Towards the Usage of MBT at ETSI

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In 2012 the Specialists Task Force (STF) 442 appointed by the European Telcommunication Standards Institute (ETSI) explored the possibilities of using Model Based Testing (MBT) for test development in standardization. STF 442 performed two case studies and developed an MBT-methodology for ETSI. The case studies were based on the ETSI-standards GeoNetworking protocol (ETSI TS 102 636) and the Diameter-based Rx protocol (ETSI TS 129 214). Models have been developed for parts of both standards and four different MBT-tools have been employed for generating test cases from the models. The case studies were successful in the sense that all the tools were able to produce the test suites having the same test adequacy as the corresponding manually developed conformance test suites. The MBT-methodology developed by STF 442 is based on the experiences with the case studies. It focusses on integrating MBT into the sophisticated standardization process at ETSI. This paper summarizes the results of the STF 442 work.

1 Introduction

Driven by technological advances and an ever-growing need for software and systems quality improvements, MBT has matured in the last decade from a topic of research into an industrial technology. MBT has been successfully used for the automatic generation of test documentation and test scripts in a wide range of application areas including information and communication technology, embedded systems and medical software. This trend is reflected by the availability of various commercial tools and increasing efforts in MBT-related standardization. The utilization of MBT in industry show significant gains in productivity, in particular due to savings in the test maintenance phase.

In 2010, the ETSI Technical Committee (TC) on Methods for Testing and Specification (MTS) published a first ETSI standard on MBT (ES 202 951) [3] as the result of a joint effort of different stakeholders at ETSI including MBT tool vendors, major users, service providers, and research institutes. In order to enable the use of this technology at ETSI, the applicability of MBT in ETSI processes has to be shown and methodology guidelines for applying MBT in the context of standardized test development are needed. For this purpose ETSI TC MTS started in 2012 STF 442. STF 442 consists of five experts from industry and academia with 30 working days each. The work was conducted from February 2012 to December 2012. STF 442 performed two case studies from the ETSI domains Intelligent Transportation Systems (ITS) and Universal Mobile Telecommunications System (UMTS) and used the gained experience for developing ETSI MBT methodology guidelines.

In the following, we present the case studies, describe the methodology and discuss problems encountered when applying MBT in the case studies.

2   Case Studies

The following four MBT tools have been used for the case studies:

- **Conformiq Designer** is the MBT tool of Conformiq Inc. [1]. Conformiq models are written in a combination of Java code and UML statecharts, i.e., in the Conformiq Modeling Language (QML). The models describe the expected external behavior of the System Under Test (SUT). Java code is used to describe the data processing of the SUT, to declare data types and classes, to express arithmetics and conditional rules as well as others. UML statecharts are used to capture high-level control flow and life cycle of objects. The core of Conformiq Designer is its semantics driven, symbolic execution based test generation algorithm. The algorithm traverses a part of the (usually infinite) state space of the system model. The test generation heuristics that Conformiq Designer uses realize various well-known test generation strategies, e.g., requirements coverage, transition coverage, branch coverage, atomic condition coverage, and boundary value analysis.

- **Microsoft Spec Explorer** for VisualStudio 2010 is a Microsoft MBT tool [10]. Spec Explorer uses state-oriented model programs that are coded in C#. Test generation is performed by exploring the state space of the system model and recording the traces. These traces are transformed into test cases. The main technique for dealing with state space explosion provided by Spec Explorer is scenario-based slicing. A scenario limits the potential executions of the model state graph, while preserving the test oracle and other semantic constraints from the system model. Slicing scenarios along with test data used as input for model operations are defined in the scripting language Cord.

- **Sepp.med MBTsuite** is the MBT framework from the sepp.med GmbH [11]. For applying MBTsuite, a graphical model of the SUT has to be provided. In our case studies, UML state and activity diagrams have been used. MBTsuite excutes models and transforms the execution traces into test cases. Apart from full path coverage, other generation strategies are available (e.g. guided generation, random generation). If defined in the model, guard conditions and priorities are taken into account at execution time. Thus, only logically consistent execution traces are obtained and processed into test cases. It is possible to filter the execution traces prior to test case generation using several built-in heuristics like, e.g., node coverage, edge coverage, requirement coverage, but also heuristics based on test management information (costs, duration).

- **Fraunhofer MDTester** is an academic MBT tool developed by the Fraunhofer FOKUS competence center MOTION [9]. MDTester is part of Fokus!MBT, a flexible and extensible test modeling environment based on the UML Testing Profile (UTP), which facilitates the development of model-based testing scenarios for heterogeneous application domains. MDTester is a modeling tool that guides the development of UTP models. UTP models are test models and not system models, i.e., they include tester knowledge like, e.g., setting of test verdicts, knowledge about test components, or default behavior. For modeling, MDTester provides the following diagrams types: test requirements diagram (based on class diagram), test architecture diagram (based on class diagram), test data diagram (based on class diagram), test architecture diagram, test behavior diagram (based on sequence and activity diagrams).

The case studies were based on ITS and UMTS protocols standardized by ETSI. In addition, STF 442 conducted the academic example of a simple automated teller machine to gain experience with the tools.

For the ITS-based case study, conformance tests for the location service functionality of the GeoNetworking protocol (ETSI TS 102 636) [6] have been generated from previously developed models. The GeoNetworking protocol belongs to the ITS network layer. The location service functionality is used to discover units with certain addresses and to maintain data on their geographical location.

The Rx interface (ETSI TS 129 214) [8] of UMTS provides the base for the second case study. The Rx interface supports the transfer of session information and policy/charging data between Application Function and Policy/Charging Rules Function on top of the Diameter protocol.

In both case studies, the modeled behavior of the System Under Test (SUT) can be described with approximately 12 control states and a slightly higher number of transitions between them. However, the main complexity of the SUT-model behavior is related to data stored and used during operation. For the GeoNetworking case study, this data refers to addresses and geographical locations; whereas session settings and policy rules are most important the behavior of the Rx interface case study.

Two different approaches have been used for modeling. The first approach started from the manually developed test purposes [7, 5] and resulted in SUT-models sufficient to cover all the test purposes, meanwhile adding some more details from standard requirements. The second approach was based on the requirements in the base standard. The constructed SUT model tried to reflect all of them in their behavior. Both approaches were successful in a sense that the models were suitable for test generation.

In spite of the fact the different tools use different formalisms as input for SUT models and provide different means to control test generation, all tools managed to generate test suites that cover almost the manually developed test purposes. Thus, from a technical point of view, modern MBT tools are able to support test development in standardization.

The case studies are documented in [4]. The report includes detailed descriptions of the SUT behavior and the models, a discussion of modeling approaches, the generated tests, and overall evaluation.

3   Methodology Guidelines

The second goal of the STF work was the development of methodology guidelines for an MBT-based development of conformance tests at ETSI [2]. ETSI has a very sophisticated test development procedure shown on the left side of Figure 1. Test development starts with the identification of requirements followed by the creation of Implementation Conformance Statement (ICS) and Interoperable Function Statement (IFS). ICS/IFS define implementation options for a standard. In the testing process, they are used for test case selection. The ICS/IFS creation is followed by the specification of the test suite structure, which in most cases arises from the functionality to be tested. Afterwards, high-level test descriptions, i.e., test purposes, are stepwise refined leading to the test cases, which are finally validated. The test development steps lead to documents represented by the ellipses in the middle of Figure 1.

The integration of MBT in the ETSI process is shown on the right side of Figure 1. The modeling for testing is based on standard and requirements. If possible, implementation options (i.e., ICS/IFS) are considered in modeling. The modeling process can be seen as an additional validation step for the standard, the requirements and the implementation options. Problems in modeling may identify ambiguities in the standard or untestable requirements. The model serves as input for the test generation. Problems identified during test generation or in the generated tests may identify problematic requirements or require adaptations in the SUT model. For integrating MBT into the ETSI test development process, documents describing test suite structure, test purposes, test descriptions and test cases have to be generated.

Even though this embedding of MBT into the ETSI test development process looks straightforward, several issues need to be solved before MBT can improve the existing process. A main problem is the
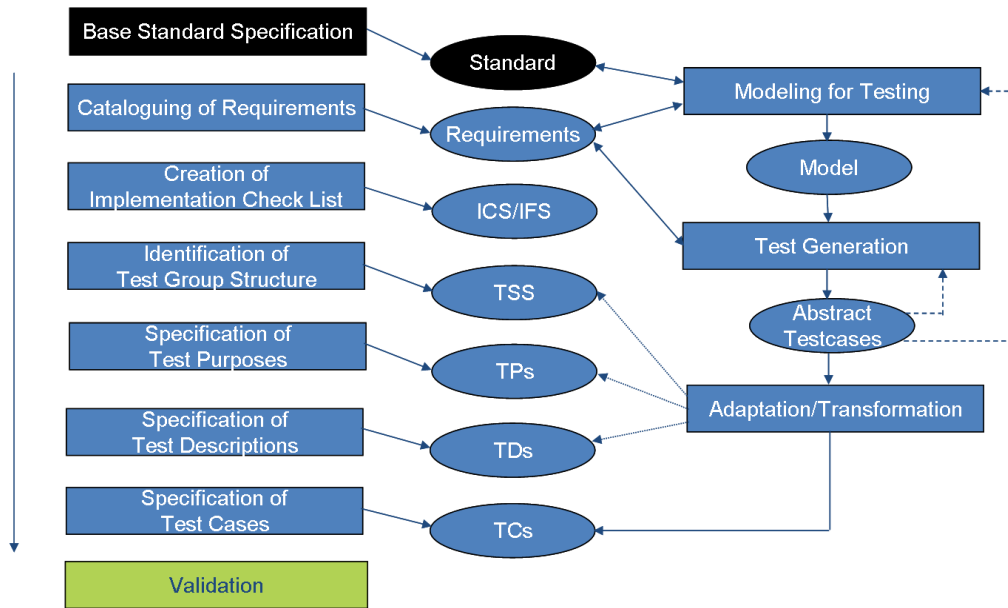
Figure 1: Using MBT within the ETSI test development process

maintenance and consistency of model and test documents. On the one hand, MBT only requires maintenance and further development of models while test cases are generated and not manually developed. On the other hand, each test case is an asset and its implementation can be very costly. Reviews and discussions are therefore mainly based on individual test descriptions and not on models. Another issue is the selection of a modeling language. Even though all MBT tools used for the case studies allow state-oriented modeling, the input languages differ considerably. A pragmatic solution to this problem may include the standardization of an ETSI modeling language.

In addition to issues regarding the test development process, the ETSI MBT methodology guidelines also offer guidance for identification and modeling of requirements, establishing traceability from models to standard requirements, choosing model scope and abstraction level, selecting test coverage criteria, improving maintainability and parameterization of generated tests, as well as assessing the quality of models and tests.

4   Summary and Conclusions

STF 442 has successfully applied MBT to generate conformance tests for two ETSI protocols. Both case studies have been performed with all tools. All tools were able to generate to test suites having an adequacy level comparable with manually designed tests. Based on the case studies, ETSI MBT methodology guidelines have been developed. The methodology guidelines focus on integrating MBT into the standardization process at ETSI. Some challenges have been identified during the STF work:

- An efficient usage of MBT in standardization requires significant expertise in several areas, like e.g., the domain of the SUT, modeling, MBT tool application, and test development. Experts experienced in all areas are difficult to find.

- There exists an abstraction gap between automatically generated and manually specified test cases. Manually test cases are usually more maintainable and can be subject of a review. By considering

parameterization, manually developed test cases allow an easy adaptation to different implementations of a standard. Solving this issue can be seen as a requirement for future MBT tools.

- The conformance test development process at ETSI is tightly intertwined with test suite maintenance issues and with handling each test case as a separate artifact. Test cases are designed individually and are subject of discussions and reviews. In contrast to the ETSI process, one of the main MBT advantages is the transfer of all maintenance work to the modeling, while tests are considered to be generated automatically as often as needed, i.e., maintenance of automatically generated tests is not necessary. For ETSI, taking full advantage of MBT may require new processes changing from the test case centric development to model standardization and maintenance.

Acknowledgements

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