Poster: SafeSmart - A VANET system for efficient communication for emergency vehicles

Luis Antonio L. F. da Costa*, Eduardo K. Duarte*, Mikael Erneberg†, Edison Pignaton de Freitas*, Alexey Vinel‡
*Federal University of Rio Grande do Sul, Brazil
†H&E Solutions AB, Sweden
‡Halmstad University, Sweden

***Abstract*—One important use case for Vehicular Ad-hoc Networks (VANETs) are applications related to emergency vehicles (EV). V2I (Vehicle-to-Infrastructure) communication can provide the infrastructure and protocol stack necessary to establish a communication channel between the transceivers in the EVs and the ones in the traffic lights, reducing accident risks and also help save valuable time. This paper outlines the system design of an EV warning system that makes use of V2I communication. A prototype of the system has been tested in a traffic simulation environment including EVs and traffic lights. To evaluate the system we performed a simulation and conducted a performance comparison between the travel times for EVs in normal traffic and when the system is in use.**

***Index Terms*—Vehicular networks, wireless networks, emergency vehicles, wireless transceivers.**

I. Introduction

Recent studies [1] show that in the United States 466 ambulance crashes where reported. From these incidents, 76.8% resulted in injuries to people inside or outside ambulances and 16.9% crashes resulted in fatalities. A total of 982 persons were injured and 99 deaths resulted from these fatal crashes. The causes of the accidents mainly vary between the drivers' fault and road conditions. Indeed, it is not easy for the drivers to locate the EV and make decision on the best maneuver to take, they often react too late or in a wrong manner. This problem can lead to severe accidents and also cost precious time for the EV to reach its destination.

VANET is an emerging technology for cooperative intelligent transport systems (C-ITS) that enables Vehicle-to-Vehicle (V2V) and V2I communication by using various IEEE and ETSI standards [2]. IEEE 802.11p standard, which is often referred to ITS-G5 in Europe and Dedicated Short Range Communication (DSRC) in USA is one possible Vehicle-to-Everything (V2X) technology. VANETs offer a promising solution to provide a communication infrastructure for EVs.

If a VANET system can be designed to allow V2I communication between two wireless transceivers - one on the EV and the other in the traffic light system - then the EV can take control of the traffic light signal state and impact a traffic jam ahead. In such a case the vehicles in the path of the EV can move with the traffic signal open, allowing for the EV to move faster and in a safer manner, in counterpart to normal situation scenario, where the drivers of the other vehicles would need to take evasive actions, even when the traffic is stopped. Similarly, V2X could be used for traffic light preemption where the traffic lights switch to green in the direction of the EV while blocking crossing directions.

Related researches have dealt with VANET technology being applied to EVs applications. In [3], the authors design an EV warning system that utilizes of V2V and V2I communication. With prototype testing using a detailed video analysis, the evaluations of the system by experts showed it can help to make EVs trips safer and faster, and thus potentially safe lives. In [4] a novel collaborative V2I interaction with the "automated emergency vehicle greenlight" (AEVGL) function is presented. The authors' approach combines traffic light infrastructure with DSRC over IEEE 802.11p to avoid accidents involving EVs at intersections. They utilize communication to preemptively switch traffic lights to red for crossing traffic to allow safe passage of the approaching EV, offering high potential for safety, comfort and efficiency improvements.

In contrast to the solutions presented in these works, the system here proposed is based on a simple and efficient communication system that utilizes minimum computational effort (e.g. no V2V communication or AEVGL function) and uses V2I communication based on the standardization documents [5]–[7].

The proposed solution consists of system that uses the current infrastructure of the transceivers in traffic lights and the features of DSRC/ITS-G5 to provide communication between the EVs and the transceivers in traffic lights. To provide a suitable environment for testing and deployment of the system VEINS framework is used, which combines the features of OMNeT++ [8] integrated development and graphical runtime environment with SUMO [9] traffic simulator. The simulation campaign is explored to evaluate the SafeSmart system.

II. SafeSmart System

Since the main problem addressed in this work is to coordinate the traffic lights to create a quicker path for the EVs, it is possible to focus on application scenarios involving traffic intersections, which is rather general scenario the system is supposed to deal with. The scenario detailed in Figure 1 illustrates one possible intersection, which represents the core of the system's application scenario: two emergency vehicles coming from different directions reaching a road intersection at approximately the same time.

[1]Annex to ISBN 978-3-903176-28-7© 2020 IFIP

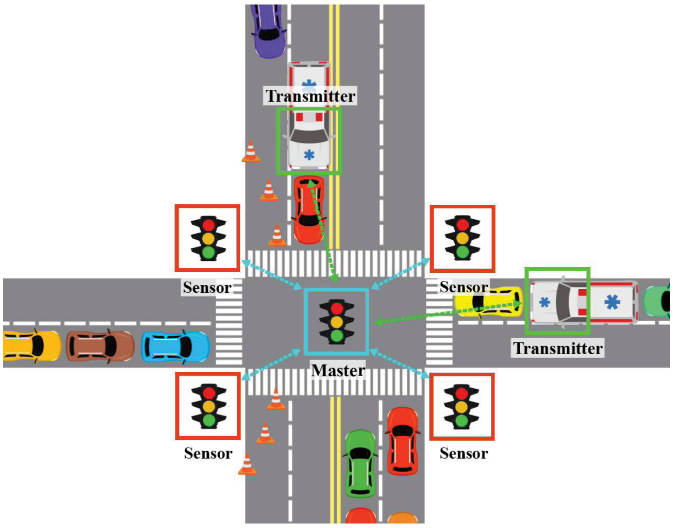

Fig. 1: Road intersection scenario with the VANET system

The transmitter in the EV communicates with the master node that delegates the traffic control scheme to the slave sensors, each one connected to one of the traffic lights present in the road junctions. The transmitter will send to the master node data containing information about the EV's status, such as position, speed and direction. At this point, the master has already previously established a secure communication channel with the slave nodes according to the security mechanisms of ITS-G5 and determined the topology of the network. After receiving the data from the incoming EVs, the master node will coordinate the traffic lights to make a quicker path for the EVs.

To comprehend the way SafeSmart system works, the developed algorithm is presented a flow chart (Figure 2), detailing the main functions and actions that would be necessary to develop the code. All the steps in the algorithm can be visualized in the flowchart in Figure 2.

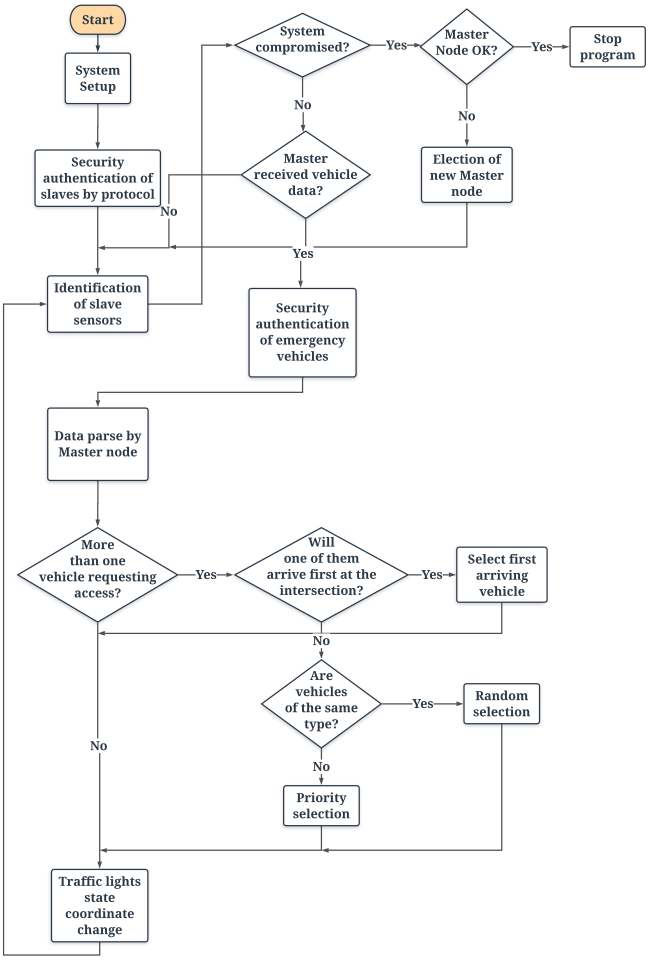

Fig. 2: SafeSmart algorithm flowchart

III. Simulation Scenario

To provide a realistic scenario where the SafeSmart solution can be further improved and deployed into the real-world, the city map of Halmstad in Sweden was chosen as the simulation scenario for the evaluation of the SafeSmart system.

The main test consisted in placing an EV following a specific straight road path on the city's road network. The route takes approximately 1.5 km long and contains 4 intersections. Throughout the path of the EV, different amounts of traffic were simulated.

The path loss exponent used is 2 and the transmission power is 20 mW. The obstacle shadowing model used is the default one included in Veins with 9 dB per cut and 0.4 dB per meter. The higher layers use models of the ITS-G5/DSRC stack according to the standards.

The test scenario has been executed under different amounts of background traffic, where each trip is generated with a random edge as source and another random edge as destination. This has been simulated by increasing or decreasing the time between the spawn of each regular vehicle on the simulation. For example, the first test involved spawning one car per second, the second test involved spawning two cars per second, and so on. Each test was repeated using different seeds five times, which allows the improvements to be noted within a 90% confidence interval.

For the execution of the tests, there were two important assumptions made: first, the EV will not go over the speed limit of the given road, ensuring safety. The second assumption is that the other regular drivers will not make any effort to clear the path for the EV. In a real scenario, it is most likely that drivers will try to clear the path for the EV, but the focus was on the worst-case scenario, where the drivers will still stand in the way of the EV, which may also happen in a real scenario if there is no empty room for the other drivers to move.

IV. Results & Discussion

Figure 3 presents the results obtained for the first four executed test scenarios. It is possible to notice that SafeSmart is not effective in the case of no background traffic. This is consistent with the expected results, because in case there are no other vehicles, since the EV is allowed to cross red lights, activating or not the traffic lights will not make the EV go any faster.

Analysing the results from the second test, with one car spawning every second, it is possible to notice that using the SafeSmart system makes the course time shorter. This happens because the EV got close to the traffic light, turning it green and enabling the traffic to clear the path on the road before the EV arrived at that point.

However, the biggest advantage of using SafeSmart is presented for an increasing amount of traffic, as seen in the last case of the tests. It is interesting to notice that, even though using the SafeSmart system will not always make the travel time the same as in the case with no traffic, time increases linearly linear when SafeSmart is used.

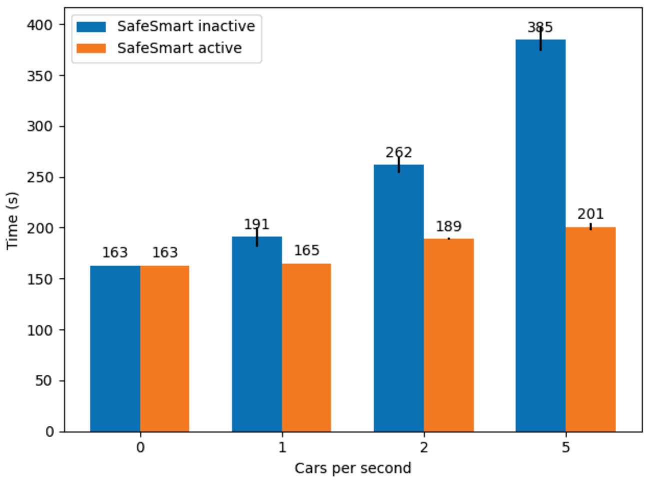

Fig. 3: EV average travel time with different traffic amounts

This happens because of many cases in which the EV will get stuck between big groups of car and the time it takes to finally be able to move forward once again. These cases are mostly avoided when using the SafeSmart system because once the EV turns the traffic light green, the traffic light around it will rapidly dissolve the traffic jam. These cases cause considerable increases in the time and are the reason for the huge variability in the time of the simulations without SafeSmart.

V. Conclusion and Future Work

This paper introduces SafeSmart, a VANET based system for EV communication. The results obtained from the tests show that the SafeSmart system presents a good performance, providing EVs a faster and safer path from one point to another, mostly in traffic jam scenarios, where other drivers might not have enough room to clear the path for the EV.

Among the possible future works, security must be considered before deploying the system in a real life scenario due to the risks of an attacker putting lives at risk. Therefore, methods of preventing and circumventing attacks from malicious users must be tested while still ensuring that the system's performance will not be too drastically affected.

Besides, it would also be very interesting to develop a dynamic traffic light control protocol to determine the best moment, in terms of distance, to activate the traffic lights. Activating them too soon could cause excessive trouble in the traffic going in other directions, even causing traffic jams. Activating too late could cause problems for the EV as the drivers might not have enough time to clear the path before the EV arrives, loosing precious time. Also, it must be considered that the EV should not cause any great disturbances on the traffic going in opposite directions. It is important to define metrics to measure this disturbance on vehicles that are near the EV but not going on the same direction.

Finally, it must be also taken into account the interference caused on the communications caused by other vehicles broadcasting their own messages. As the penetration of V2X technology grows, the interference issue will become each time more important. This could affect the reliability of the system, as the range of communications would most likely decrease in a scenario with many vehicles transmitting at the same time.

Acknowledgment

The research leading to the results reported in this work has received funding from the Knowledge Foundation in the framework of SafeSmart "Safety of Connected Intelligent Vehicles in Smart Cities" Synergy project (2019–2023), Swedish Foundation for Strategic Research (SSF) in the framework of Strategic Mobility Program (2019-2020), and the ELLIIT Strategic Research Network. This support is greatly acknowledged.

References

[1] T. L. Sanddal, N. D. Sanddal, N. Ward, and L. D. Stanley, "Ambulance crash characteristics in the us defined by the popular press: A retrospective analysis," in *Emergency medicine international*, 2010.

[2] S. Zeadally, R. Hunt, Y.-S. Chen, A. Irwin, and A. Hassan, "Vehicular ad hoc networks (vanets): status, results, and challenges," *Telecommunication Systems*, vol. 50, pp. 217–241, 2012.

[3] A. Buchenscheit, F. Schaub, F. Kargl, and M. Weber, "A vanet-based emergency vehicle warning system," *2009 IEEE Vehicular Networking Conference (VNC)*, pp. 1–8, 2009.

[4] O. Sawade, B. Schäufele, and I. Radusch, "Collaboration over ieee 802.11p to enable an intelligent traffic light function for emergency vehicles," *2016 International Conference on Computing, Networking and Communications (ICNC)*, pp. 1–5, 2016.

[5] E. ETSI, "302 637-3," *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service*, pp. 2000–04, 2018.

[6] T. ETSI, "103 301," *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services*, pp. 2000–04, 2016.

[7] "Intelligent transport systems — Cooperative ITS — Using V2I and I2V communications for applications related to signalized intersections," International Organization for Standardization, Standard, Jun. 2019.

[8] A. Varga, "Omnet++," in *Modeling and tools for network simulation*. Springer, 2010, pp. 35–59.

[9] D. Krajzewicz, G. Hertkorn, C. Rössel, and P. Wagner, "Sumo (simulation of urban mobility)-an open-source traffic simulation," in *Proceedings of the 4th middle East Symposium on Simulation and Modelling (MESM20002)*, 2002, pp. 183–187.