Improving Vehicular Ad hoc Networks (VANET) Communication Performance by using Time Gap Following Distance (TGFD) Model

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ABSTRACT

Today, there is a growing research study of IEEE 802.11p as one of option to help the drivers to travel more safely. Message dissemination protocols are primordial for safety vehicular applications. Periodic safety message (PSM) and Warning safety message (WSM) are two types of safety messages which may be exchanged between vehicles. In this paper we investigate the feasibility of deploying safety applications based on periodic message dissemination through simulation study with safety requirements as our priority concern. Vehicles are supposed to issue these messages constantly to inform their neighboring vehicles about their current status and use received messages for preventing possible unsafe situations on time. As reliability is the main concern in periodic message dissemination, a new metric called TGFD (Time Gap Following Distance) is defined which gives us more accurate benchmark for evaluating QoS in safety applications specifically. Thus, in order to improve the performance, the effective transmission TGFD studied.

Keywords: VANET, Time gap, time gap interval, time gap range, safety, transmission interval

I INTRODUCTION

In VANET safety applications, the research objective is to provide improvement of driver and passenger safety level by exchanging safety relevant information between neighboring vehicles. The safety information is either presented to the driver or used by ITS (Intelligent Transport System) active safety device. Some examples are: cooperative forward collision warning, left or right turn assistant, lane changing warning, stop sign movement assistant and road-condition warning. Due to the inflexible delay requirements, applications of this class may demand direct vehicle-to-vehicle communication. Each safety application requires some message exchanging between vehicles for better communication. These massages can be classified in two categories: warning safety message and periodic safety message, which have different dissemination policies and roles in safety improvement. Warning safety messages are issued by vehicles to announce neighboring vehicles about the already happened events in a specific area of a road, like accidents, flooded road and fallen tree on the road whereas, safety messages are issued constantly. Using the received PSM vehicles try to prevent possible events (not already happened) like unexpected lane changing, forward collisions, wrong left or right turning, etc. Moreover, safety messages might be used by other applications (e.g. routing protocols). Yet messages mentioned above are complementary to each other. (Joe, & Ramakrishnan, 2015)

While WSM may be able to announce the driver in time about already happened events (accidents) in order to prevent worst incidents, safety messages can prevent many incidents before they take place. Furthermore, since WSM inform events, they are more important compared to PSM and should be disseminated with higher priority. The dissemination of WSM as well as comfort messages has been widely investigated in recent literature (Benslimane, 2004) However, to the best of our knowledge, there are quite few studies about periodic safety message dissemination and previous works are mostly discussing simplified cases which will be reviewed in the next section. In this paper, we intend to fill this gap by conducting extensive simulation study to evaluate the performance of disseminating periodic safety messages in a typical crowded traffic situation while using IEEE 802.11p. Furthermore, realizing the importance of reliability requirement in safety applications specifically, a new metric named TGFD transmission interval is defined, which gives us more accurate capability to investigate quality of service. In order to improve the performance, we study the effects of message transmission interval by using time gap (Fadilah, & Shariff, 2014).

Transmission intervals play an important role in collisions reduction. Safety-related messages are broadcasted periodically based on this transmission interval value (Mahajan *et. al*., 2006). This parameter is directly related to the requirements of the safety applications and it depends on traffic flow, vehicle speeds, and driver's behavior, among other things.

While smaller transmission interval can increase the information accuracy with frequent updates, the number of messages is also increased which may lead to a high probability of message collision. It can 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 in the literature (Tong, et. al., 2015)

This paper is organized as follows: Section II presents our proposed Time Gap Interval system in 802.11p-based VANET. Section III presents the details of the simulation tools, the experimental environment and the methodology we followed to perform the simulations. Experimental results are described in Section IV. Section V describes the related work with regard to warning messages in VANET. Finally, Section VI presents some concluding remarks

II TIME GAP TRANSMISSION INTERVAL WARNING SYSTEM

We investigate the effects of the transmission interval is directly related to the requirements of the safety applications and should be determined based on vehicle speed, driver's reaction time, traffic density, etc. While smaller transmission interval can 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 transmission interval has not been investigated analytically and even through simulation in the literature.

$$Ft = S \times D \qquad (1)$$

This information is used by the drivers and active safety systems of the vehicle for preventing unsafe situations. In order to clarify our simulation scenario, we invoke some vehicle's traffic theory. From Tian, *et. al*., (2015) we know that there are three macroscopic parameters: speed (km/h), density (vehicle/km/lane) and flow (vehicle/h/lane) of which their average values are related where Ft is traffic flow, S is mean speed and D is density. We argue that the transmission interval, denoted by TGFD, should be set in a way that all vehicles have enough fresh information about their neighbors. A vehicle can be supposed to have enough fresh information if the safety system has more up-to-date information about neighbors than the driver and so it warns the driver if he or she makes mistake.

$$T_{\text{interval}} \leq (ivD - wR) / rV \qquad (2)$$

Where T_{interval} (s) stands for transmission interval time gap, ivD (m) stands for inter-vehicle distance; wR(m) stands for warning radius and rV is relative speed. The awareness radius shown in Fig.1 should be relatively large to give the system in B sufficient time to be informed about any significant status (e.g. speed, position, etc.) changes of A. Therefore, if we refer to the driver's reaction by TGFD, then

$$TGFD = RT + T_{ap} + T_b + T_{pr}$$

TGFD model in this research is an extended reaction time model for VANET that also includes the transmission delay component which suitable VANET inter vehicle communication. This is because; the reaction gap of a driver seems to be an essential parameter of the car-following model. Where RT is driver reaction time, T_{ap} is application break time, T_b is VANET broadcast safety message time and T_{pr} is propagation time (Fadilah & Shariff, 2014).

$$wR \geq rV \times TGFD \qquad (3)$$

The value of message transmission interval has been computed in Table 1, giving two different levels of speed V=100 km/h and 120 km/h and TGFD= 1.5 s (Fadilah & Shariff, 2014) the worst case when the vehicle in front has to stop completely. Let TGFD represent the time window duration for a safety application to work properly by receiving at least one message and assume to be transmission interval of issuing each periodic safety message.

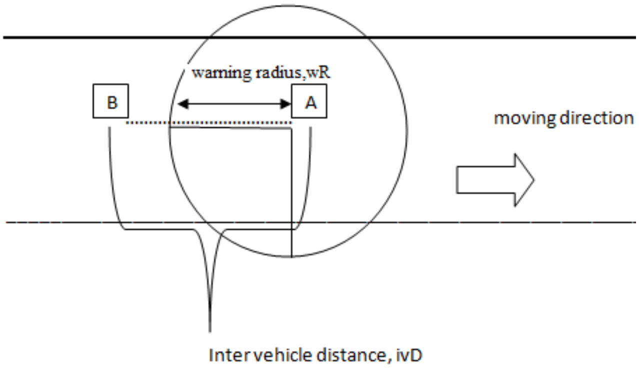

Figure 1. Message Dissemination Interval

III SIMULATION ENVIRONMENT

We conduct extensive simulations using NS2 while we make use of a deterministic radio propagation model, the two-ray-ground. A typical one-hop broadcast algorithm was implemented and the functionality of the algorithm was examined. Each node sends UDP packets of size 100 or 200 bytes every 100 or 200 ms with a time jitter of 10%. Vehicles use transmission ranges of 50 to 300 m for message exchange (Karumanchi, S., Squicciarini, A., & Lin, D. 2015). Table 1 shows the simulation setup parameters.

Table 1. Parameter

Parameter	Value
Propagation model	Two-ray-ground
Transmission range (m)	50, 100, 150, 200, 250, 300
Carrier sense range	About twice the transmission range
MAC type	IEEE 802.11 (the base for DSRC standard)
Channel bandwidth (Mbps)	6
Traffic type	CBR (UDP)
Period of message dissemination (ms)	100, 200
Message payload size (byte)	100, 200
Number of vehicles	600
Speed (km/h)	100, 120
Traffic density (vehicle/km/lane)	50
Number of lanes	8
Simulation time (s)	60

The overall goal of this work was to evaluate the effectiveness of the TGFD transmission interval presented in section III, as well as measuring and comparing the behavior of some important metrics such as the propagation delay of warning messages, the number of blind nodes and the number of packets received per node when modifying the different parameters of a VANET scenario. The simulation results presented in this paper were obtained using the ns-2 simulator (Issariyakul & Hossain, 2011). The ns-2 is a discrete event simulator developed by the VINT project research group at the University of California at Berkeley.

Our simulated system tries to follow the upcoming WAVE standard as closely as possible. Achieving this required extending the ns-2 simulator to implement IEEE 802.11p. In terms of the physical layer, the data rate used for packet broadcasting was fixed at 6 Mbit/s. The MAC layer was extended to include different priorities for channel access.

Our methodology relied of first selecting the most representative parameters for VANET, then defining a reference scenario and, finally, varying the selected parameters, thereby generating and evaluating a large number of different scenarios. The selected parameters were: 1) the total number of vehicles, 2) the scenario size, 3) the size of the messages sent 4) the priority of these messages and 5) their periodicity. Each simulation had duration of 450 seconds. In order to achieve a stable state before gathering data traffic, we only start to collect data after the first 60 seconds.

Finally, there are two types of nodes. Nodes that are damaged and send warning messages while the rest of vehicles that propagate these messages over the whole map area. In our experiments damaged nodes send warning packets with maximum priority (AC3) every second (TGFDwsm= 1s) and the rest of the nodes send lower priority (AC1) packets with positioning information every two seconds. These nodes also make the diffusion of the warning packets

IV RESULTS

In this paper, we intend to fill this gap by conducting extensive simulation study to evaluate the performance of disseminating TGFD transmission interval safety messages in a typical crowded traffic situation while using IEEE 802.11p (the base for WAVE standard). For this purpose, some metrics determining QoS, like delivery rate and delay have been evaluated (Wisitpongphan, N., Tonguz, O., Parikh, J. S., Mudalige, P., Bai, F., & Sadekar, V. (2007)). Furthermore, realizing the importance of reliability requirement in safety applications specifically, a new metric named TGFD transmission interval is defined, which gives us more accurate capability to investigate quality of service. In this paper we presented a warning advertisement system for IEEE 802.11p-based VANET, and we made a performance analysis of inter-vehicle communication systems to improve traffic safety. To evaluate our system we enhanced the ns-2 simulator to support the novel IEEE 802.11p technology. We selected the most representative parameters for VANET, and then we defined and simulated a basic scenario.

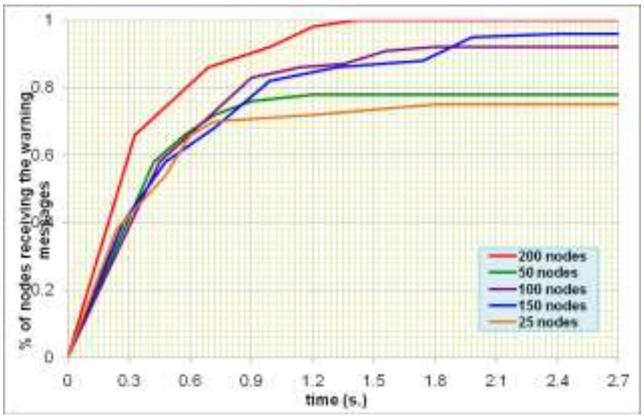

Figure 2. Average propagation delay for different size of nodes

Figures 2 show the simulation results when varying the number of nodes and maintaining the rest of parameters unaltered. We selected 25, 50,100 (basic scenario), 150 and 200 nodes.As we expected, the propagation delay is lower when the node density increases. Information reaches about 50% of the vehicles in less than 0:3 seconds, and propagation is completed in less than 0:8 seconds. When simulating with 200 nodes, propagation was completed in only 0:6 seconds.The behavior in terms of percentage of blind nodes highly depends on this factor. In fact, when node density is high, there are no blind nodes. This characteristic is explained because the flooding propagation of the messages works better with higher node densities. Due to collisions, the number of packetsreceived per node slightly decreases when the number of nodes increases

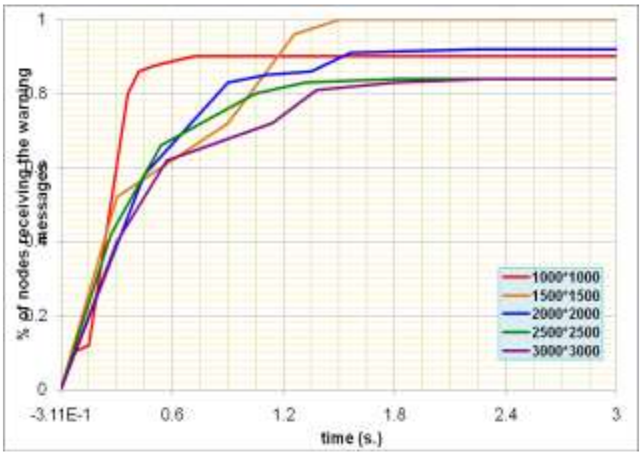

Figure 3. Average Propagation delay for different size of area

When varying the size of the area, maintaining unaltered the density of nodes and the rest of parameters. We selected scenario areas of 1000 ×1000m, 1500×1500m, 2000×2000m (basic scenario), 2500×2500m and 3000×3000m. Node density is set to 25 vehicles per square kilometer. Figure 3 depicts the average propagation delay of the warning messages. As can be seen, when the area increases, the system needs more time to inform 70% of the vehicles (approximately 0:11, 0:24, 0:31, 0:36 and 0:44 seconds respectively).

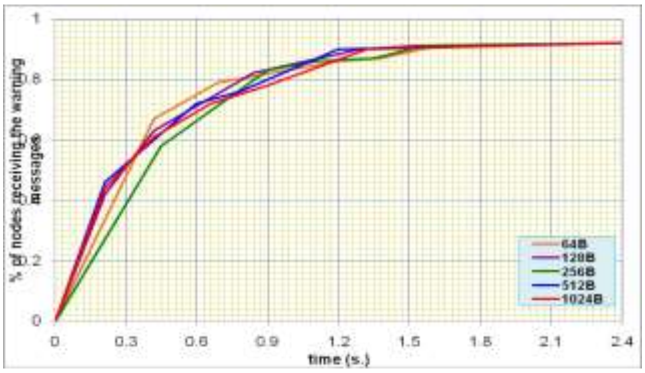

Figure 4. Average propagation delay for different size of sent packets

In this section we evaluate the impact of varying the size of the warning messages sent by nodes in terms of propagation delay. The selected values were: 64, 128 and 256 (basic scenario), 512 and 1024 Bytes. Figure 4 show the propagation delay of the simulation. As can be observed, the size of the messages sent does not affect the propagation delay in our system since the current degree of congestion is relatively low. The system needs less than 0:34 seconds to reach to the 70% of the vehicles.

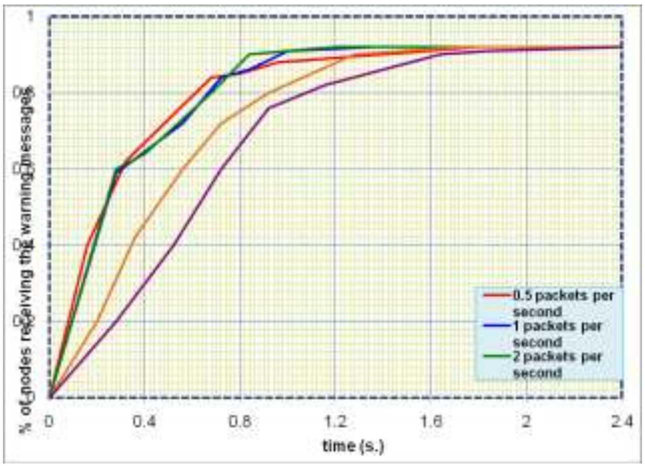

Figure 5. Propagation delay for differ the priority of message

In this section we vary the priority of regular (background) traffic to assess the impact in terms of warning messages effectiveness (Torrent-Moreno, M., Jiang, D., & Hartenstein, H. (2004)). Figure 5 show the simulation results when varying the priority of the messages sent by undamaged nodes, maintaining the rest of parameters unaltered. We selected AC3 (highest priority in our simulation system), AC2, AC1 (basic scenario) and AC0 (lowest priority). As can be seen, packet priority affects the propagation delay, but not to the percentage of blind nodes and the total number of messages received. The results demonstrated that, to obtain the lowest possible propagation delay in our system, the best solution is to give the less priority to the background traffic, while warning messages must have the highest priority. In that case, about 70% of the nodes are informed in only 0:3 seconds. If we increment the priority of the normal messages, the system needs more time to inform 70% of the nodes (0:35 and 0:38 seconds). The worst case scenario arrives when all the messages (warning and normal) have the same priority, since the system needs 40% more time to inform 70% of the vehicles. The priority does not affect the percentage of blind nodes

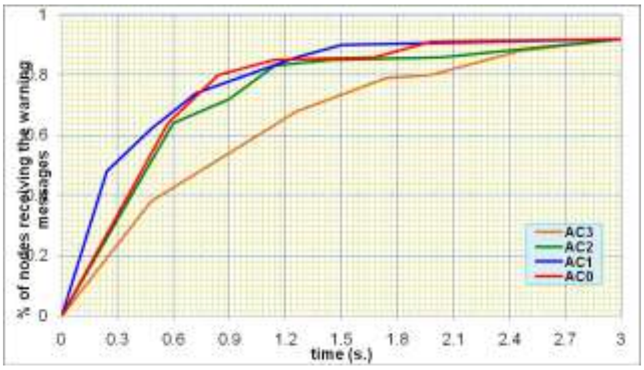

Figure 6. Propagation delay for different data rate with same priority

In this section we studied the impact of varying the periodicity of the messages sent in two different situations: first, when the priority of all the messages is the same and second, when the priority of the normal messages is lower than the priority of the warning messages. Figure 6 shows the propagation delay when varying the data rate considering that all the messages have the same priority.

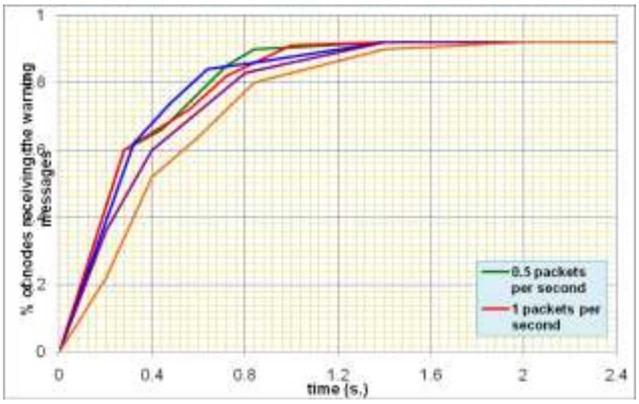

Figure 7. Propagation delay for different data rate with different priority

Figure 7 shows the propagation delay when varying the data rate considering that the priority of normal messages is lower than the priority of warning messages. As can be seen bycomparing both figures, when the message priority di®ers the system's behavior is improved since it requires less time to inform 70% of the vehicles. In both cases, when the data rate increases, the system requires more time to inform the rest of vehicles. Therefore, to achieve optimum performance, was must find a trade-off between message generation intervals and system responsiveness. Besides, we must make sure that message priority is handled adequately to avoid that warning messages compete with other traffic

V CONCLUSION

In this paper we investigate the feasibility of deploying safety applications based on periodic message dissemination (PSM) through simulation study with safety requirements as our priority concern. Vehicles are supposed to issue these messages constantly to inform their neighboring vehicles about their current status and use received messages for preventing possible unsafe situations on time. As reliability is the main concern in periodic message dissemination, a new metric called TGFD (Time Gap Following Distance) is defined which gives us more accurate benchmark for evaluating QoS in safety applications specifically. In this paper we presented a TGFD safe transmission interval for IEEE 802.11p-based VANET, and we made a performance analysis of inter-vehicle communication systems to improve traffic safety. As a conclusion, the current technology of IEEE 802.11p layer has still some challenges for VANET safety applications but this TGFD transmission interval can provide acceptable QoS to driver assistance safety applications.

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