Development of Car2X Communication and Localization
PHY and MAC Protocol Following Iterative Spiral Model
Using Simulation and Emulation

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Abstract. The communication between objects, i.e. between cars (car-2-car, C2C), between cars and infrastructure (car-2-infrastructure, C2I) and between cars and vulnerable road users (car-2-VRU, C2VRU) is a major stepping stone towards traffic applications to enable efficient and safe traffic flow. However, these applications pose very high requirements to the communication protocols, which go beyond the capabilities of an available standardized solution.

This contribution shows how iterative design processes can help to fulfill these requirements, while re-using a maximum of elements from one level to the next and thus avoiding unrealistic overhead. In especially, the added value of simulation and emulation in this iterative process is elaborated.

Keywords: Car-2-Car communication, Car-2-X communication, simulation, emulation, iterative design process.

1 Introduction

The communication between objects, i.e. between cars (car-2-car, C2C), between cars and infrastructure (car-2-infrastructure, C2I) and between cars and vulnerable road users (car-2-VRU, C2VRU) is a major stepping stone towards traffic applications to enable efficient and safe traffic flow. However, these applications pose very high requirements to the communication protocols, which go beyond the capabilities of an available standardized solution. Consequently, a specific protocol must be designed, which take into account all these requirements. Due to the complex requirements, the design of the communication protocols must be performed extremely careful. Systematic approach, thorough testing and extensive verification are major preconditions for the successful development of communication units.

This contribution shows how iterative design processes can help to fulfill these requirements, while re-using a maximum of elements from one level to the next and thus avoiding unrealistic overhead. In especially, the added value of simulation and emulation in this iterative process is elaborated.
In the remainder of this contribution, the activities of the development for the layer-2-protocol of a C2X-communication subsystem are described, where testing and verification are tightly integrated into a multi-level iterative protocol design flow. In the remainder of this contribution, the general flow for protocol design is described (ch. 2), before the concrete protocols that are already available for C2X-communication are presented (ch. 3). This chapter includes a short description of the authors’ project background from the Ko-TAG project. In ch. 4, the hardware and software setup of the emulator is presented, before first measurement results are shown and discussed in ch. 4.3.

2 State of the Art of Protocol Design

2.1 Process Models

A plethora of process models has been described for the development of software, hardware, and systems [1], where typically linear and iterative process models are distinguished. Iterative models differ from the linear models in such a way that the design and the verification are performed iteratively in a sequence of different abstraction levels. Iterative models are regularly used for the development of very complex microelectronic systems, i.e. in defense, aerospace or automotive industry, but find much less acceptance for the development of smaller systems. However, the extensive use of simulation and emulation can help to increase the number of iterations and thus to decrease the distance between two design cycles.

The spiral model for the design of new communication protocols is shown in Fig. 1 and contains the following steps:

- Level 1: The requirements are described in a customer requirements specification. These requirements include parameter like number of nodes, activity behavior of the nodes, channel conditions, real-time and energy requirements, necessity of multi-hop operation, etc.
- Level 2: Existing algorithms are researched and analyzed, and a proof of concept is elaborated. This might be done with abstract behavioral models, like sequence flow and state diagrams, preferably using Unified Modeling Language (UML). If necessary and suitable, top-level (abstract) simulations or calculations can help to proof the concept.
- Level 3: For communication protocols, event driven network simulators might help to support the transition from abstract description to concrete firmware implementation. This level is shortly described in subchapter 2.2.
- Level 4: Next step can be an emulator platform, where hardware can be used in a closed and reproducible test environment. The general approach is described in subchapter 2.3. Our concrete development is presented in ch. 4.
- Level 5: The tests conclude in real field trials, where as many of the test scenarios should be executed. However, full control of all parameters – and thus reproducibility - cannot be guaranteed. It is important to understand that the tools of the earlier steps can help to accelerate the implementation of the field tests. This is described in subchapter 2.4.