

Title	車載ネットワークシステムのモデル検査に関する研究
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# Abstract

In-vehicle networking (IVN) systems consist of electronic components that are connected by buses and communicate through multiple protocols according to their requirements. Communications between these subsystems are getting more complicated as the requirements for safety, comfort, and entertainment. Different communication protocols have their special mechanisms to transmit messages on buses, which affect safety and timed property of the IVN system. In practice, intelligent vehicles need to exchange safety data between subsystems that use various protocols, such as the Controller Area Network (CAN) and FlexRay. Such systems are more likely to encounter delays and message loss during transmission, presenting serious safety issues. Moreover, IVN systems are extremely complicated because of their large number of nodes, multiple communication protocols, and diverse topologies. As a result, it is difficult to check properties of the system directly and accurately. Besides, safety-critical events occur with a probability in the IVN system, such as the probability of failures and the probability of emergency events happened during driving. These probabilistic events are crucial to estimate real-time and reliability of the IVN system.

In this work, we propose a framework based on UPPAAL model checker, for modeling and verifying communicative behaviors between multiple protocols in an IVN system. Due to the complicated of the IVN system, we present an appropriate abstraction with two stages for modeling IVN systems that utilize CAN and FlexRay during the design phase. The architecture of the IVN system is abstracted to reduce the number of nodes first, and then the composition of each protocol is abstracted to simplify states of systems based on protocol specifications. As there are numerous IVN system structures, a reusable framework is developed to build a design model for IVN systems with different topologies. In the framework, an IVN system model consists of protocol, interface, configuration, forwarder and environments modules. The environments and forwarder modules are changeable according to system design. The protocol, interface and configuration modules are fixed to construct various IVN systems.

Using this framework, we check IVN systems from qualitative verification and quantitative verification. Through the qualitative verification, the timed properties of communication are analyzed using the UPPAAL platform; we verify the reachability and response time of messages in the best case and worst case. Through the quantitative verification, the probability of message reachability during a time interval is given by application probability models in the SMC-UPPAAL; the probability density and probability distribution of response time is used to analyze the frequency for receiving messages. The two verifications complement each other. The qualitative verification is exhaustive, but the efficiency and capability is limited. The quantitative verification is more efficient, but the properties are satisfied with some degree of confidence.

The framework is evaluated through several aspects. First, we evaluate the validity of the abstraction. The framework is preservation for outside of the subsystem, however, the inside of subsystem cannot be preserved. We list properties from specifications, and the framework is validated by checking the communication behavior against the protocol specifications and some properties can be checked. But some properties cannot be checked because of the abstraction. Second, we demonstrate the applicability of the framework with three typical topologies. Third, we compare source code of three different systems in UPPAAL, the framework is reusable for different system with little change. Finally, we show the performance of the framework in qualitative verification and quantitative verification.

**Keywords:** Model Checking, Statistical Model Checking, UPPAAL, In-vehicle Network System, CAN and FlexRay.