On the Performance of Safety Message Dissemination in Vehicular Ad Hoc Networks

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Abstract

One of the most promising and critical application of vehicular ad hoc networks (VANETs) is improvement of the road traffic safety. Currently there is a growing belief that putting an 802.11-like radio into road vehicles could help the drivers to travel more safely. Although research in this field is in preliminary stage, some simple implementations are quite promising; to the best of our knowledge there is no comprehensive feasibility study in the literature. So, as a first step, in this paper we investigate the feasibility of beacon safety message dissemination in VANETs through extensive simulation study. Vehicles are supposed to issue these massages periodically to announce other vehicles about their current situation and use received messages for preventing possible unsafe situations. We evaluate the performance of some simple protocols by the means of quality of service (QoS) metrics like delivery rate and delay and take special attention to reliability and fairness requirements of safety applications. Our results show in spite of global interest, safety applications in VANETs encounter severe challenges which should be addressed properly in the future research. We believe that to become a reality, this issue needs much more research, industry and government support.

I. Introduction

Vehicular Ad-Hoc Networks (VANETs) are special case of Mobile ad Hoc Networks (MANETs), where wireless-equipped vehicles form a network spontaneously while traveling along the road. This sort of network does not need any infrastructure and connection links between nodes, are available just when they are adjacent. Direct wireless transmissions from vehicle to vehicle make it possible to communicate even where there is no telecommunication infrastructure such as the base stations of cellular phone systems or the access points of wireless dedicated access networks, as it has been required in previous Intelligent Transportation Systems (ITS) [1,2].

This new technology has been attracting lots of interest in the recent years for Intelligent Transportation Systems (ITS) and also leads to joint efforts of governments, standardization bodies, car manufacturers, universities and research centers in several national/international projects. The US FCC has allocated 75 MHz of spectrum in the 5.9 GHz band for Dedicated Short Range Communication (DSRC) to enhance the safety and productivity of the nation's transportation system [3]. The FCC's DSRC ruling has permitted both safety and non-safety (commercial) applications, provided safety messages are accorded priority. The USDOT and IEEE have taken up the standardization of the associated radio technology Wireless Access for Vehicular Environments (WAVE), now described as IEEE 802.11p [4]. In addition some other projects outside of US like PReVENT project [5] in Europe, InternetITS [6] in Japan or Network on Wheels [7] in Germany are aimed to solve existing challenges. So in a near future, vehicles could benefit from spontaneous wireless communications to drive safer.

Although many decisions have not been taken yet, according to FCC frequency allocation we can categorize two main classes of applications for vehicular ad hoc networks. The first one which was mentioned above is to improve safety level in the roads, and the second, which is predicted to grow very fast in the near future, is commercial services i.e., comfort applications.

In comfort applications, the goal is to improve passenger comfort and traffic efficiency and/or optimizing the route to a destination. Examples for this category are: traffic-information system, weather...
information, gas station or restaurant location and price information, and interactive communication such as Internet access or music download.

However, safety applications aim to increase the safety of passengers by exchanging safety relevant information via inter-vehicle communication (IVC). The information is either presented to the driver or used to activate an actuator of an active safety system. Example applications of this class are: emergency warning system, lane-changing assistant, intersection coordination, traffic sign/signal violation warning, and road-condition warning. Applications of this class usually demand direct vehicle-to-vehicle communication due to the stringent delay requirements. Regarding to special type of each application, safety messages could be categorized in two groups: periodic beacon safety messages and event announcing safety messages. In the former the in-danger vehicle issues some warning messages. These messages have some sort of preventive role against possible incident. Each vehicle tries to inhibit the unpleasant events by analyzing those messages using own active safety system and also their information can be used by other (non-safety) applications (e.g., traffic monitoring) or protocols (e.g., routing). The latter includes some messages which a vehicle issues when it detects an unsafe situation, e.g., a car crash, icy surface, etc. In other word event announcing messages are issued in response of an unsafe situation but the preventive messages are issued periodically by all the vehicles and they are not shown any events necessarily.

Although there are some studies for simplified cases (which will be reviewed in the next section), to the best of our knowledge, there is no comprehensive study for investigating the feasibility of safety message dissemination in real-life vehicular environments. So as a first step, in this paper we conduct extensive simulation study to evaluate existing communication challenges in vehicular ad hoc networks for dissemination of periodic beacon safety messages, while we are aware of much other effort needed in other fields like software development, database engineering, etc., to have the ideas implemented in real-life. During our study we show how feasible safety message dissemination is, and also some metrics determining quality of service (QOS) of safety messages like delivery rate and delay have been used for presenting our results and evaluate fairness and reliability of the protocol. We would study the effects of three parameters on quality of service metrics including a) transmission range (transmitter power level), b) message transmission interval and c) packet payload size. We show that there are some optimum (sub-optimum) set of values which lead to a higher quality of service for our simple message dissemination protocol.

The rest of the paper is structured as follows. Section II reviews the relevant literature. Section III is the problem definition and also introduces our simulation set-up. We show some of the existing challenges in section IV and in the section V some methods to amend those challenges are presented. Finally, the paper will be concluded in section VI accompany with some directions for future works.

II. RELATED WORK

Vehicular ad hoc networks tend to be very challenging and a comprehensive survey about communication challenges is provided in [8] by the authors of the current paper. Broadcasting techniques and more specifically reliable broadcasting is a topic broadly investigated in the literature, but most of the previous works are about multi-hop broadcasting, i.e., flooding [9, 10, 11, and 12]. However to the best of our knowledge, one-hop broadcasting has not been considered so widely.

Some researchers tried to develop methods for increasing delivery rate when a source broadcasts data for all nodes in its neighborhood. In [13,14] authors propose, first, an analytical model able to find a transmission power that maximizes 1-hop broadcast coverage in CSMA environment and then an adaptive algorithm that converges to the beforehand fixed transmission power. Since their method considers only static scenarios and all nodes use the same transmission power, it may not be applicable in VANETs situation which nodes have high mobility and probably heterogeneous density.

The authors in [15], proposes a centralized power control methodology called FPADV to find the optimum transmission range for each node in a very dense VANETs environment. The final goal is to keep traffic load lower than a predefined threshold i.e., about half of nominal channel capacity. They consider static situation and their algorithm has not been simulated using well-known network simulators. However their research addresses periodic safety message dissemination, similar to what we consider in this paper.

Another category of research tackled the problem of reliable broadcasting by considering more deterministic MAC layers, instead of CSMA, trying to avoid collision. Reference [16] proposes an algorithm for safety message dissemination in VANETs. The mentioned approach needs the road to be conceptually divided into geographical sectors of relatively small length. This implies that cars must be able to determine the sector they are currently in (e.g. by utilizing GPS).
Thus each sector is allowed to transmit only in specific time slots. These time slots are allocated in such a way, that only sectors in a sufficient distance transmit in parallel. Also in a similar research, [17, 18] propose similar algorithms (but for general MANETs), which has some slight differences in slot allocation methodology. Although this algorithms present good results in simulation study, their real-life capability of implementation is in doubt, because of their need to centralize knowledge of all nodes in the network to allocate slot times properly. That is why the industrial community has based their preferred standard for VANETs on IEEE 802.11-like protocol called DSRC.

Recently in [19] an algorithm is proposed for increasing the delivery rate of one-hop broadcasting in mobile ad hoc networks. The authors argue that since there is not RTS/CTS dialogue in broadcast network, hidden terminal problem affects delivery rate severely (as it will be shown in the current paper too) we need to adopt another mechanism for increasing reliability of message dissemination. Their approach includes issuing negative acknowledge (NAK), whenever a node detects a collision. The sender then reacts to the NAKs by re-broadcasting the message. Of course, it seems that this algorithm is effective just for low-density ad hoc networks. In scenarios like what we have considered in this paper, it is possible that the NAKs, itself becomes an overhead for the network.

Probably the most similar piece of work to our study is performed in [20, 21], which the authors set up some simulation studies for investigating several characteristics of safety message dissemination in VANETs. [20] Discusses the effect of priority in MAC layer on broadcast delivery rate for one-hop broadcast under ideal and more realistic propagation models. Also reference [21] which is one of the first works in this field, studies the feasibility of exchanging safety message between vehicles based on IEEE 802.11a. Their scenario includes 4 lane highway (2 lane per direction) and medium traffic density (average distance =30m), then some quality of service metrics have been evaluated versus number of transmission.

Our work is different from above mentioned studies in several-fold. Firstly, we consider jammed traffic situation in a typical 8 lane highway (the example for such scenario could be the entrance of big cities in rush hours) in spite of some previous works which conduct study in medium size situations, so our case is more real-life. Secondly, we take special attention to reliability and fairness requirements of safety applications and lastly we study the effect of three parameters in quality of service of safety message dissemination protocols: a) transmission range, b) message transmission interval, c) size of data exchanged between vehicles. However, none of the previous works has considered them.

### III. PROBLEM DIFFINATION AND SIMULATION SETUP

As it is noted in the previous section, in this paper we address the challenges in dissemination of periodic (preventive) safety messages between vehicles in IEEE 802.11-like MAC layer, which has been accepted as base for upcoming DSRC standard. So, in our interested scenario, there are some vehicles positioned in a parallel highway sending some information about themselves to other neighbor cars. This information is used by the drivers and mostly by the active safety systems of the cars for preventing unsafe situations. Although many decisions about the information to be sent and the frequency of sending information and etc., has not been taken yet, we use some assumptions which seems to be logical (see table I). More comprehensive discussion about the reasons behind those numbers can be found in [21, 22].

As it is shown in Fig.1, in a typical jammed traffic, vehicles could be positioned very near to each other. Therefore when they want to send their information to neighbors, simultaneous sending collides with each other and the performance of the channel (in terms of delivery rate, delay, etc.) degrades severely. For example, in this figure cars positioned in column 4, depending on their transmission range could interfere with each other and also near side columns, (i.e., 5,6,3,2). There are many reasons to describe why this low performance network communication occurs.

Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA), i.e., 802.11 Link Layer protocol, is a totally asynchronous approach. Although, it is widely used in commercial applications, it is known for not being able to manage the medium resources very efficiently due to two well-known problems, i.e., exposed nodes and hidden nodes. Especially, in case of broadcast messages, the situation is more adverse.

As it is shown in our simulation, for high density situation like ours, even in unrealistic propagation models we could only count on about half of the nominal channel bandwidth. So, if we accept IEEE 802.11 MAC protocol as base for upcoming DSRC standard in inter-vehicle communication, which is
apparently has been done, some problems like low throughput are inevitable. However, there are some control parameters which we could alleviate the adversity. Some of these parameters including power level, data packet size, and transmission interval will be discussed in this paper through simulation study.

In order to study the performance of periodic message dissemination in a typical vehicular ad hoc network we conduct extensive simulation using GloMoSim library-2.03[23]. A simple one-hop broadcast algorithm was implemented and the functionality of the algorithm was examined in typical jammed traffic situation. Our scenario consists 1.5 kilometer of 8 parallel lanes highway with 5m width for each lane. We simulated a snapshot of traffic, so cars of each lane are separated by 20m from the following car. Therefore, there are 75 cars in each lane numbered from left to right (e.g., cars from number 1 to 75 in the first lane, 76 to 150 in the second lane and etc.) We make use of a deterministic radio propagation model, the two-ray-ground model, with a different communication ranges from 50m to 300m. Each node sends UDP packets of size 100 or 200 bytes every 100ms or 200ms with a jitter of 10%. Table I shows our simulation set up parameters.

### IV. EXISTING CHALLENGES

In this section we will show and discuss some of the most important communication challenges in safety message dissemination protocols using a typical scenario. These results help us to know problems better and then in the next section we introduce some methods to amend these problems through simulation study.

#### A. Low Reliability

In our first step we investigated the effect of distance on delivery rate, which we define as the number of received packet by each vehicle divided by the number of sent packet by other vehicle. This is important because of characteristics of MAC layer which is based on CSMA/CA. On the other hand, safety level of any message dissemination algorithms is affected by the distance which messages can propagate successfully. Fig.2 shows results for a typical scenario: 200m transmission range, message dissemination interval of 200ms and packet size of 200 bytes which is one of our good results in terms of delivery rate. Since, we want to emphasize the strict quality of service requirements in such safety applications; we bring delivery rates for all available connections (not only average values) and therefore each dot in figures 2, 3, 4 is related to a vehicle. As it can be seen, the delivery rates are decreasing dramatically by increasing the distance. The mentioned phenomenon is the worst in the border of transmission range (farther than 66% of transmission range for all simulated scenarios, i.e., 130m in below figure).

We can describe this border effect, mainly by well-known hidden terminal problem [24].

<table>
<thead>
<tr>
<th>Table I. Simulation setting parameters</th>
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<tr>
<td><strong>Propagation Model</strong></td>
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<tr>
<td><strong>Transmission Range(m)</strong></td>
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<tr>
<td><strong>Carrier sense range</strong></td>
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<tr>
<td><strong>MAC Type</strong></td>
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<td><strong>Channel bandwidth (Mbps)</strong></td>
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<td><strong>Traffic Type</strong></td>
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<td><strong>Period of message dissemination (ms)</strong></td>
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<tr>
<td><strong>Message size(byte)</strong></td>
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<tr>
<td><strong>Number of Vehicles</strong></td>
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<tr>
<td><strong>Mobility</strong></td>
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<tr>
<td><strong>Average Vehicle Distance (m)</strong></td>
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<tr>
<td><strong>Number of Lanes</strong></td>
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<tr>
<td><strong>Simulation Time (sec)</strong></td>
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<td><strong>Quality of Service thresholds (acceptable ranges)</strong></td>
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</table>
Figure 2. Broadcast delivery rate versus distance from the sender, for a typical scenario.

B. Poor Fairness

Another experiment which helps us to know the behavior of our simple message dissemination protocol is to show how fair each vehicle can have its message delivered, by other neighbor vehicles. This observation is mainly important due to MAC layer characteristics: when the medium is busy in some points, nodes have less chance to acquire the channel and so they will have poor delivery rate. This is very harmful in safety point of view, as some vehicles have out-of-date information about neighbors. Fig.3 shows the result for delivery rate for all 600 nodes (the scenario is the same one mentioned in section IV.A). As it can be seen there are 8 ranges where vehicles encounter lower delivery rates. These vehicles are positioned in the center of each lane (e.g., 30th - 40th vehicles in lane 1, 115th - 125th vehicles in lane 2 and etc.).

C. Acceptable Delay

Although multi-hop message dissemination could be used for safety messages, we argue that single-hop protocols would be much better in case of performance. Since, safety messages are aimed to be delivered to vehicles when they are near to each other, a simple single-hop transmission (which could be up to 500m with current technology) is enough for proper coverage. On the other side multi-hop transmission causes the medium to be saturated very soon, which leads to selective multi-hop transmissions [25]. As we use single-hop dissemination, the delay between sending and receiving of the messages are very low and for the most cases is below the acceptable value (i.e., 150ms) as it is shown in Fig.4, for our above mentioned scenario. Of course there are some exceptions in very saturated medium situations, which will be addressed in the next section.

V. IMPROVING THE PERFORMANCE

Observing such a low delivery rate and poor fairness, the important question would be how to amend the problem in a way we could get acceptable quality of service for safety applications? We also made some other assumptions for QoS requirements of safety applications, i.e., delays below 150ms and delivery rates above 90%. In mobile ad hoc network's literature there are some techniques for controlling channel capacity and end-to-end delay. In this paper, we investigate effect of three parameters, which we think are more relevant to VANETs, as follows:

Transmission range: The transmission range is the average maximum distance in usual operating conditions between two nodes. Since, radio transmissions are affected by the environment; it is quite difficult to predict the comportment of a system and to define a radio transmission range of a node in real-life. These are some measurable characteristics of the hardware which indicate the performance of the hardware in that respect. The transmitted power is the...
strength of the emissions measured in Watts (or mill Watts). Government regulations limit this power, but also having a high transmit power will also be likely to drain the batteries faster. Nevertheless, having a high transmit power will help to emit signals stronger than the interferers in the band. The sensitivity is the measure of the weakest signal that may be reliably heard on the channel by the receiver (it is able to read the bits from the antenna with a low error probability). This indicates the performance of the receiver, and the lower the value the better the hardware. Since, sensitivity is hardware's characteristic, we changed the power level in order to achieve different transmission range assuming two-ray-ground propagation model.

While higher transmission range results in longer distance awareness and is better in terms of safety concerns, it leads to larger interference domain. As a result packets are more likely to collide with each other and throughput degrades. Finding the optimum power level in order to higher capacity is a broadly studied topic in wireless literature, but most of the studies are addressing unicast situation in medium-density scenarios and low load scenarios [26, 27, 28]. There are quite limited studies for broadcasting environment which some of them reviewed in the section II. In this paper we changed transmission range from 50m to 300m. Then, we measure broadcast delivery rate and delay for each data transmission. We are aimed to investigate the effect of radio range on the mentioned quality of service parameters. Since in this work we study a snapshot of the system, we assume fixed and similar transmission rage for all vehicles.

**Transmission Interval:** this parameter is related directly to quality of service requirements of safety applications and should be determined based on vehicles speed, acceleration, driver reaction time, etc. For finding some nominal values we argue that a vehicle at high freeway speeds (90 mph) moves 2 meters within its lane in 50msec. This is usually not a significant movement at high speed. Thus messages repeating faster than once every 50msec are unlikely to provide significantly new information. On the other hand an update slower than once every 500msec is probably too slow. Driver reaction time to stimuli like brake lights can be of the order of 0.7 seconds and higher [21]. Thus, if updates come in slower than every 500msec, the driver may realize something is wrong before the safety system, which could be late for preventing unsafe situations.

While lower transmission interval could prevent unsafe situation in higher speeds and more unsafe conditions, it results in more saturated channel and so it is more likely to cause collision between simultaneous transmissions. To the best of our knowledge, finding the best value for this parameter has not been investigated analytically and even through simulation yet. In this paper, we used 100ms and 200ms for transmission interval which seems to be reasonable for most of the scenarios.

**Packet payload size:** To come up with a packet size value we consider that every packet will contain several parameters composing the state of the sender especially location, speed, road hazards, etc., according to some standards like SAE J1746 and MS/ETMCC [21]. Also, there should be some aggregated information about sender’s neighbors. In addition, by including security issues which are very important in inter-vehicle communication we can reach packet sizes ranging from 100 bytes to 500 byte for each message.

While more accurate information could provide safer situation, similar to what we argued for transmission interval, adding packet size may leads to more saturated channel and as a result more collisions. Nevertheless, due to nature of CSMA/CA it could be intuitively understood that the effect of increasing packet size on the performance is not as adverse as increasing transmission frequency. The reason for this is that the bottleneck for MAC protocol is channel acquisition. When a node could catch the channel, it would be able to send its data and some small differences in amount of data do not make noticeable difference. We will show that our experiments confirm this issue. In this paper we conduct our simulation by two typical values: 100 byte and 200 byte.

### A. Evaluation Metrics

For evaluating different simulation scenarios we have defined three QoS parameters, as follows:

**Single Hop Broadcast Delivery Rate:** (standing for the reliability) percentage of vehicles that successfully received a packet amongst all vehicles positioned at a distance equal to transmission range of the sender, at the moment that the packet is sent to the channel. This metric is one of the most important QoS requirements for any safety applications, since low delivery rate causes some vehicles unaware form the unsafe situations and results in some accidental events. Although, there is no standard reference for nominal values for this parameter we have assumed that only rates above 90% are significant for safety applications. It is to be noted, we do not consider mean value, but all values are realized to be more than 90%.

Regarding to criticality of our application, i.e., safety, we decided to present our results more accurate. Our parameters are: average delivery rate, standard deviation of delivery rates, and the maximum distance.
which, delivery rates are above 90%, called briefly effective range. The last parameter measures the distance from the sender, which could present delivery rates above 90%.

**Fairness:** one of distinctive characteristics of safety applications is their sensitivity to fairness. In spite of the most of the other application with the average delivery rate is important, in safety application due to criticality, the delivery rate for every connection (transmission) is needed to be higher than some thresholds. For making issue more clear, we investigate the fact that how fair each transmission (by a vehicles) gets delivered by neighborhood vehicles. We will show that some vehicles might not have enough chance to get their safety message delivered which cause other vehicles unaware about their status. Therefore, it increases the risk of occurring unsafe situations.

**End-to-End Delay:** Time between issuing a safety message from a sender to when it is received by vehicles in one hop neighborhood of the sender. Clearly, this parameter is also is very critical for safety applications to be monitored. Messages delivered lately could be useless as driver would not have enough time to react. Therefore low delay is necessary condition for a safety message. In this case, likewise, we assumed that just delays below 150ms are acceptable. For evaluating delay we use two parameters: average delay and maximum delay.

**B. Simulation Results**

In this section we present some results from our simulation study in order to investigate a simple one-hop broadcast protocol in terms of the above mentioned metrics. It is obvious that the behavior of any protocol highly depends on the channel load. Usually, saturated environments provide a challenge for every protocol. As it was described previously, throughput of the channel degrades dramatically due to substantial characteristics of CSMA/CA MAC protocol. So, we can just count on a load equal to half of the nominal channel capacity. In this simulation we selected three different scenarios as follows:

- Vehicles sending 200 bytes packets every 100ms. In other word each vehicle sends 10 packets every second, which each packet contains 100 bytes data. So we call it briefly 10P200B through this paper.
- Vehicles sending 200 bytes packet every 200ms. In other word each vehicle sends 5 packets every second which each packet contains 200 bytes data. So we call it 5P200b through this paper.
- Vehicles sending 100 bytes packets every 100ms. In other word each vehicle sends 10 packets every second which each packet contains 100 bytes data. So we call it briefly 10P100B through this paper.

Each vehicle imposes some load to the shared medium which might result in saturated channel. Table II shows approximate channel load in each scenario for different transmission ranges. For example for one of our scenarios the load can be computed as follows. It is to be noted for each vehicle the communication diameter (Comm.diameter in the following equation) is twice the communication range:

\[
8\text{[lane]}\ast\text{500 m[comm diameter]} \\
20\text{m[between vehicles]} \\
200[\text{vehicle / comm diameter}] \\
200[\text{vehicles}]\ast10[\text{pkt / s}]\ast200[\text{bytes / pkt}]\ast8[\text{bits / byte}]=3.2\text{ Mbps} \approx 53\%\text{ channel capacity}
\]

<table>
<thead>
<tr>
<th>Transmissions</th>
<th>50m</th>
<th>100m</th>
<th>150m</th>
<th>200m</th>
<th>250m</th>
<th>300m</th>
</tr>
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<tbody>
<tr>
<td>10P200B</td>
<td>11%</td>
<td>22%</td>
<td>33%</td>
<td>44%</td>
<td>53%</td>
<td>66%</td>
</tr>
<tr>
<td>5P200B</td>
<td>6%</td>
<td>11%</td>
<td>17%</td>
<td>22%</td>
<td>27%</td>
<td>33%</td>
</tr>
<tr>
<td>10P100B</td>
<td>6%</td>
<td>11%</td>
<td>17%</td>
<td>22%</td>
<td>27%</td>
<td>33%</td>
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Fig.5a shows average delivery rate versus transmission range. As it can be seen, by increasing the load of the scenario, the delivery rate decreases. On the other hand increasing transmission range results in more crowded channel and therefore lower delivery rate occurs. Comparing the second and the third scenarios (mentioned in the above table) could be interesting. According to this table, generated load for both scenarios are equal but from Fig.5a we can see their delivery rates are not similar. Actually the scenario with higher transmission interval and larger data packets behaves much better than the other, which sends smaller packets but, with smaller transmission interval. This phenomenon can be described by the nature of CSMA/CA MAC protocols, where nodes have to compete to acquire the channel. As a matter of fact, when the number of nodes grows, acquiring the channel would be bottleneck, so sending more packets causes the need for more frequent channel acquiring. That is why our simulation results show lower delivery rate for the third scenario.

Fig.5b shows standard deviation of delivery rates in terms of transmission range. We bring this parameter because due to random characteristics of the MAC protocol, delivery rates are likely to have different probabilities. As it can be conclude, standard deviation of delivery rate increases as the transmission
range increases and more crowded channel usually leads to high standard deviation.

The next result is to measure the range feasibility of our message dissemination protocol for safety applications. We consider a threshold equal to 90% for delivery rates to be significant for a typical safety application. So, we measured the distance which therein minimum delivery rates are above 90% (we call it effective range). As it can be seen from Fig.5c, the first scenario, i.e., 10P200B is the worse because of high saturated channel load. Although second, i.e., 5P200B and the third one, i.e., 10P100B impose similar load to the channel but according to reasons we brought before (see section IV.B ) the second scenario behaves much better and it has acceptable effective distance.(i.e., more than 150m).

Our next observation presents delivery rates for each vehicle, in order to see how fair medium is allocated for each vehicle to send its transmission. So the smoother curves, the better performance is. We are aimed to show how transmission range and transmission interval may affect the fairness of our single-hop protocol. Fig.6 shows the results for different transmission ranges with fix transmission interval and packet payload size, i.e., 200ms and 200 bytes respectively. In all cases there are 8 ranges (i.e., vehicles positioned in the center of each lane) which present lower delivery rate, However by increasing transmission range the difference is increased. In other words decreasing transmission range leads to more fair behavior. Also Fig.7 shows the effect of transmission interval on the fair behavior of the protocol. Our experiments show that by increasing the transmission interval, the delivery rate of vehicles gets flatter and therefore all vehicles have similar chance to announce others about their status. However, similar to what was argued beforehand, the effect of decreasing transmission interval is much more noticeable than the effect of increasing packet size.

In the next part of our study we evaluate our simple protocol in terms of End-to-End delay. Results are shown in Fig.8 for average delays. As it can be seen delays are generally below our acceptable threshold i.e., 150ms. The only exception is in scenario 10P200B where in transmission range equal to300m, the channel gets highly saturated and average delay goes up to 550ms. This is because in a busy medium each vehicle has to wait for a longer time trying to acquire the channel. Our observation shows similar results for maximum delays which have not been mentioned due to lack of space.

C. Discussion

Our results show that safety applications in
Figure 6. Delivery rate for all nodes for different transmission ranges (scenario: 5P200B)

Figure 7. Delivery rate for all nodes in different scenarios (transmission range= 150m)

Vehicular ad hoc networks which need hard QoS satisfaction, despite of their criticality and public concern have many severe technical challenges. The main cause of these challenges is MAC layer and its special characteristics of shared medium. Current trend toward using IEEE 802.11-like MAC layer in VANETs is mostly because of implementation concerns. However, using more deterministic MAC layers (i.e., TDMA-like) could be quite better in terms of performance.

We conduct our simulation with two-ray-ground propagation model which might not be model necessarily a good modeling of real-life propagation.
model especially in VANETs, where there would be many obstacles and also the speed of cars affects signal propagation. So, we should expect worse results in real implementation.

It can be understood from our work that accepting the necessity of MAC layer, we have some design parameters to amend the performance of the protocol, i.e., transmission range, transmission interval, packet payload size. We showed that there would be optimum set values for these parameters which leads to higher delivery rate (i.e., more reliability) and lower delay and in the same time longer distance for successful message dissemination and more fair delivery rate. We also showed that increasing transmission interval could lead to much higher performance. It suggests that one promising method for alleviating saturated medium and at the same time taking care about requirements of safety application could be sending more information but in lower frequency.

The difficulty becomes more appear when we consider this fact that the above mentioned design parameters are limited in two sides: In one side their value is limited by communication concerns and from other side they are limited by quality of service requirements of safety applications. For example, although in safety point of view the longer transmission range is better (due to larger announcement area), it results in saturated medium; therefore there should be some trade-off for determining transmission range. Also similar considerations are existing for transmission interval and packet payload size. In addition due to high vehicle mobility, it might be needed to adapt the mentioned parameters dynamically. Making the short, there are many challenges in both sides i.e., safety application and network performance, for finding optimum values.

It seems that ultimate answer for beforehand mentioned problem, would be an adaptive algorithms which controls the load of the channel by setting design parameters dynamically using feedbacks from the road and vehicles situation, considering communication and safety requirements.

VI. CONCLUSION REMARKS AND FUTURE WORKS

In this paper we conducted extensive simulation study for evaluating the performance of safety message dissemination in vehicular ad hoc networks. We set up simulation for a simple one-hop broadcasting scenario based on some typical and reasonable values in both safety applications and network performance points of view.

We found that in some jammed traffic situations performance of message dissemination would degrade dramatically, in a way that we would need to control the channel traffic by tuning some design parameters. We introduce three design parameters: a) transmission range, b) transmission interval and packet payload size. We used broadcast delivery rate and end-to-end delay for evaluating our study and considered different aspects, like reliability and fairness.

We showed that by increasing transmission interval, in spite of some advantages in safety level the channel gets saturated. Also, increasing transmission interval and decreasing packet payload size could help control the load of channel. So, there should be some optimum set of values which satisfy both networking and safety's quality of service desires. One of our important findings is that, effect of increasing transmission interval is much better than decreasing packet payload size which is mostly because of the competitive nature of the MAC layer.

In our future work we are aimed to do following studies in the continuing of current work: 1) using real-life vehicle mobility patterns and scenarios, 2) investigation theoretical analysis for finding the best values for our design parameters, 3) developing methods for setting optimum or sub-optimum values for our design parameters in an adaptive approach depending on road traffic situation, e.g., speed, density, level of danger, etc.

VII. References