

Combining the Advantages of Simulation and Prototyping for the Validation of Dependable Communication Architectures: the TEODACS Approach

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ABSTRACT

One main challenge during the validation of automotive communication architectures is to consider the assembled system and more especially the interactions between the different components. We propose in this work a test and validation infrastructure based on tightly coupled co-simulation and prototype platforms. The co-simulation framework, on one hand, enables the efficient simulation of the entire network and the accurate analysis of the communication at different abstraction layers. On the other hand, the prototype framework is required for the model calibration and for the system validation on a realistic environment. We discuss further how the interconnection of these two platforms supports the analysis of both single components and entire communication networks. Experimental results illustrate our approach.

INTRODUCTION

The time-triggered paradigm [14] has been introduced to provide a reliable architecture for safety-critical systems. One of its important attributes is to shift the complexity to an earlier design phase and force the system designer to completely define the system behavior and thus a-priori solve the potential conflicts. The automotive industry has moved toward this concept with the introduction of FlexRay [1]. This communication protocol provides features like increased data rates (a factor of 10 faster than the CAN protocol) and the simultaneously support of time- and event-triggered schemes for both deterministic network behavior and the efficient transmission of single events. The deployment of FlexRay has influenced the entire system. The shorter bit durations, the large configuration space, the complex interactions between the layers as well as the paradigm shift are as much challenges the suppliers have to deal with.

The research project TEODACS (Test, Evaluation and Optimization of Dependable Automotive Communication Systems, www.teodacs.com) has been started with focus on these challenges. Its aims are to understand the interactions between the layers building a dependable network and to evaluate the different effects influencing the communication (e.g. topology, EMC). This project is a conjoint work between the virtual vehicle competence center, the industrial partners austriamicrosystems, AVL and CISC Semiconductor as well as the academic partners University of Applied Sciences FH Joanneum and the Institute for Technical Informatics (ITI) from the Graz University of Technology. The approach is based on the development of a co-simulation framework (FlexRayXpert.Sim) tightly interfaced to a realistic prototype (FlexRayXpert.Lab). The simulation framework, on one side, provides observability of the internal components and thus enables the efficient analysis of the system. On the other side, the prototype presents a real behavior both in the time and value domain. The coupling of these two platforms combines the advantages of the two approaches: It enables for example the analysis of real scenarios within the simulator or the validation of the simulation models on the basis of the prototype. The interfacing concept between the two environments provides access to the network at different abstraction levels. These different access points support efficient stimulation and analysis of single components as well as of the entire system.

The paper is organized as follows: The next section discusses the challenges of testing communication systems. In the third section the main concepts of this research projects are presented. Section 4 presents experimental results based on industrial test cases and summarizes the benefits of our approach. Finally, the last section concludes this paper.

VALIDATION OF COMMUNICATION ARCHITECTURES: THE CHALLENGES

Monitoring of distributed embedded systems is frequently used for debugging, logging and other analysis on the data level; see [21, 22, 23] for further information. Commercial tools for the analysis and diagnosis of the most popular automotive or real-time communication protocols are available. Examples are CANalyzer¹ for the CAN protocol, TTPView² for the TTP protocol, or the EB6100 with the EB tresos Inspector³ for the FlexRay protocol. Implementation issues of these and similar tools along with some use-case scenarios can be found, e.g., in [19, 20]. All these solutions, however, only enable the monitoring of the bus traffic on

top of the data link or higher layer employing COTS network controllers. The focus is set to the exchange of messages (e.g. engine speed) and not to the low level services (e.g. signal integrity within the physical cable). Moreover, the user is assumed to be an expert in his domain and the tool does not require to embed much technology know-how. Consequently, for the systematic, in-depth testing of a FlexRay based communication subsystem this needs to be complemented by bus monitoring and dedicated measurements on lower abstraction levels, as well as an appropriate data analysis.

One challenge for this in-depth analysis is the large domain of expertise required. Hence, know-how in the domain of signal integrity (signal quality within the cable, termination concepts [10]), analog and digital design (bus drivers, communication controller), PCB development as well as embedded software development is required. Furthermore, profound understanding of the effects influencing the system (e.g. EMC, vibration, large thermal gradients, splash of corrosive materials) is also needed to apprehend the environmental constraints and improve the robustness of the system. A further challenge is the analysis of the interactions between the layers. Hence, the communication is organized as a stack of layers and lower layers can influence higher ones. For example, it is important to know how the topology influences the communication (with respect to robustness or transmission delays) and if given configurations can be used for different bus topologies.

The approach chosen within the TEODACS project is to combine the advantages of hardware prototypes and simulation environments. Different works address the analysis of the communication network using dedicated hardware. The scope of the DECS project [17] is set to the analysis of system inconsistencies within automotive networks. It deploys a dedicated star-coupler with additional monitoring and non-symmetrical replay facilities (each branch can be separately controlled). The DECOS project [8] uses the TTx Disturbance Node² and provides an automated fault injection environment supported by SQL for the efficient validation of FlexRay networks. The STEACS project [4] proposes a systematic test approach for FlexRay networks based on the decomposition of the communication network into a fine-grained model. This approach is enhanced within the ExTraCT project [3] to perform the test transparently (i.e. concurrently to normal system operation and without any support from the application). All these works are making use of dedicated tester nodes; however, their scope is focused to specific components and does not take into account the communication system as a whole.

¹ <http://www.vector-informatik.com>

² <http://www.ttautomotive.com>

³ <http://www.elektrobit.com>

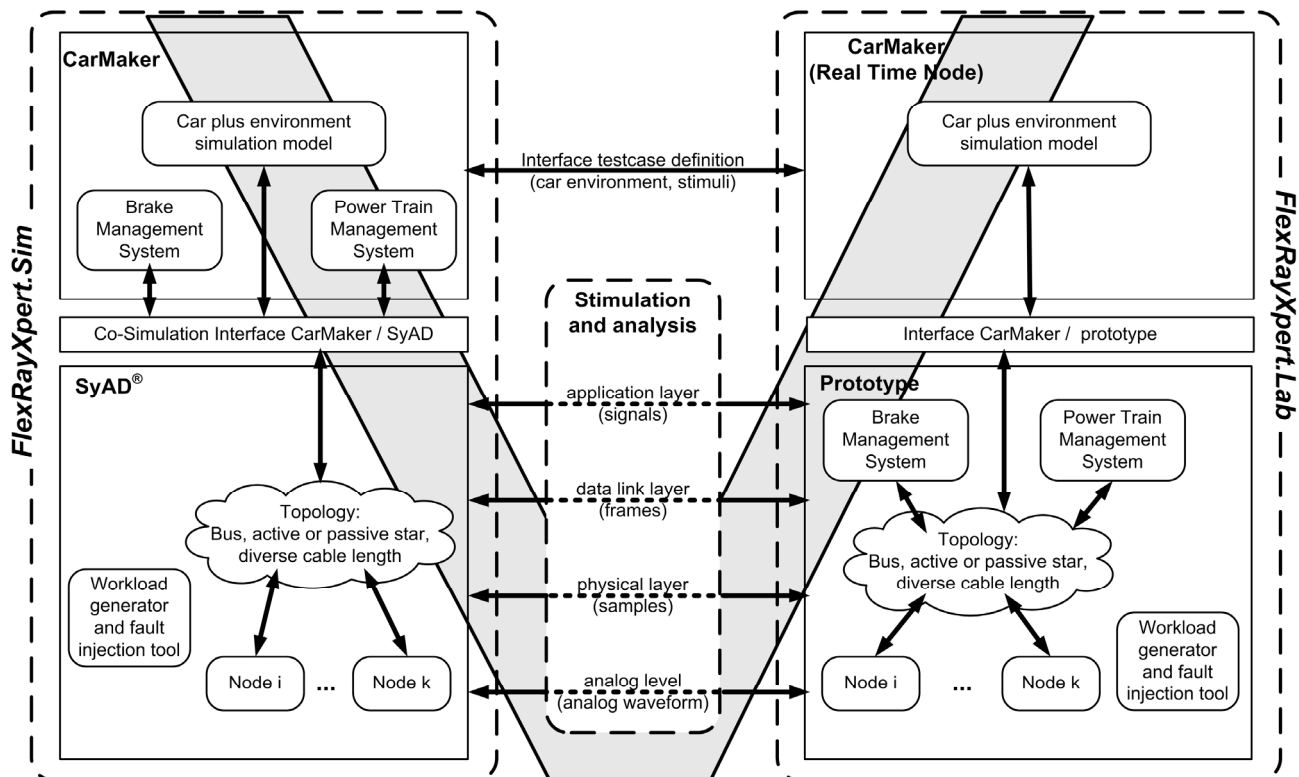


Figure 1: TEODACS approach

Regarding the simulation of automotive communication systems, different solutions for single components exist. For example, a FlexRay communication controller has been developed in SystemC [15] for the analysis of interconnected AUTOSAR components. Furthermore, a communication controller model developed with Verilog has been proposed in [16] for the assessment of message missing failures. Moreover, different FlexRay transceiver models are available: A generic model including physical effects like thermal power and modeled using VHDL-AMS is presented in [7], while the model presented in [18] is a specific behavioral Saber model. All of these approaches are focused on one single component, and the interactions with the other components are difficult to analyze.

One of the main challenges while simulating the entire communication architecture is the trade-off between the accuracy of the simulation model and the processing time. The observation window is in the order of several minutes with a resolution on the time scale under the nanosecond. High resolution (both in the time and in the value domain) is required for the modeling of the signal integrity within the cables as well as for modeling the external effects affecting the network (e.g. EMC). Moreover, the system under test consists of several ECUs (microcontroller unit, communication controller and bus drivers) and sums up several million of

transistors. The complexity can evidently not be managed with standard approaches that model the entire system at transistor level.

Another challenge is the definition of an appropriate process flow for network configuration. It includes the configuration of the FlexRay schedule, the slot allocation to the different nodes as well as the mapping between signals (messages from the application) and frames (containers sent on the bus). The number of parameters concerned rapidly grows with the system complexity (FlexRay configuration scheme, number of nodes considered, number of messages exchanged) and the configuration process has to be automated in order to minimize human errors.

It is the aim of the research project TEODACS to gather expertise for the deployment and validation of FlexRay based distributed systems. The novelty aspect of our project is the analysis of the communication services as an assembled component and the exploration of the interactions between the layers thereof. A main advantage of our approach is to combine the different expertise domains from our partners for the heterogeneous testing and evaluation of the system as a whole.