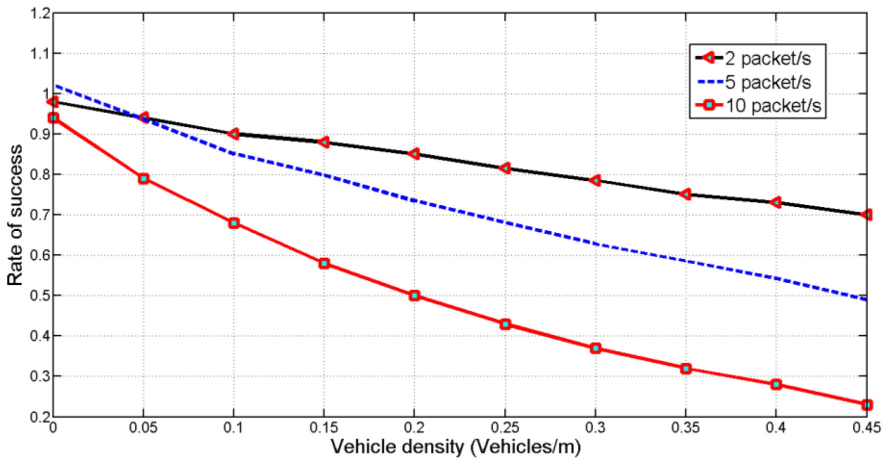

Figure 6: Success rate of various packet size and density of vehicle.

The time delay of various packet size based on vehicle density is shown in Fig. 7. From Fig. 7, we can observe that if vehicle density increases the status packet delay also increases. The chance of sending status message from the vehicle decreases as a result, the system reliability will decrease.

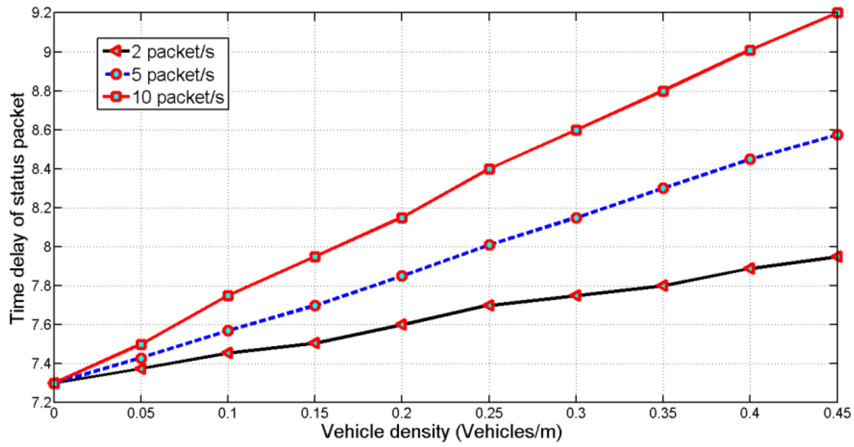

Figure 7: Status pocket delay for various packet size and density of vehicle.

When the emergency message is received by the RSU immediately it will broadcast to the other vehicles which are under this coverage. The packet travel time with respect to vehicle density is shown in Fig.8. From Fig. 8.we can observe that the travel time of the proposed method based on equation (11) is lesser compared to other methods. The success rate of emergency message based on the density of the vehicle is shown in Fig. 9. The delay time of emergency message until it reaches the destination is determined by using AMA algorithm and it is compared with the adaptive traffic beacon (ATB) in [22]. From Fig. 9, we can observe that it will increase the delay but the success rate is much higher under heavy density vehicles. Also it states that the system reliability increases dramatically adapting new algorithm.

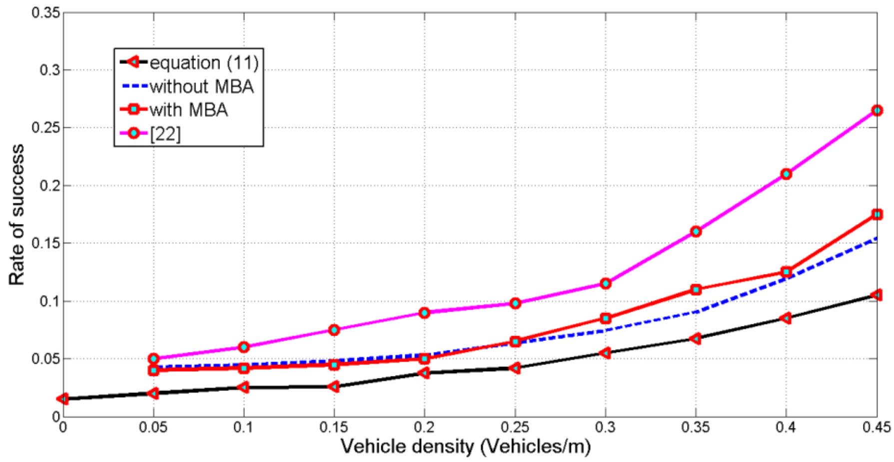

Figure 8: Emergency message travel time and density of vehicle.

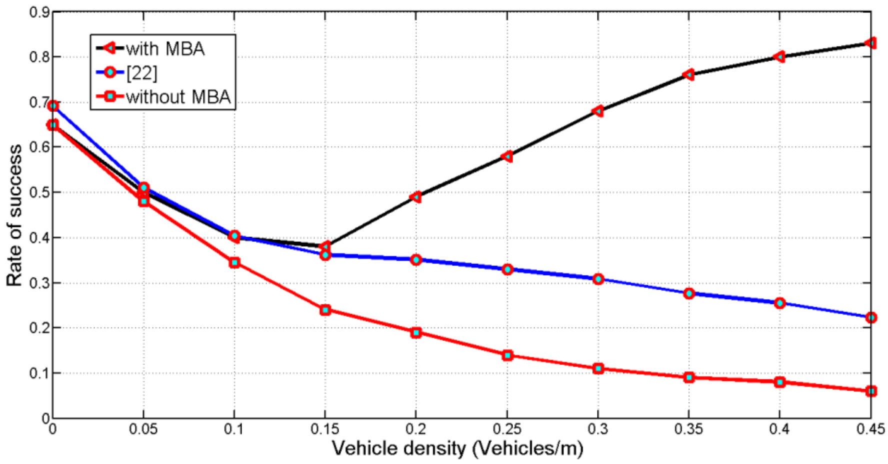

Figure 9: Success rate of emergency packet with vehicle density

Conclusion

In this paper, for increasing the reliability of short range communication system, a mathematical model is presented. It is based on the mobility model and estimates the communication range, success rate of transmission, delay time of emergency packet and status packet by using different rules. The mobility model follows different safety rules to follow-on the vehicle, various safety zones, density of the vehicle, and the speed of vehicle. The impact of increased number of vehicles moving around the transmitter, transmitted packet collision by neighbouring vehicles, channel fading, etc are considered for estimating various parameters. The vehicles are transmitting the status packet with in the SI and the coverage area and the successful rate is shown mathematically and by simulation. The performance of current short range communication is undesirable under dense vehicular environment and it can be solved by introducing MBA algorithm. Both the analytical and simulation results show that the reliability of the proposed model is higher and the performance of MBA is higher than that of other algorithms.

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