Improving Intersection Safety with IVC

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***Abstract*—Research in Inter-Vehicle Communication (IVC) is currently deeply investigating safety applications as they are potentially the main driver to use Dedicated Short-Range Communication (DSRC) radios in addition to other safety-enabling technologies like radar, ultrasonic sensors, and stereo cameras. One envisioned safety application is the so-called Intersection Collision Warning System (ICWS) which warns the driver if other approaching vehicles endanger the own vehicle by ignoring traffic rules or misinterpretation of dangerous situations for example. Building such an intersection safety application still reveals several challenges regarding communication requirements, like the minimum information dissemination rate. These IVC applications will not only be evaluated with the help of network metrics like delay, jitter, goodput and channel utilization, but in terms of safety, i.e. how many crashes can be avoided and how the severity of the impact can be reduced in case of still resulting crashes. To investigate the effectiveness of such intersection safety applications we mainly rely on simulation, but we aim to conduct real-world measurements where applicable.**

I. Introduction

One major achievement in Inter-Vehicle Communication (IVC) in the last years was the standardization of physical layer as well as medium access mechanisms for Dedicated Short-Range Communication (DSRC) in IEEE 802.11p standard [1]. Therefore, the focus of researchers has now turned to higher layer protocols that might be realized on top of this standard. The use cases are manifold, however, safety applications have been identified as one of the most promising reasons to deploy DSRC. ETSI has proposed the use of Cooperative Awareness Messages (CAMs) as a basis for all envisioned safety applications.

To better understand which safety applications might profit from IVC, we can distinguish between crashes happening with or without other involved vehicles. Obviously, one can only take advantage of communication in the latter case. Still, the situations in which crashes happen, are diverse and range from rear crashes to complex situations like overtaking or intersection crashes. Whereas safety applications for highways and rear crashes [2] received a lot of attention and have been already well investigated. We decided to concentrate on intersection safety applications as a major portion of road traffic accidents happens at intersections.

Increasing intersection safety has already been subject of several international projects. For example, the US project Cooperative Intersection Collision Avoidance Systems (CICAS) studied the potentials of different intersection warning systems. The EU funded project PReVENT-INTERSAFE investigated possibilities of on-board systems in combination with Vehicle-to-X (V2X) communication. The follow-up project INTERSAFE-2 used additional infrastructure (sensor devices) at intersections for improving the safety benefit for low market penetration. The findings of both projects focused on using on-board systems and gathering information of the environment with the help of IVC.

Although, there have been efforts to improve safety at intersections, they are not yet sufficient to build real safety applications based on IVC. Several studies (e.g., [3]) already reported difficulties for intersection safety applications due to the fact that Line of Sight (LOS) between endangering vehicles is rarely available. Hence, lots of interesting research questions remain in this field and some of them are described in detail as potential contributions in Section III.

II. State of the Art

Le et al. had a look on busy time fraction of DSRC systems for intersection safety [4]. Since they were using a simplified radio propagation model which uses only a fixed unit-disk communication range open questions regarding channel utilization remain.

A detailed study on communication requirements for crash avoidance applications has been published in [5]. The authors changed collision-free vehicle traces by artificially injecting collisions with constant velocity to evaluate their protocol for crash mitigation. However, simplifying assumptions like idealistic radio signal propagation and not considering low speed collisions ($< 7\,\mathrm{m/s}$) limit the contribution for intersection safety applications.

Similarly, we observed that most of the studies investigating intersection safety applications did not consider realistic radio signal propagation (e.g. shadowing effects of buildings). Although, there have been measurements even considering Non Line of Sight (NLOS) radio propagation [3], [6], [7] which is in most cases essential for intersection safety applications. To the best of our knowledge nobody has evaluated intersection applications with safety metrics and also considered NLOS communication.

Two driving simulator studies [8], [9] have shown independently that using Intersection Collision Warning System (ICWS) are able to substantially reduce reaction times of drivers when cross traffic is endangering their own vehicle.

III. Contributions

For improving intersection safety with IVC, we will build an intersection safety application that allows us to answer questions regarding communication requirements. The main

goal of the system is to substantially reduce the number of collisions at intersections while keeping false positive alarms acceptable. Therefore, contributions will be in the field of wireless communication as well as in the actual implementation of such systems. In the following, we list research questions that will be answered in the scope of this PhD project:

- **What information is needed?** Here, it should be answered whether it is sufficient to transmit the current trajectory only (i.e., position, moving direction, speed, and acceleration) or additional information might be useful. One possibility might be to add future route information (turn intention at the intersection) or to include a short driving history in the CAMs.
- **How much information is needed?** We are interested in an upper-bound for sending as well as receiving CAM intervals. However, the trade-off between transmitting more information at once (related to the previous question) and more frequent information broadcasts needs to be considered here.
- **When to send the information?** For intersection applications it obviously does not make sense, to spread information all the time. Therefore, we need to investigate when CAMs are essential for the success of such applications.
- **What about simultaneousness of IVC applications?** Since DSRC technology will also be used for other applications, we need to evaluate proposed solutions also in the presence of multiple applications. Moreover, this concurrency issue needs to be investigated with respect to single and multiple radios.
- **What about market introduction?** Finally, we can not only design such applications with full market penetration in mind. Hence, it is important to look at proposed solutions also with low market penetration. To enable the target technology, also other technologies (3G, 4G communication or radar technology) need to be integrated and considered.

The research community has realized that there is a need for evaluating IVC applications against their own effectiveness; for example the success of IVC safety applications will be measured in prevented accidents [10]. Hence, all questions will be assessed by safety metrics, but still network metrics like delay, jitter, goodput and channel utilization will be used to gain insights during the design of the application.

Most of the published solutions for safety applications do not evaluate their communication protocols with safety metrics like crash mitigation or impact reduction. We already made a first step towards evaluating real-world impact by introducing a risk classification [11]. For validating the risk classification, we enabled crashes in the road traffic simulator SUMO by introducing traffic offending vehicles. Moreover, we implemented a basic crash detection module which currently is only able to distinguish real and almost crash situations. For assessing the real-world impact, it will be extended to further categorize by their resulting impact. Finally, the real-world impact needs to determined with respect to the type of safety application itself — driver warning systems versus automated systems.

Another important step towards deliverable IVC intersection safety applications, is the use of appropriate channel models for simulating radio propagation. It has been shown by measurement campaigns [3], [6] that shadowing effects of buildings greatly influence the performance of ICWS. Therefore, we will evaluate existing models with respect to their applicability for safety applications and conduct new measurements which might be relevant to better understand signal propagation at intersections.

The primary tool for assessing effectiveness of safety applications is simulation. Since, credibility of simulation studies is often lacking, we are aware that reproducibility of simulation results is one chance to regain it. Therefore, we will not only provide information about the five basic building blocks mentioned in [12], but in addition publish the used simulation scenarios after corresponding publications have been published.

REFERENCES

[1] "Wireless Access in Vehicular Environments," IEEE, Std 802.11p-2010, July 2010.

[2] M. Segata and R. Lo Cigno, "Emergency braking: a study of network and application performance," in *ACM VANET 2011*, Las Vegas, NV, September 2011, pp. 1–10.

[3] J. Karedal, F. Tufvesson, T. Abbas, O. Klemp, A. Paier, L. Bernado and, and A. Molisch, "Radio Channel Measurements at Street Intersections for Vehicle-to-Vehicle Safety Applications," in *71st IEEE Vehicular Technology Conference (VTC2010-Spring)*. Taipei, Taiwan: IEEE, May 2010, pp. 1 –5.

[4] L. Le, A. Festag, R. Baldessari, and W. Zhang, "Vehicular Wireless Short-Range Communication for Improving Intersection Safety," *IEEE Communications Magazine*, vol. 47, no. 11, pp. 104 –110, November 2009.

[5] J. J. Haas and Y.-C. Hu, "Communication requirements for crash avoidance," in *7th ACM International Workshop on Vehicular Internetworking (VANET 2010)*. Chicago, IL: ACM, September 2010, pp. 1–10.

[6] C. Sommer, D. Eckhoff, R. German, and F. Dressler, "A Computationally Inexpensive Empirical Model of IEEE 802.11p Radio Shadowing in Urban Environments," in *IEEE/IFIP WONS 2011*, Bardonecchia, Italy, January 2011, pp. 84–90.

[7] T. Mangel, F. Schweizer, T. Kosch, and H. Hartenstein, "Vehicular safety communication at intersections: Buildings, Non-Line-Of-Sight and representative scenarios," in *IEEE/IFIP WONS 2011*, Bardonecchia, Italy, January 2011, pp. 35–41.

[8] S.-H. Chang, C.-Y. Lin, C.-C. Hsu, C.-P. Fung, and J.-R. Hwang, "The effect of a collision warning system on the driving performance of young drivers at intersections," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 12, no. 5, pp. 371–380, 2009.

[9] H. Chen, L. Cao, and D. B. Logan, "Investigation Into the Effect of an Intersection Crash Warning System on Driving Performance in a Simulator," *Traffic Injury Prevention*, vol. 12, no. 5, pp. 529–537, 2011.

[10] F. Dressler, F. Kargl, J. Ott, O. K. Tonguz, and L. Wischhof, "Research Challenges in Inter-Vehicular Communication - Lessons of the 2010 Dagstuhl Seminar," *IEEE Communications Magazine*, vol. 49, no. 5, pp. 158–164, May 2011.

[11] S. Joerer, M. Segata, B. Bloessl, R. Lo Cigno, C. Sommer, and F. Dressler, "To Crash or Not to Crash: Estimating its Likelihood and Potentials of Beacon-based IVC Systems," in *4th IEEE Vehicular Networking Conference (VNC 2012)*. Seoul, Korea: IEEE, November 2012, to appear.

[12] S. Joerer, C. Sommer, and F. Dressler, "Toward Reproducibility and Comparability of IVC Simulation Studies: A Literature Survey," *IEEE Communications Magazine*, vol. 50, no. 10, pp. 82–88, October 2012.