

On the Standardization of Conformance Tests for Communicating Systems

– State of the Art and Future Trends –

Prof. Dr. Jens Grabowski

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Before I start ...



I come from ...



I come from ...





GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN



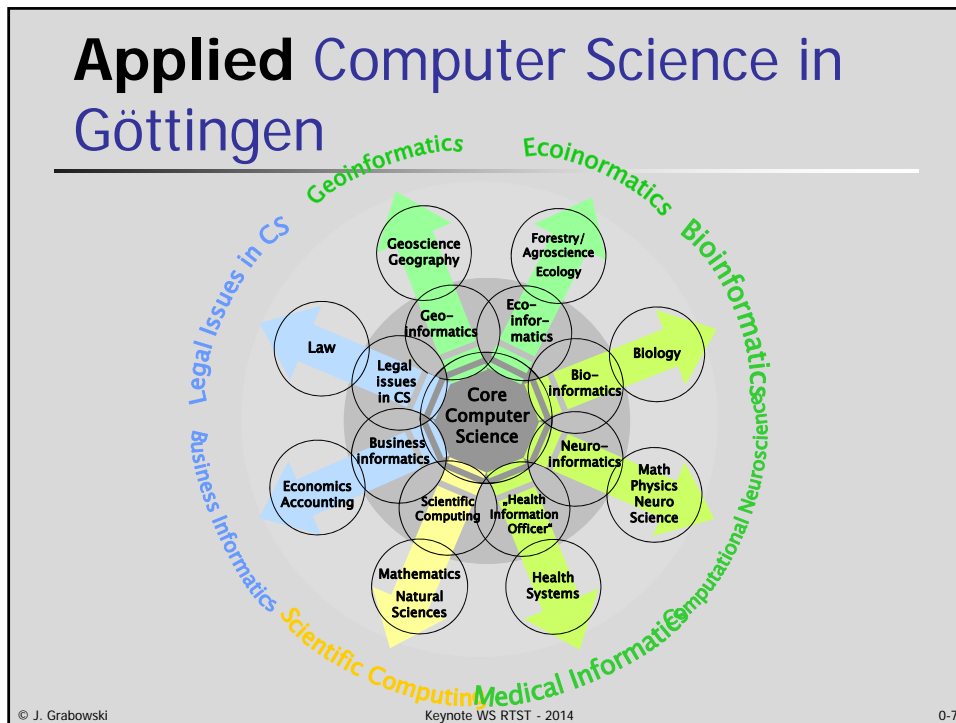
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Georg-August Universität Göttingen

- Founded 1737
 - by King Georg II of Great Britain (Georg August of Hannover)
- 44 Nobel laureates
- Rankings
 - No. 63 (THE)
 - No. 79 (Shanghai)
- 13 faculties
 - covering almost all academic disciplines, including medicine
- About 26,500 students

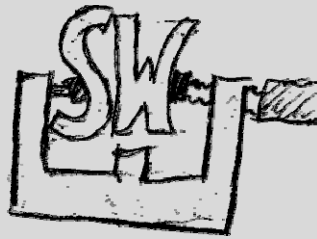
Applied Computer Science in Göttingen



International Programs

- M.Sc. in Internet Technology & Information Systems (ITIS)
- M.Sc. Applied Computer Science
 - Summer term 2014: 57 applicants from India
 - Winter term 2014/15: 45 applicants from India
- PhD Program in Computer Science (PCS)
- PhD Program in Environmental Informatics (PEI)

Research Group: Software Engineering for Distributed Systems



- Logo indicates workbench for
 - systematic software development and
 - continuous quality assessment and quality improvement



Software Engineering for Distributed Systems Group



Jens Grabowski



Annette Kadziora



Heike Jachinke



Gunnar Krull



Fabian Glaser



Patrick Harms



Steffen Herbold



Verena Honsel



Philip Makedonski



Daniel Honsel



Xiaowei Wang



Sripriya Srikant Adhatarao

Current Research Topics



- Quality Assurance (QA)
 - Usage based testing
 - Usability Engineering
 - Test Languages
 - TTCN-3, TDL, UML Testing Profile
 - QA for test specifications
 - QA for Grid and Cloud systems
 - Interoperability testing
 - Reliability engineering
 - Model-based Testing
 - Managed Software Evolution

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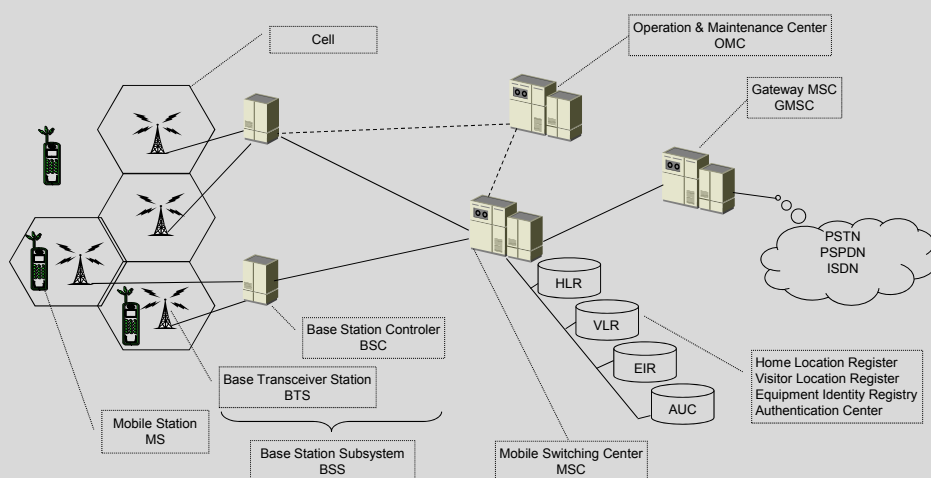
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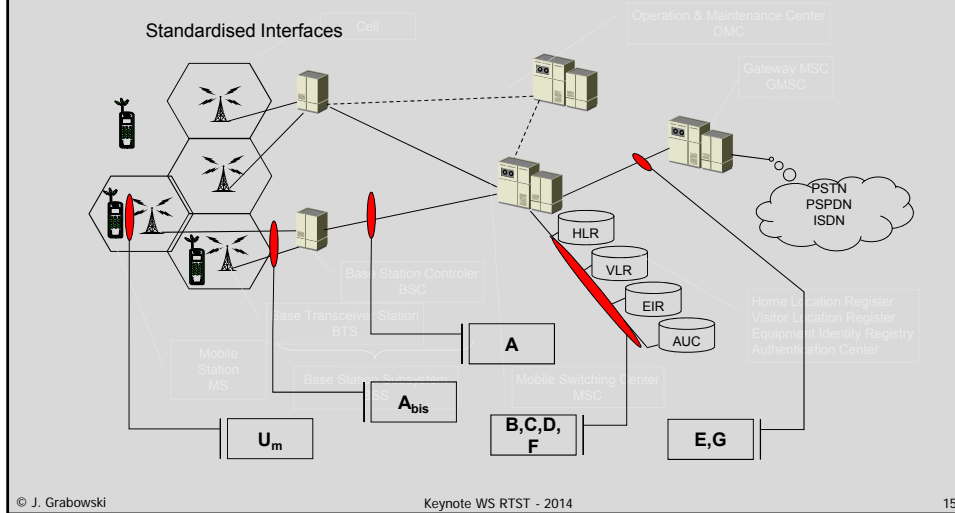
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- Test Description Language (TDL)
- Summary and Conclusions

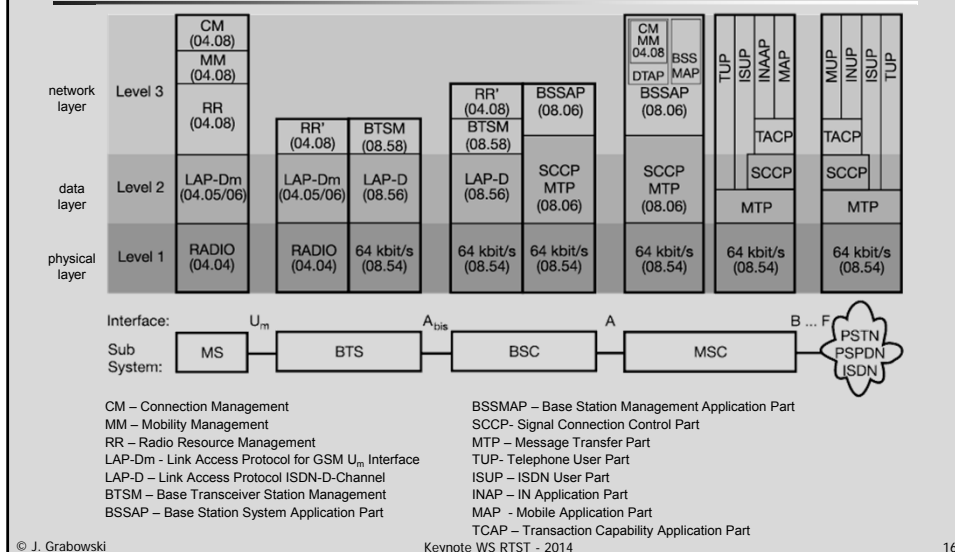
Motivation: 1(5) Why Conformance Testing?



Motivation: 2(5) Why Conformance Testing?



Motivation: 3(5) Why Conformance Testing?



Motivation

4(5)

- Conformance testing is **black-box testing**
- Test development is **based on standards**
- Goal: Proof of conformance to standards

Motivation

5(5)

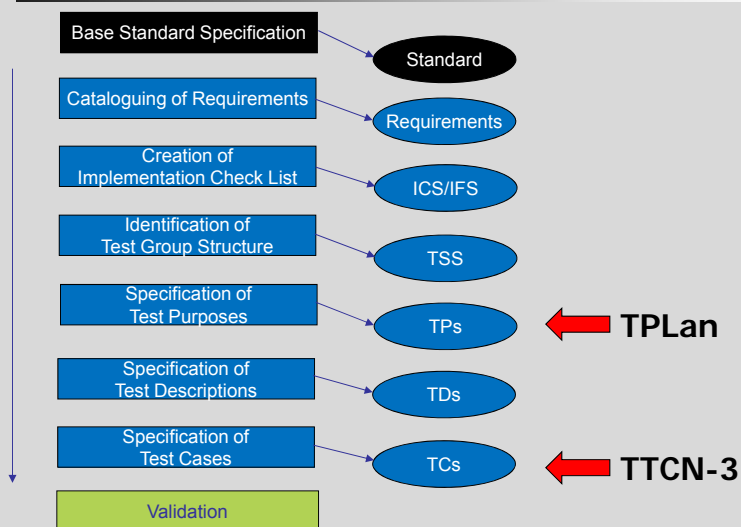
- European Telecommunications Standards Institute (ETSI)
 - Members
 - >750 members, from 63 countries on 5 continents
 - Standards
 - Between 2,000 and 2,500 standards every year
 - Since establishment in 1988: >30,000 standards
 - Key global technologies: GSM™, 3G, 4G, DECT™, smart cards
 - ETSI work includes the development of
 - test methodology and test languages
 - test specifications



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Standardization of Conformance Tests: Process Overview

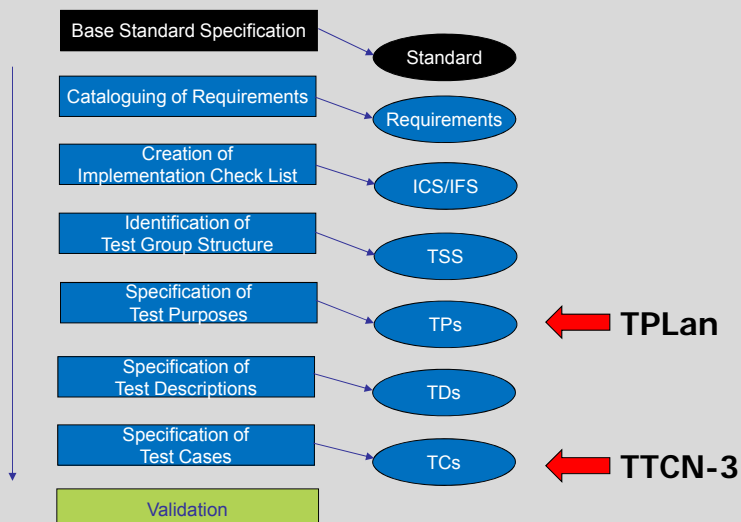


Standardization of Conformance Tests: TPlan (ETSI ES 202 553)

- Example from GeoNetworking protocol (ETSI TS 102 636)

TP Id	TP/GEONW/PON/SEQN/BV/02
Test objective	Test of the local sequence number incrementing
Reference	TS 102 636-4-1 [1], clauses 7.3.2, 9.2.3.3, 9.3.4.2
Config Id	CF01
PICS Selection	
Initial conditions	
with { the IUT being in the "initial state" and the IUT having received Beacon information from ItsNodeB and the IUT having sent a GeoUnicast packet to ItsNodeB containing the Sequence Number field indicating value SN1 }	
Expected behaviour	
ensure that { when { the IUT is requested to send a GeoUnicast packet to ItsNodeB } then { the IUT sends a GeoNetworking packet containing a correctly formatted Common Header containing HT field indicating value 'Z' (GEOUNICAST) containing GeoUnicast Extended Header containing SN field indicating value SN1 + 1 } }	

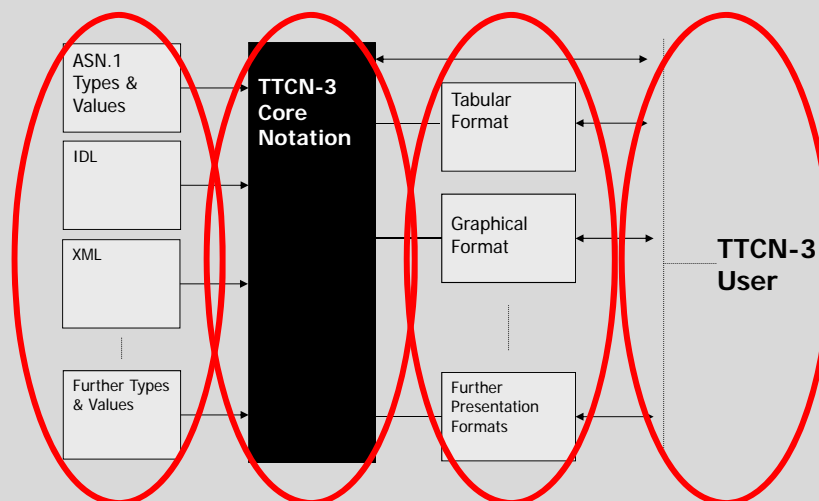
Standardization of Conformance Tests: Process Overview



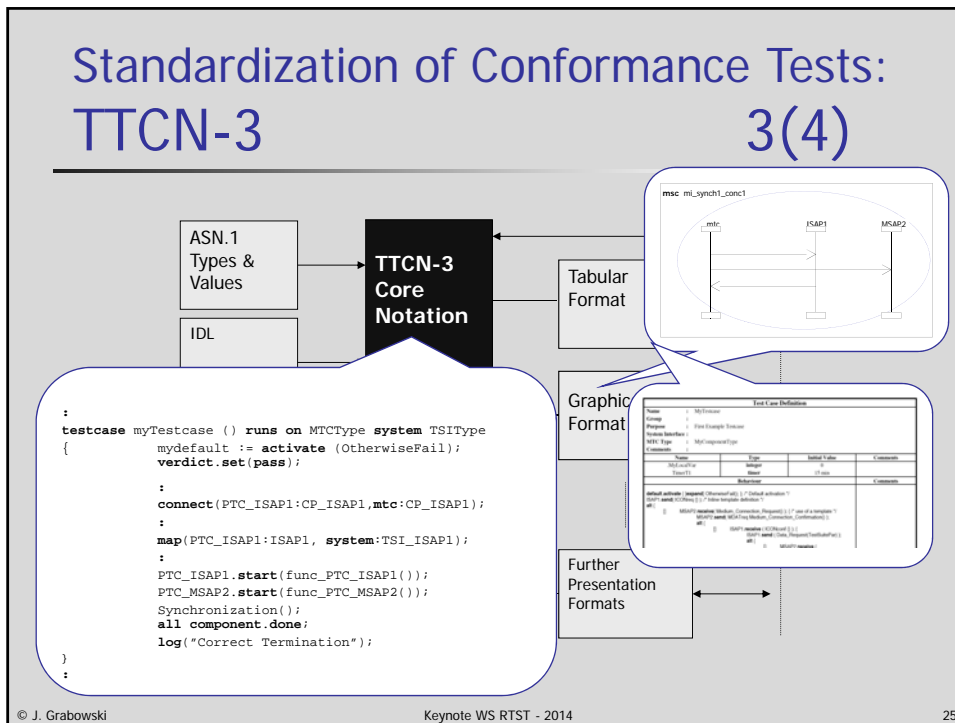
Standardization of Conformance Tests: TTCN-3 1(4)

- The standardised test specification and implementation language
- TTCN-3 is
 - developed by ETSI from 1999 to 2001
 - continuously maintained and further developed
- Applicable to all kinds of reactive and distributed systems
- Example applications at ETSI:
 - WiMax, VoIP with SIP, IMS, IPv6, dPMR, DMR, ITS
- Also used for test specifications by:
 - 3rd Generation Partnership Project (3GPP)
 - Automotive Open System Architecture (AUTOSAR)
 - Terrestrial Trunked Radio (TETRA)
 - Open Mobile Access (OMA)

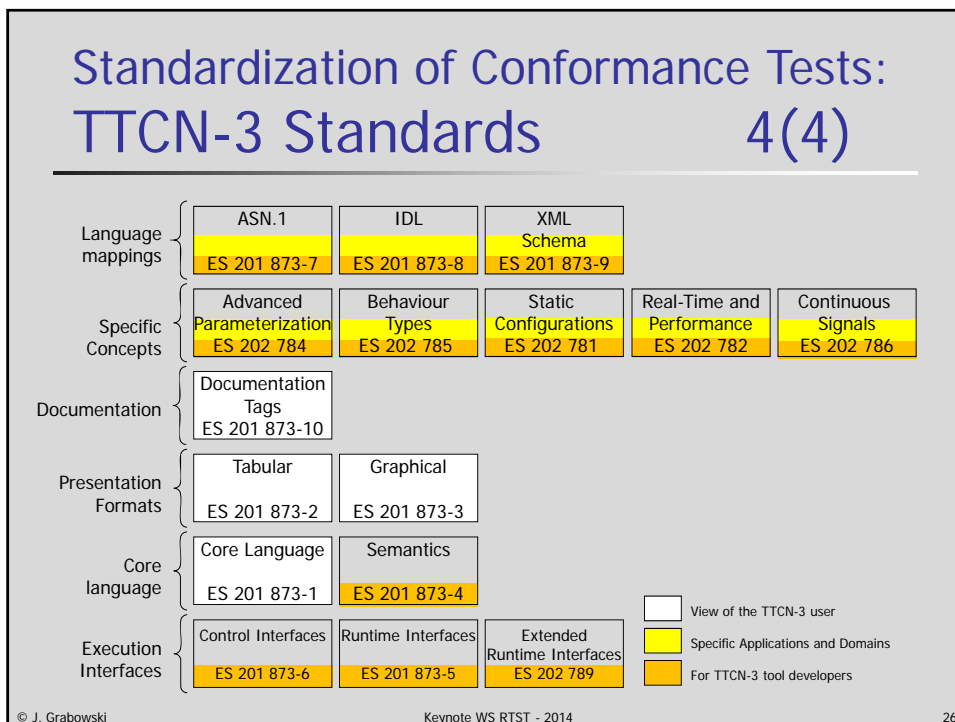
Standardization of Conformance Tests: TTCN-3 2(4)



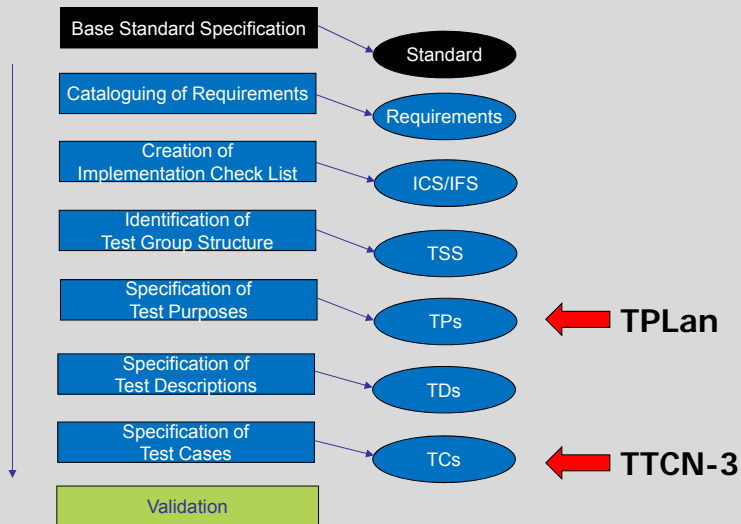
Standardization of Conformance Tests: TTCN-3 3(4)



Standardization of Conformance Tests: TTCN-3 Standards 4(4)



Standardization of Conformance Tests: Process Overview



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Towards the Usage of Model-Based Testing in the Standardization of Communicating Systems

- Contents
 - Introduction
 - Case Studies
 - ETSI MBT Methodology Guidelines
 - Conclusions

Introduction

1(2)

- Model-Based Testing (MBT) has matured into an industrial technology
 - Successfully used in a wide range of application areas
- Enable MBT technology at ETSI
 - ETSI standard on model-based testing
 - ETSI MBT User Conference
 - Next step: Applying MBT in standardized test development
- Goals
 - Assess feasibility
 - Create a methodology and a process
 - Determine next steps in MBT standardization

Introduction

2(2)

- Specialist Task Force (STF) 442 initiated by ETSI
- Manpower
 - 4 speicalists with 30 days each (120 working days total)
- Duration
 - Feb. 2012 – Dec. 2012, publication of documents April 2013
- Expected Results
 - Case study report
 - Experiments with state of the art MBT tools
 - Evaluation: MBT and ETSI test development
 - ETSI MBT methodology guidelines
 - Tool independent
 - Outlining the usage of MBT at ETSI

Towards the Usage of Model-Based Testing in the Standardization of Communicating Systems

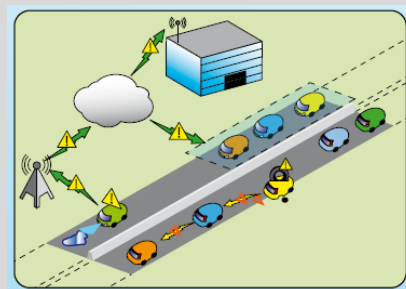
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Case Studies: Overview

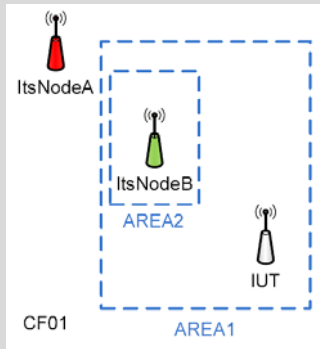
- Tools
 - Fraunhofer MDTester (academic)
 - Conformiq Designer
 - Microsoft SpecExplorer
 - Sepp.med MBTSuite
- Case studies
 - Academic example
 - Automated Teller Machine (ATM)
 - GeoNetworking protocol (ETSI TS 102 636)
 - Intelligent Transportation Systems (ITS)
 - Location service functionality of the GeoNetworking protocol
 - Packet routing in ad-hoc networks, packet distribution in a geographical area
 - Diameter protocol (ETSI TS 129 214)
 - UMTS, LTE, Rx interface
 - Conveys session information and policy/charging rules between the Application Function (AF) and the Policy/Charging Rules Function (PCRF)

Case Studies: GeoNetworking Protocol

- Vehicles exchange information with
 - other vehicles,
 - road infrastructure, and
 - Internet peers.
- Example usages
 - Locating free parking lots
 - Instant notifications
 - Braking actions
 - Road hazards
 - Traffic conditions



Case Studies: GeoNetworking Test Purpose Example



TP Id	TP/GEONW/PON/SQN/BV/02
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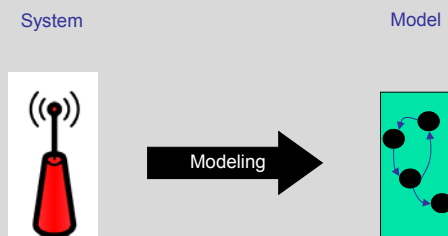
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Case Studies: Modeling 1(3)

- What is modeling?
 - A sometimes simplified "mathematical description of a system or process, used to assist calculations and predictions". – Oxford Dictionary



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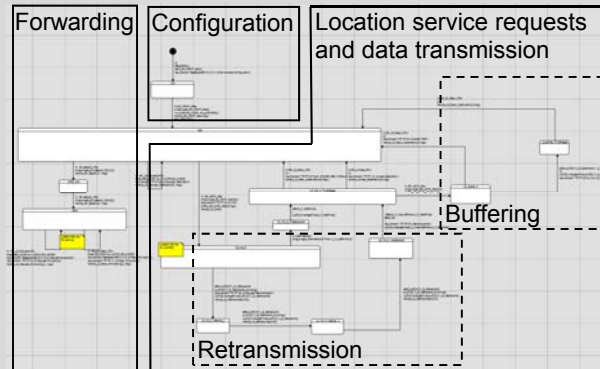
Case Studies: Modeling

2(3)

- GeoNetworking model example (Conformiq Designer)

- Model comprises

- Graphical part
 - FSM (shown)
- Code part
 - Message handling
 - Internal data
 - Generating response data
 - Guard conditions



Case Studies: Modeling

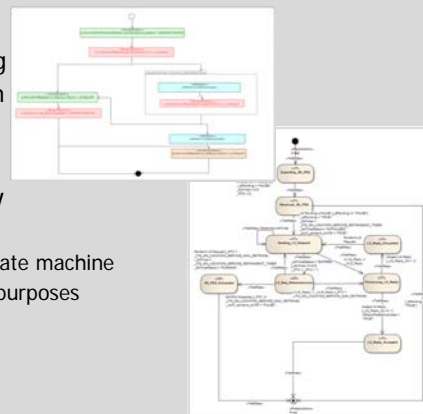
3(3)

- Challenges

- Expertise in protocol, tool, and testing
- Choosing the right level of abstraction
- Dealing with complexity

- Models for GeoNetworking case study

- SpecExplorer
 - C# code is mapped to an extended state machine
 - Lower abstraction level than the test purposes
 - Complete modeling, slicing
- Conformiq, MBTSuite, MD Tester
 - Extended state machines (Conformiq)
 - Annotated UML state and activity diagrams (MBTSuite, MD Tester)
 - Abstraction level of the test purposes
 - Simplified modeling using test configurations



Case Studies: Test Generation

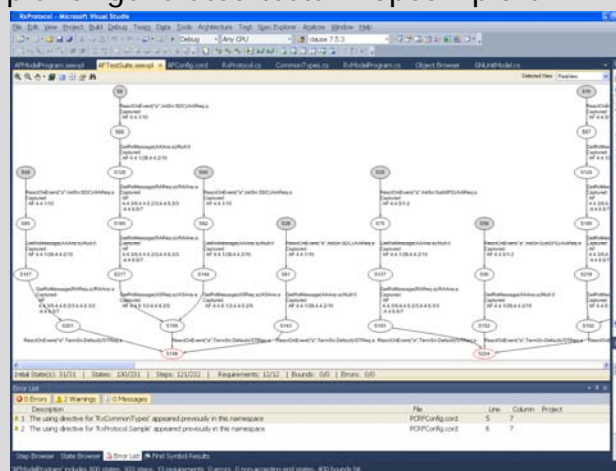
1(2)

- Influencing test generation
 - Different modeling approaches lead to different test suites
 - Each tool has different means to control test generation
- Generating tests for GeoNetworking case study
 - SpecExplorer
 - Coverage goals were selected requirements extracted from standard
 - Conformiq Designer, MBTSuite, MDTester
 - Coverage goals were based on standardized test purposes

Case Studies: Test Generation

2(2)

- Example for generated tests in SpecExplorer



Case Studies: Evaluation of Test Generation

- Test purposes (TP) were used for comparison
- The manually created TPs could be covered in all case studies
- Tools have also means to go beyond the TPs
- The generated test cases were at least on the same level of abstraction as the TPs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
TP 01 LS Init								X	X	X	X	X	X	X	X	X	X	X
TP 02 No 2nd LS Init															X			
TP 03 Flush LS Buffer after LS Reply														X				X
TP 04 LS Buffer FIFO																	X	
TP 05 Lifetime expired																		X
TP 06 LS Request Retransmission																		
TP 07 LS Retransmission maxRetransTimes																		
TP 08 LS Request Destination				X	X													
TP 09 LS Request is the same from an other node					X													
TP 10 LS Request Forwarding																		
TP 11 LS Reply Forwarding																		
TP 12 Unicast Destination																		

Preconditions / Dependents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Method init()																		
Method get_GSM_MQTT_Key(String,String)																		
Method GetRetransmission_get_GSM_Response()																		
TP 01 LS Request Destination																		
Move from GetRetransmission_TPS1_Init to GetRetransmission_TPS1																		
TP 02 LS Request is the same from an other node																		
TP 10 LS Request Forwarding																		
TP 02 LS Init																		
TP 11 LS Reply Forwarding																		
Method get_Internet_sendString()																		
TP 06 LS Request Retransmission																		
GetRetransmission_L1_Init_2_TimedPassed to G-LS_Buffer_2																		
GetRetransmission_L1_Init_2_Parameters_2 to G-LS_Buffer_2_Parameters_2																		
TP 03 Flush LS Buffer after LS Reply																		
GetRetransmission_L1_Buffer_TimedPassed to GetRetransmission_L1																		
TP 12 Unicast Destination																		
TP 04 LS Buffer FIFO																		
Use Case TP_InitParameters																		

Case Studies: Adaptation to Test Environment

- Support of test execution
 - Possible to generate executable test cases with all tools
 - 3 out of 4 tools have TTCN-3 support
- Test harness
 - Adaptation to the target test system
 - Adding of data not specified in the model, because it does not influence the test generation
 - Parallelization
- Improving maintainability
 - Parameterization
 - Renaming of test cases, messages, variables, etc.
 - Re-structuring of test behaviour (e.g. preamble, test body, postamble)

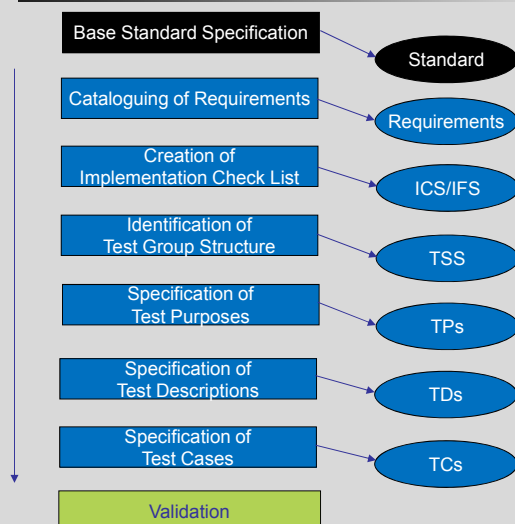
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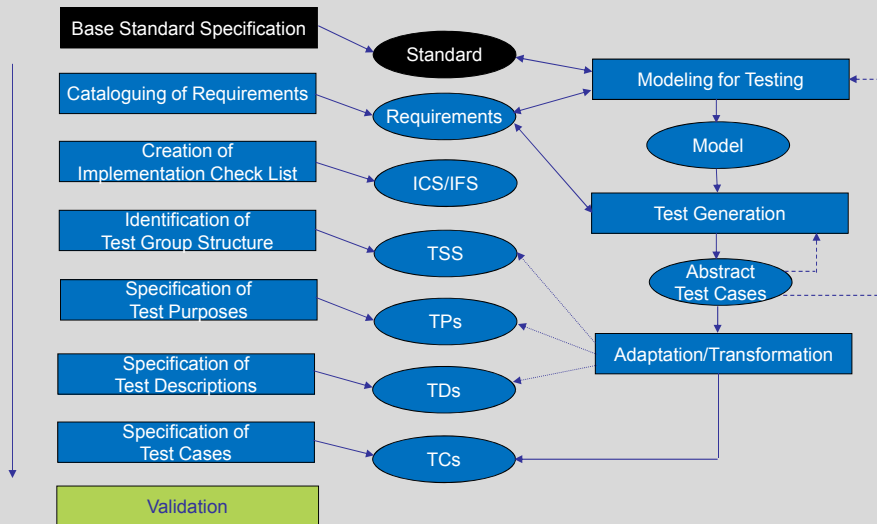
ETSI MBT Methodology Guidelines

1(3)



ETSI MBT Methodology Guidelines

2(3)



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ETSI MBT Methodology Guidelines

3(3)

- Modeling
 - Identification of requirements
 - Identification of modeling strategy
 - Annotating models with references for requirements
 - Modeling guidelines
 - Model quality
- Automatic test generation
 - Defining test coverage
 - Generating test cases
 - Quality of generated test cases
- Transformation and adaptation of generated test cases
 - Transformation and adaptation steps
 - Quality of adapted test suite

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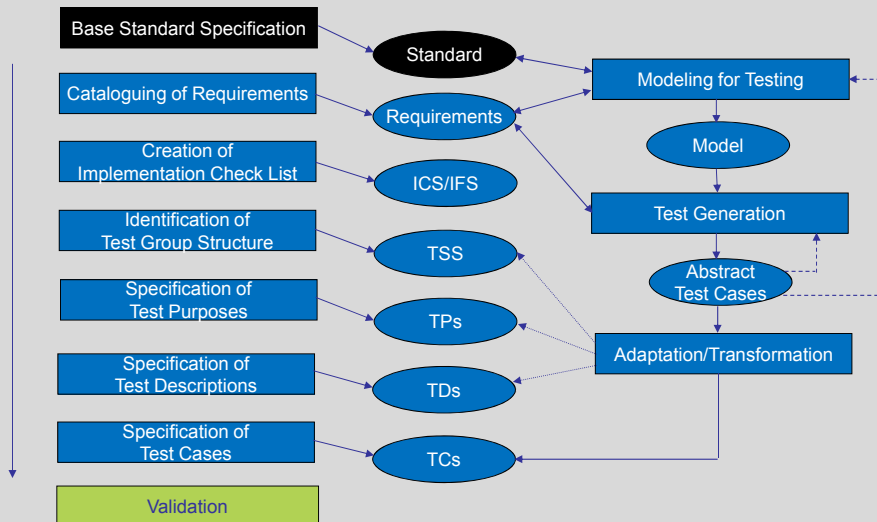
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Conclusions

- Case studies were successful with all tools
 - All case studies have been modeled
 - Abstract test cases were successfully generated
 - Test coverage comparable with the manually designed test suite
- MBT can be applied in standardized test development
 - Additional validation of base standards and requirements
 - MBT allows better control of test coverage
- Challenges
 - Gather expertise in base standard, testing and modeling
 - Abstraction gap between generated and manually written test cases
 - Maintenance of test suite vs. maintenance of test model
 - Standardization requires stable and standardized modeling techniques

Methodology for MBT in Test Standardization (revisited)



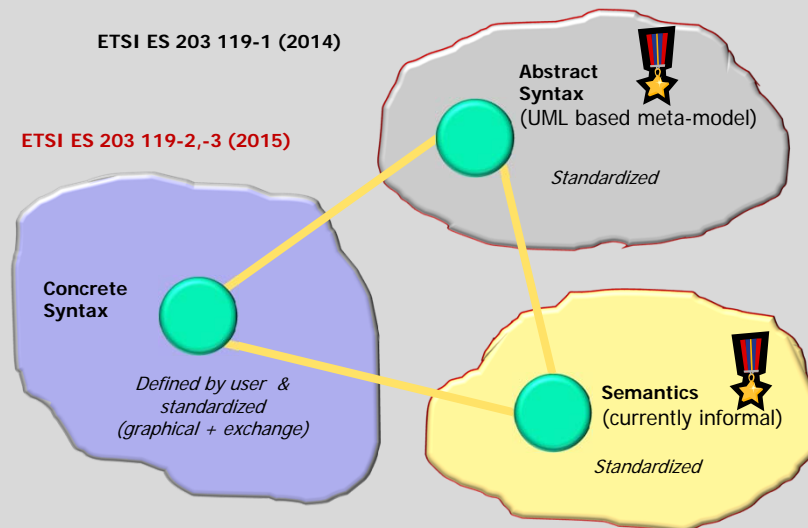
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Test Description Language (TDL): TDL Design & Standards

ETSI ES 203 119-1 (2014)

ETSI ES 203 119-2,-3 (2015)



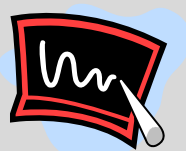
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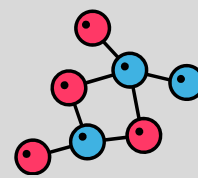
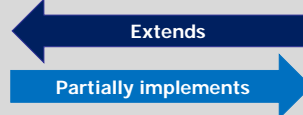
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Test Description Language (TDL): Extensibility

- Concrete syntax may cover only parts of the meta-model
- Meta-model can be extended by a user if need arises
- User extensions of the meta-model can be subjected to further TDL standardization and maintenance



User-defined TDL
concrete syntax



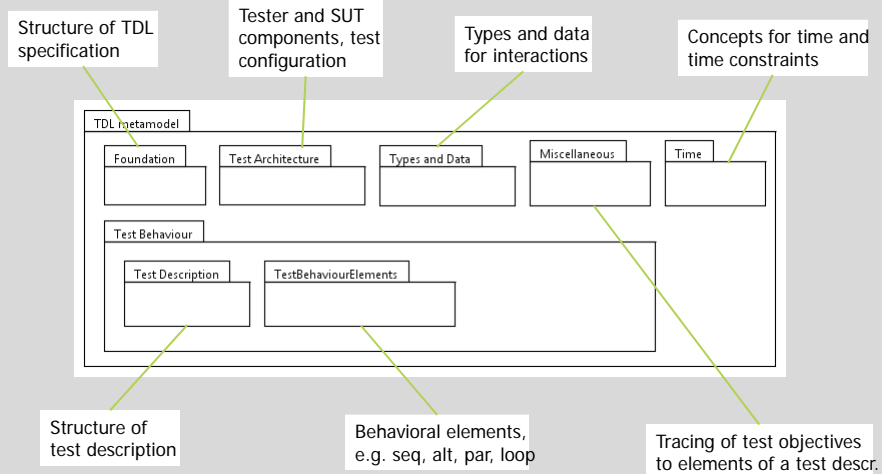
TDL meta-model with
user extensions

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Test Description Language (TDL): Meta-Model Overview

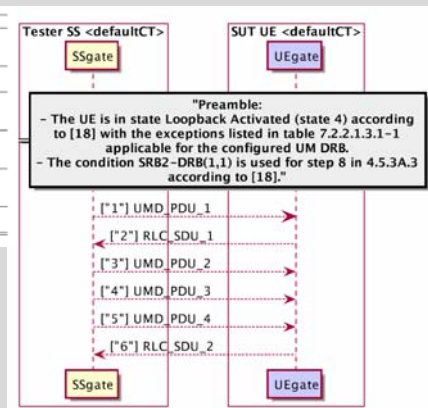


Test Description Language (TDL): 3GPP Example

Textual TDL syntax

Step	Procedure	Direction	Message
1	The SS transmits UMD_PDU#1 containing a complete RLC SDU#1 (FI field = 00).	SS → UE	UMD_PDU_1
2	Check: Does the UE transmit RLC SDU#1?	UE → SS	RLC_SDU_1
3	The SS transmits UMD_PDU#2 containing the first segment of RLC SDU#2 (FI field = 01).	SS → UE	UMD_PDU_2
4	The SS transmits UMD_PDU#3 containing the second segment of RLC SDU#2 (FI field = 11).	SS → UE	UMD_PDU_3
5	The SS transmits UMD_PDU#4 containing the last segment of RLC SDU#2 (FI field = 10).	SS → UE	UMD_PDU_4
6	Check: Does the UE transmit RLC SDU#2?	UE → SS	RLC_SDU_2

UML-like graphical TDL syntax



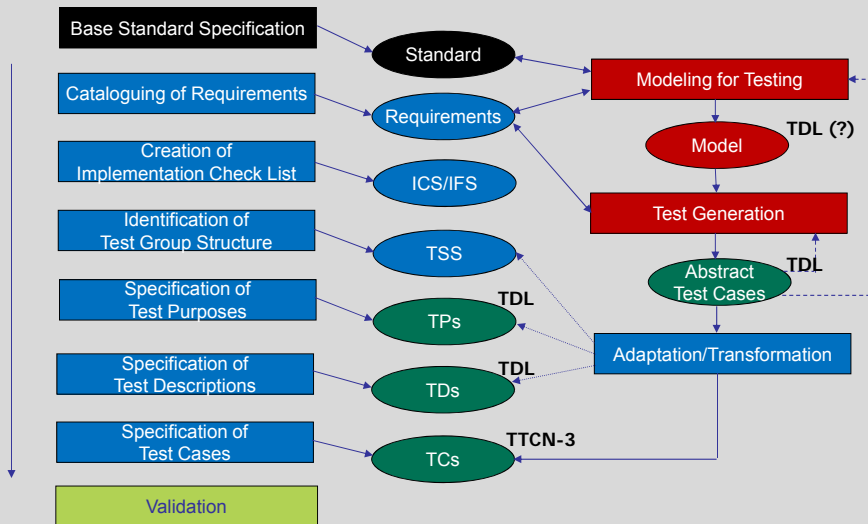
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Summary

- Standardization process of conformance tests at ETSI.
- Possibilities for the usage of MBT in the development of standardized conformance tests.
- Current development of TDL at ETSI

Future



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Thank you for your attention

- Further information can be found at



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<http://www.etsi.org/>



<http://www.ttcn-3.org/>

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