Backwards Compatible Extension of CAMs/DENMs for Improved Bike Safety on the Road

Stefan Loewen, Florian Klingler, Christoph Sommer and Falko Dressler
Heinz Nixdorf Institute and Dept. of Computer Science, Paderborn University, Germany
{stefan.loewen,klingler,sommer,dressler}@ccs-labs.org

***Abstract*—In the past, research and standardization in the field of Intelligent Transportation Systems (ITS) have focused on motorized vehicles and large car manufacturers are now starting to implement the resulting standards. With bikes gaining more and more popularity and, thus, a share in accidents, it is important to consider the special safety needs of cyclists. We propose a way of extending established ITS standards with new fields meeting cyclists needs while keeping a maximum of backwards compatibility to already deployed ITS vehicles. We demonstrate this approach by presenting examples for extensions of the ETSI ITS-G5 CAM and DENM message formats.**

I. Introduction

Intelligent Transportation Systems (ITS) are an important building block of our future mobility. A key part of ITS is direct wireless communication between road users, which can enable wholly new safety features. Worldwide, standards of communication stacks have reached maturity [1]. Already many car manufacturers are working towards the deployment of this technology in new cars. In Europe, Volkswagen announced[1] market-ready cars using the ITS-G5 standard from 2019 on. In Japan, Toyota already sells[2] such *ITS Connect* equipped cars. This demonstrates that the technology is no longer just theory, but a real life fact.

Still most of the research in the field of vehicular networking focuses only on motorized vehicles like cars or trucks. In the rare case when pedestrians and cyclists are considered, they are often treated summarily as Vulnerable Road Users (VRUs). Yet, the subgroups of VRUs differ a lot in their behavior, safety needs, and potential ways of integrating them into an ITS. We focus on bicycles, whose role as an integral part of urban transportation systems has been increasing massively[3][4] in the past decade. At the same time, bikes are a prime candidate for retrofitting wireless communication technology in the form of after-market extensions. Yet, their needs remain largely unaccounted for in current standardization.

In this paper, we present an approach of extending established standards for vehicular communication while keeping them backwards compatible with already deployed vehicles. Our contributions can be summarized as follows: we highlight the need to take bicycles into special consideration when designing ITS; we propose an approach for extending established standards in a backwards compatible way; and we demonstrate ways in which such extensions can be used to improve the safety of bikes on the road.

[1] www.volkswagenag.com/en/news/2017/06/pwlan.html

[2] www.toyota-global.com/innovation/intelligent_transport_systems/

[3] theguardian.com/cities/2016/nov/30/cycling-revolution-bikes-outnumber-cars-first-time-copenhagen-denmark

[4] nyc.gov/html/dot/downloads/pdf/bike-safety-study-fullreport2017.pdf

II. Related Work

The VRUITS project aims at identifying the needs of VRUs in ITS applications. Scholliers et al. [2] present the results of the first phase of the project in which they analysed accident data to identify critical scenarios for VRUs and reviewed other ITS applications in regards to the identified scenarios. These applications are mostly concerned with detecting VRUs and warning car drivers about them instead of warning VRUs themselves about potentially dangerous situations.

Santa et al. [3] (S-CICLO project) take the cyclists' perspective into consideration and have built an embedded hardware unit that allows bidirectional integration of bicycles into vehicular networks. Their focus lies on development of this hardware unit as well as a Human Machine Interface (HMI) for communicating warnings to the cyclist and an Android app to show warnings to car drivers. For communication between vehicles they use unmodified Cooperative Awareness Messages (CAMs) as standardised by ETSI.

Céspedes et al. [4] take a completely different approach to bike safety by focusing on crowded bike lanes and developing a platooning system among bikes. For wireless communication they use IEEE 802.15.4 network interfaces thereby deviating from the prevalent standards for vehicular networking.

The XCYCLE project takes a comprehensive approach to bicycle safety. As part of this project, Blokpoel and Stuiver [5] present a system that detects VRUs via roadside sensors and warns nearby cars in cases where a collision seems likely. For this system they propose extending the ETSI ITS-G5 standard by a new message type called Sensory Observation Message (SOM) as well as extending CAMs with predictions of future locations. The new message type would only be understood by devices supporting this extension. The same holds for the future locations integrated into CAMs.

Summing up, in general other projects working on ITS for VRUs either use *(a)* the unmodified ETSI ITS-G5 standard without taking into account the special needs of cyclists, or *(b)* create whole new protocols without caring about backwards compatibility. In contrast, we consider backwards compatibility a prime goal when extending ITS to fit cyclists' needs as current ITS are already successfully deployed.

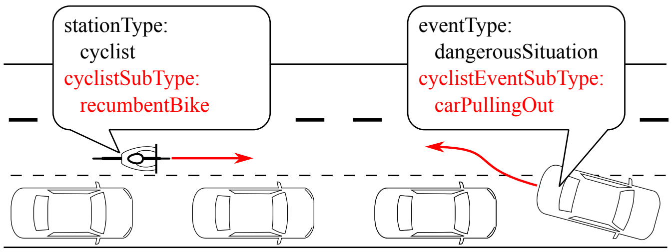

Figure 1. Sample extensions of CAM/DENM messages for bike safety.

III. Extending Established Standards

A. Approach

We considered the following three approaches to wirelessly exchange information for bike safety.

One alternative to implement ITS solutions for cyclists would be to design specialized systems that take care of communication with the cyclists' surroundings. This makes the system design rather easy since there are no preset boundaries to comply to. The big drawback is that it produces isolated solutions that are incompatible with existing standards and, thus, with existing systems. To be successful on a large scale, these solutions need to achieve a high market penetration which is a difficult and lengthy goal to achieve.

Another alternative would be to build on the ETSI ITS-G5 standard which already has wide industrial support – e.g., the Car-2-Car Communication Consortium (C2C-CC), which consists of many large car manufacturers as well as car part suppliers. This helps solving the problem of market penetration. The two most relevant ITS-G5 message types are CAMs [6] and Decentralized Environmental Notification Messages (DENMs) [7]. Yet, since the current focus of the standard is clearly on motorized vehicles like cars and trucks, these messages lack details needed in an ITS that includes bikes.

We therefore propose a third alternative, a backwards compatible extension of CAMs/DENMs. These messages are defined using the ASN.1 format [6], [7]. The definition of both message formats contains multiple extension points in the form of SEQUENCE statements ending with the extension marker (an ellipsis). These extension points can be used to add new fields and containers to the message formats, while parsers complying with the old message format ignore additions that are unknown to them. To achieve real backwards compatibility, we propose extending the message formats at these extension points and including more abstract versions of the sent information in legacy fields, which are known to a wider range of parsers/products.

B. Examples

In the following, to make our proposal clearer, we briefly discuss potential realizations of two very different examples:

Type of bicycle: CAMs contain a STATIONTYPE integer field, which defines the type of vehicle sending the message. For cars and trucks it allows a rather detailed specification, but cyclists are summarized as CYCLIST, disregarding the safety needs and potential capabilities of different types of bikes. A non-backwards-compatible extension would be to introduce additional vehicle types beyond the 16 types currently assigned a number, but this would result in older parsers interpreting this value as UNKNOWN, thus, losing *all* information on the vehicle's type. We instead propose to keep the STATIONTYPE field set to CYCLIST and to introduce a new field CYCLISTSUBTYPE allowing values like PEDELEC or RECUMBENTBIKE (see Figure 1). Old parsers would ignore the new subtype but still recognize the message as one sent by a bike.

Dangerous maneuver: Each DENM contains an EVENTTYPE field of type CAUSECODE to specify the event that triggered the DENM. The CAUSECODE type is an extensive list of possibly dangerous situations but cannot encode the fact that a car is reversing out of a parking space. Again, instead of simply introducing a new cause code which would then be ignored by older parsers, we propose to set EVENTTYPE to a cause code like DANGEROUSSITUATION, which roughly resembles the situation. The detailed information could then be added as a new field CYCLISTEVENTSUBTYPE which is set to the new cause code CARPULLINGOUT (see Figure 1).

IV. Conclusion and Future Work

We proposed a method for extending established vehicular networking standards with information relevant to the safety of cyclists on urban roads while guaranteeing graceful degradation, that is, structuring messages so that they provide fallback information for vehicles using older versions of the standard. We also provided examples for a concrete realization. Our next steps are to continue a dialog with the community on potential information elements and investigating their benefits in field operational tests with working prototypes.

Acknowledgements

Research reported in this paper was conducted in part in the context of the project *Safety4Bikes*, supported by the German Federal Ministry of Education and Research (BMBF) under grant number 16SV7672.

References

[1] C. Sommer and F. Dressler, *Vehicular Networking*. Cambridge University Press, Nov. 2014.

[2] J. Scholliers, D. Bell, A. Morris, and A. B. García, "Improving Safety and Mobility of Vulnerable Road Users through ITS Applications," in *TRA 2014*, Paris, France: IFSTTAR, Apr. 2014.

[3] J. Santa, P. J. Fernández, and M. A. Zamora, "Cooperative ITS for Two-Wheel Vehicles to Improve Safety on Roads," in *IEEE VNC 2016*, Columbus, OH: IEEE, Dec. 2016.

[4] S. Céspedes, J. Salamanca, A. Yañez, C. Rivera, and J. C. Sacanamboy, "Platoon-based cyclists cooperative system," in *IEEE VNC 2015*, Kyoto, Japan: IEEE, Dec. 2015, pp. 112–118.

[5] R. Blokpoel and A. Stuiver, "Sensory observation message and CAM extensions for VRU safety," in *ITS European Congress*, Glasgow, Scotland, Jun. 2016.

[6] ETSI, "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service," ETSI, EN 302 637-2 V1.3.2, Nov. 2014.

[7] ——, "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specification of Decentralized Environmental Notification Basic Service," ETSI, EN 302 637-3 V1.2.0, Aug. 2013.