Toward a Modeling Language Prototype for Modeling the Behavior of Wireless Body Area Networks Communication Protocols

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Abstract: Modeling and evaluating the behavior of the medium access control (MAC) protocols of wireless body area networks (WBANs) through the model-checker toolset UPPAAL-SMC necessitate a certain level of expertise. The thing that is not available for many MAC protocol designers. To facilitate the use of UPPAAL-SMC, we propose to define a model-driven engineering (MDE) approach that uses a modeling method (MM) as a start and the UPPAAL-SMC as a target and back. In this paper, we use the ADOxx platform to define the domain-specific modeling language (DSML) of WBAN that is presented through the name WBAN modeling language (WBAN-ML) to model the behavior of the WBANs MAC protocols. The prototype implementation result of the WBAN-ML is presented in this paper.

1 MOTIVATION

Throughout the last years, the statistics (Latré et al., 2011; Chen et al., 2011; Movassaghi et al., 2014) have shown that many people die because of the late diagnosis of chronic and fatal diseases, such as cancer, cardiovascular, asthma, and diabetes. While in recent times, the development of technologies, such as microelectronics miniaturization, sensors, and wireless networks led to the emergence of wireless body area networks (WBANs) as a solution.

The WBAN (Latré et al., 2011; Chen et al., 2011; Movassaghi et al., 2014) is composed of bio-medical sensors nodes that can be worn on or placed in the human body to measure certain physiological parameters of the human body, such as temperature and pressure. These sensors nodes must wirelessly send their data to a control and monitoring device carried on the body. This device then delivers its data via a cellular or Internet network to an emergency center or a doctor room on the basis of which an action can be taken.

WBANs (Latré et al., 2011; Chen et al., 2011; Movassaghi et al., 2014) have enormous potential to revolutionize the present and the future of health care services, they provide a proactive diagnosis of many deadly diseases, as well as remote and real-time monitoring. On the other hand, WBANs impose several challenges to the medium access control (MAC) protocols design concerning the energy-efficiency, quality-of-service, priority, scalability, reliability, and security. The importance of WBAN encouraged the researchers to propose new MAC protocols in order to satisfy the WBAN requirements, and then, evaluate the performance of these proposed MAC protocols.

The WBAN is considered as a stochastic environment, where the prediction of the time when the physiological parameters change their values is non-deterministic. The problem is how to model and evaluate the behavior of the MAC protocols under the stochastic nature of the WBAN. As a solution, we used the statistical model-checking (SMC) toolset UPPAAL-SMC (David et al., 2015). This toolset can provide a stochastic interpretation of the stochastic behavior of complex and real-time systems, such as WBANs.

Modeling and evaluating the behavior of MAC protocols through the stochastic timed automata (STA) and the metric interval temporal logic (MITL) specifications adopted by UPPAAL-SMC necessitate a certain level of expertise. The thing that is not available for many MAC protocol designers. To facilitate the use of UPPAAL-SMC powerful analysis algorithms, we propose to define a model-driven engineering (MDE) approach that uses a modeling method as a start and the UPPAAL-SMC as a target and back.

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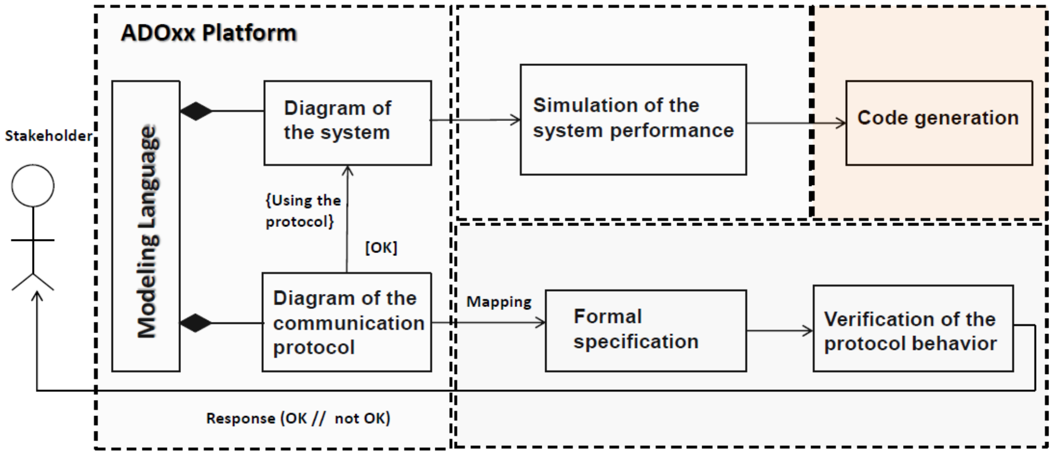

Figure 1: The WBAN-MDE global structure.

The stakeholders of this MDE are the WBAN communications protocols designers and researchers for the purpose of modeling, simulating, and verifying the behavior of the WBAN communication protocols, especially, MAC protocols as illustrated in Figure 1.

2 PROPOSITION

Our contribution aims to define an MDE approach that uses the ADOxx platform as a start and the UPPAAL-SMC toolset as a target. To realize this approach, we should define, at first, our modeling method in ADOxx through the Meta-models of our domain-specific modeling language (DSML), domain-specific query language (DSQL), and domain-specific representation (DSR): 1) we create the DSML Meta-models to model the behavior of the MAC protocols. 2) We specify the DSQL Meta-models to check the MAC protocols properties. 3) We create the DSR Meta-models to express the analysis results in an understandable way for the MAC protocols designers. Then, we should introduce the Meta-models of UPPAAL-SMC's STA, Queries, and Traces. Finally, we should model the transformations from the ADOxx models to UPPAAL-SMC models and back. The steps involving the construction of our approach are the follows:

- Step 1: Creation of the Meta-models of the DSML for modeling the behavior of the MAC protocols.
- Step 2: Introduction of the Meta-models of the UPPAAL-SMC's STA.
- Step 3: Definition of the transformation rules from the DSML to UPPAAL-SMC's STA using the extensible stylesheet language transformations (XSLT).
- Step 4: Specification of the Meta-models of the DSQL to check the MAC protocol properties.
- Step 5: Introduction of the Meta-models of the UPPAAL-SMC Queries.
- Step 6: Definition of the transformation rules from the DSQL to UPPAAL-SMC Queries using a transformation method.
- Step 7: Introduction of the Meta-models of the UPPAAL-SMC Traces that presents the results of the model checking process. This latter checks if the stochastic timed automata model satisfies the property specified by the Query.
- Step 8: Creation of the Meta-models of the DSR to express the analysis results in an understandable way by the MAC protocols designers.
- Step 9: Definition of the transformation rules from the UPPAAL-SMC Traces models to DSR using a transformation method.

ADOxx Meta modeling platform (Karagiannis et al., 2016) is an open-source experimentation environment for researchers and practitioners to realize individual Meta-models and model processing functionalities for domain-specific conceptual modeling methods as modeling tools. The Meta-model (Kelly and Tolvanen, 2008) is considered as a specification language-the word "meta" is used because the specification language is one level higher than the usual models. A Meta-model is defined as a conceptual model of a modeling language. It describes the concepts of a language, their properties, the legal connections between language elements, model hierarchy structures, and model correctness rules. The Meta-model is not only important in defining languages but also it is advantageous in systematizing and formalizing weakly defined languages, providing a more "objective" approach to analyzing and comparing languages and examining linkages between modeling languages and programming languages. The Meta-model is also successfully used in building modeling tools, interfaces between tools (e.g., CDIF, XML), and repository definitions. According to (Fill and Karagiannis, 2013; Karagiannis, 2015; Karagiannis et al., 2016), the Conceptualization of Modeling Methods is a process of realizing a Modeling Method. This process is divided into five phases forming a lifecycle (or more specific, the conceptualization Lifecycle). These phases are defined as follows:

- Step 1: The Creation phase uses techniques of knowledge acquisition and requirements elicitation in order to obtain modeling language requirements and the modeling functionality requirements.
- Step 2: The Design phase produces specifications for the Meta-model, the language grammar, and the recommended graphical representation and functionality.
- Step 3: The Formalization phase ensures that the outcome of the previous phase has no ambiguity, either with the purpose of sharing specification within a community or in preparation for a platform-specific implementation.
- Step 4: The Development phase will produce a modeling prototype or proof of concept on the targeted Meta-modeling platform.
- Step 5: The Deployment/Validation phase deals with packaging and installing the modeling proof of concept and analyzing its user experience and the conformance to modeling requirements.

Based on the conceptualization phases, we start realizing our modeling method. We define in the following the DSML of WBAN that is presented through the name WBAN Modeling Language (WBAN-ML) to model the behavior of the WBANs MAC protocols.

3 WBAN-ML

Our contribution aims to create a simple WBAN-ML that can be used by the WBANs MAC protocols designers and researchers to model the behavior of their proposed WBANs MAC protocols. We propose to use a simple flowchart to model the behavior of MAC protocols. The realization of WBAN-ML requires Meta-models, concepts, and notations. We divide our WBAN-ML into three models of three Meta-models based on the ADOxx Meta-Metamodel, as depicted in Figure 2: the WBAN model, the Node model, and the Hub model.

The WBAN model concepts are the external environment, where the body can exist, the body, the nodes and the hub that are placed on the body. The notations used for the WBAN model concepts are the same notations adopted by the WBAN community, as depicted in Figure 3. The Meta-model of the WBAN model is defined in Figure 5.

The Node model and the Hub model have the same behavior modeling concepts, except that the node has three sensors concepts. The notations used for these concepts are the same notations used for the ordinary flowchart concepts, as depicted in Figure 4. The Meta-models of the Node and the Hub models are defined in Figures 6 and 7, respectively.

We mention that this part is under discussion and modification, the reason for its short description. The Figure 8, represents the prototype implementation result of the WBAN-ML.

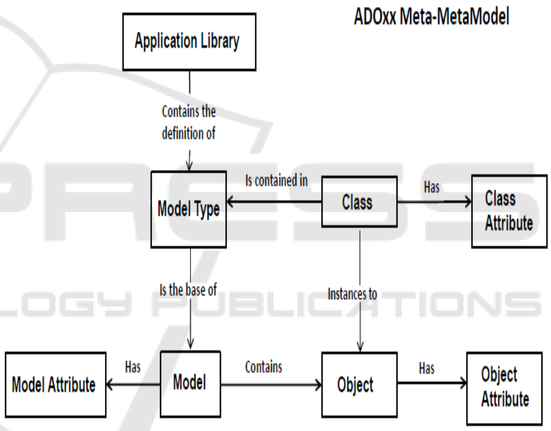

Figure 2: Used part of the ADOxx Meta-Meta model.

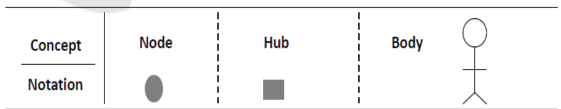

Figure 3: Concepts and notations of the WBAN model.

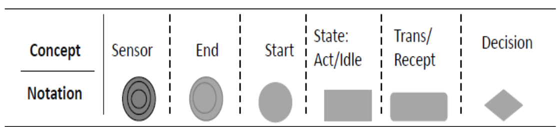

Figure 4: Concepts and notations of the Node and the Hub models.

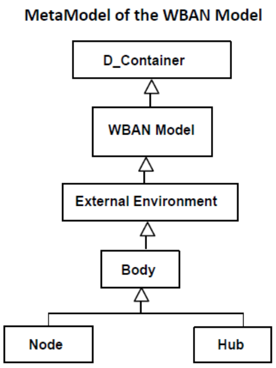

Figure 5: Meta-model of the WBAN model.

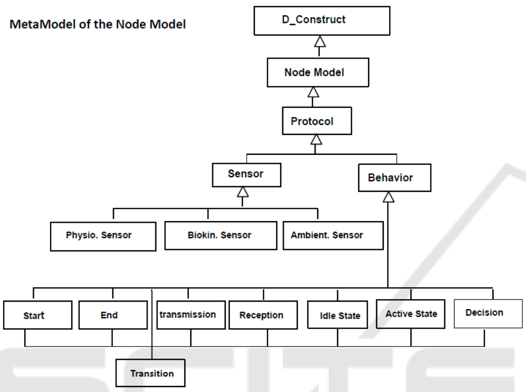

Figure 6: Meta-model of the Node model.

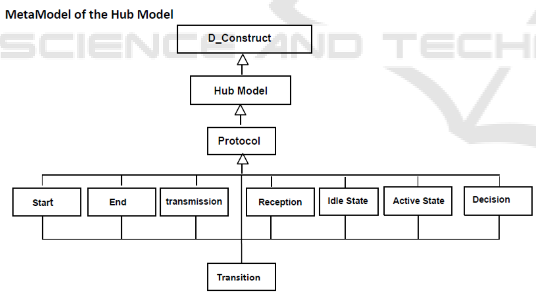

Figure 7: Meta-model of the Hub model.

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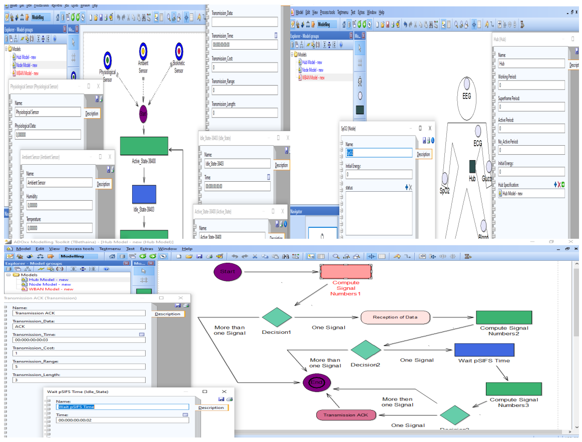

Figure 8: Prototype of the WBAN-ML.

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