Use Case Representations of Connected and Automated Driving

KPI Requirements and Measurements in the 5GCAR Project

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***Abstract*— Cooperative and connected V2X applications drive further improvements of advanced driver assistance systems (ADAS) and automated driving. Three different use cases showing new applications are demonstrated within the 5GCAR project: lane merge coordination, cooperative perception for maneuvers of connected vehicles, and vulnerable road user protection. These use case representatives on the one hand will be demonstrated mid-2019 on a test track, and on the other hand serve as platforms for evaluating key performance indicators (KPIs) of the developed implementations.**

Keywords—Connected car; Automated driving; 5G; V2X communication; Cooperative vehicular applications;

I. INTRODUCTION

For the final demonstrations in the 5GCAR project [1], three use case classes are selected and representatives for each class are identified. The classes are *Cooperative Maneuver*, *Cooperative Perception*, and *Cooperative Safety* [2]. The use case representative for *Cooperative Maneuver* is the *Lane Merge Coordination.* For the use case class *Cooperative Perception*, two representatives – *Long-Range Sensor Sharing* and *See-through* - are demonstrated. For the use case class *Cooperative Safety*, the *Network-assisted Vulnerable Road User (VRU) Protection* is showcased.

For a successful use case execution, requirements on the automotive and the communication *Key Performance Indicators* (KPIs) have to be met [3]. The expected limits of the use cases are estimated. In a number of experiments, data analysis provides measurements for the observed KPIs. A comparison between KPI requirements and measurements provide an overview on possibilities and gaps which are expected for the use case applications. The following contributions build the contents of the presented poster:

- Demonstrations of relevant use cases for future needs in automotive applications as demonstrated by the 5GCAR project
- Comprehensive analysis of use case experiments
- Comparison of KPI requirements and measurements

II. 5GCAR USE CASE REPRESENTATIVES

In the following, the use case representatives are explained. For each representative, the case that some of the participating vehicles are not connected to the network is considered. Only the connected vehicles are influenced by the network.

A. Lane Merge Coordination

The goal of the lane merge coordination use case is the sharing and coordination of driving trajectories among a group of vehicles to improve the traffic safety and efficiency. A subject vehicle which wants to join the main lane is coordinated with remote vehicles driving on the main lane in order to merge smoothly and safely with minimal impact on the traffic flow (cf. Fig. 1). To capture non-connected vehicles, a camera system with object recognition capabilities is used [4]. The lane merge coordination plans the cooperative maneuver and distributes corresponding instructions to connected vehicles, while the behavior of unconnected vehicles is predicted and considered. For this demonstration, the evaluation focus from a service perspective is whether a feasible maneuver is derived and implemented that also respects inter-vehicle distances as well as acceleration and deceleration constraints.

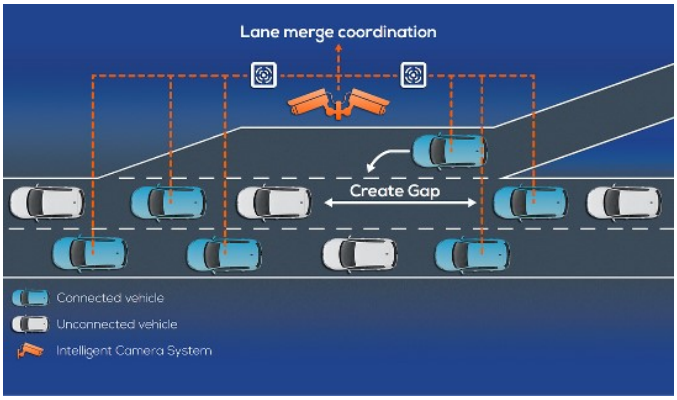

Fig. 1. Lane merge coordination of connected vehicles considerung the behaviour of unconnected vehicles

B. *Long-Range Sensor sharing / See-through*

The cooperative perception demonstration uses vehicle-to-infrastructure and vehicle-to-vehicle communication for enabling long range and short-range sensor sharing between vehicles for safer and more efficient maneuvers.

The long-range sensor sharing uses on-board sensors for object detection and shares this information with other connected vehicles. It provides a substantial help to a human driver or an automated vehicle. As shown in Fig. 2, Vehicle 4, not connected to the network, can represent a risk for Vehicle 5. As Vehicle 3 embeds an object detection system (based on radar, lidar, and/or camera), information about Vehicle 4 (position, speed, acceleration, …) is sent to Vehicle 5.

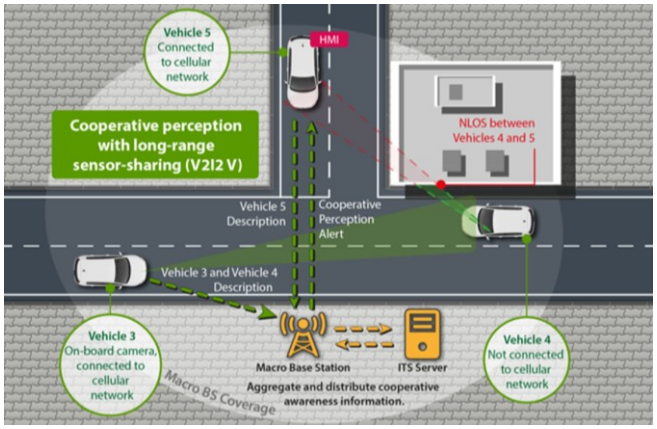

Fig. 2. Cooperative perception with long-range sensor sharing

The short-range sensor sharing is enabled by a *See-through* application which uses low latency video streaming from an on-board camera of a vehicle to allow a rear vehicle to see through it. A driver or automated vehicle driving behind another car/truck requests the sharing of its video to be able to do short term driving decisions. The front vehicle uses disparity information of a stereo camera system to synthesize the video image according to the relative pose (position & orientation) of the rear vehicle, in order to make the video look as if it was perceived by the rear vehicle itself. For data communication (i.e. video transmission), the direct communication link between 5G-V2V modems is used.

C. *VRU Protection*

The vulnerable road user protection consists of a network-based positioning and collision prediction system for preventing accidents with pedestrians or cyclists that cannot be predicted using in-vehicle sensors (camera, radar, etc.). This is typically the case when VRU and vehicle are not in line of sight to each other. As shown in Fig. 3, the road users send out broadband 5G reference signals to surrounding synchronized Base Stations (BS#1-BS#4). The *Location Server* estimates the absolute positions using individual time difference of arrival measurements. These measurements are fused with available sensor data from the vehicle and the VRU to anticipate future trajectories of the users based on motion models and a map [5]. If the collision prediction algorithm indicates a potentially critical situation, an alert message is triggered and transmitted to the road users.

III. USE CASE KPIS

For the 5GCAR use cases, the most relevant KPIs are the localization accuracy, the communication latency and its reliability. The use cases have different demands on the localization accuracy, latency, and reliability, while the use case specific network architectures and processing steps lead to different communication latencies.

The comparison between requirements and the data measured on a test track is targeted in our poster presentation.

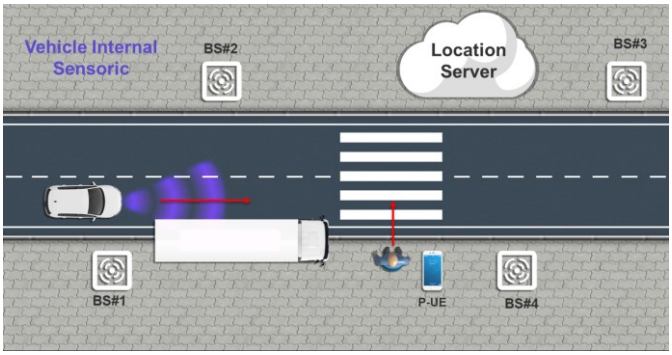

Fig. 3. Vulnerable Road User (VRU) protection

IV. SUMMARY

For three selected use cases for connected and automated driving, the required KPI values are examined. The use cases are derived within the 5GCAR project. The KPI values are compared to measurements captured in experiments on a test track. The comparison gives an overview on possibilities and gaps regarding connected and automated driving applications.

ACKNOWLEDGMENT

This work has been performed in the framework of the H2020 5GCAR project co-funded by the EU. The authors would like to acknowledge the contributions of their colleagues of 5GCAR.

REFERENCES

[1] 5GCAR – 5G Communication Automotive Research and innovation, www.5gcar.eu

[2] N. Brahmi, T. Frye, D. Martinan, P. Dafonte, X. Abad, M. Sáez, B. Cellarius, S. Gangakhedkar, H. Cao, L. Sequeira, K. Berger, R. Theillaud, J. Otterbach, A. Grudnitsky, B. Villeforceix, S. Allio, M. Lefebvre, J.-M. Odinot, J. Tiphene, A. Servel, A. E. Fernández Barciela, H. Broszio, K. Cordes, and T. Abbas, "5GCAR Demonstration guidelines", 2018, https://5gcar.eu/ [Online;accessed 03-2019].

[3] A.E. Fernandez Barciela, A. Servel, J. Tiphene, M. Fallgren, W. Sun, N. Brahmi, E. Ström, T. Svensson, D. Bernardez, J. A. Zarate, A. Kousaridas, M. Boban, M. Dillinger, M. Condoluci, T. Mahmoodi, Z. Li, J. Otterbach, M. Lefebvre, G. Vivier, T. Abbas, and P. Wingard, "5GCAR scenarios, use cases, requirements and KPIs", 2017, https://5gcar.eu/ [Online; accessed 03-2019].

[4] K. Cordes and H. Broszio, "Constrained Multi Camera Calibration for Lane Merge Observation", 14th International Conference on Computer Vision Theory and Applications (VISAPP), 2019, SciTePress

[5] M. Mizmizi, S. Mandelli, S. Saur, and L. Reggiani, "Robust and Flexible Tracking of Vehicles Exploiting Soft Map-Matching and Data Fusion", IEEE 88th Vehicular Technology Conference: VTC2018-Fall