COMMON TESTING APPLICATION WITH XML CONVERSION PLUG-IN FOR LTE DSP SW INTEGRATION

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The eNodeB base station is a part of the LTE telecommunication network. The amount of features inside the eNodeB incrementally increases in the product development phase. In the LTE DSP SW integration, the features that already exist are combined with the incoming features by using a continuous integration method. Testing the existing and new features leads into the fact that a shorter the time in testing cycle is used by an individual test. The way of testing is needed to be continuously developed to keep the testing coverage at the required level.

The main purpose of the LTE DSP SW integration is to verify that the interfaces of the DSP software components are working according to the interface specification. In the LTE DSP SW integration, the eNodeB is configured by eNodeB control messages. The eNodeB control messages have a particular format because of the test environment of the LTE DSP SW integration.

This thesis presents the technology of LTE, testing in general, integration as a part of the incremental development process and how the issues mentioned are related into the work of the LTE DSP SW integration. A solution to increase the performance of the testing is studied by a computer application. The goal of this thesis is to develop a computer application using the Qt programming language. The application requirements are based on the needs of the LTE DSP SW integration. The application generates the eNodeB control messages using XML source files as input. The application reduces the manual work in a situation where the existing messages change or new messages are introduced. The application is capable of executing a task in few seconds that takes from one hour to many days when done manually. The development process of the application, usability and possibilities to develop the application are further analysed based on the evaluations during the study.

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Yleiskäyttöinen testiohjelma XML-muunnoslisäosalla LTE DSP SW integroinnille

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LTE, ohjelmistotestaus, integraatio, Qt, sovellus, XML, UML, eNodeB, sanomat

eNodeB-tukiasema on LTE-matkapuhelinverkon osa. Tuotekehitysvaiheessa tukiaseman ominaisuuksien määrä on koko ajan inkrementaalisesti kasvava. Uuden ominaisuuden yhdistäminen jo olemassa olevaan tapahtuu LTE DSP SW -integroinnissa jatkuvaa integrointimenetelmää käyttäen. Uuden ja vanhan testaaminen johtaa yksittäisen testin testausajan lyhenemiseen. Tilanne vaatii jatkuvaa testauksen kehitystä, jotta kokonaistestauskattavuus pysyy riittävänä.

LTE DSP SW -integroinnin ensisijainen toimenkuva on verifioida, että tukiaseman DSP-ohjelmistokomponenttien rajapinnat toimivat rajapintavaatimusten mukaisesti. Integrointityössä tukiasema konfiguroidaan eNodeB-kontrollisanomilla. LTE DSP SW -integroinnin testiympäristöstä johtuen eNodeB-kontrollisanomilla on oma formaatti.

Tässä työssä esitellään LTE-teknologiaa, testausta yleisesti ja integrointia inkrementaalisessa tuotekehityksessä sekä lisäksi sitä, miten edellä mainitut liittyvät LTE DSP SW -integrointiin. Ratkaisua testauksen tehostamiseen haetaan tietokonesovelluksesta. Tässä työssä kehitetään LTE DSP SW -integroinnin tarpeiden pohjalta tietokoneohjelma Qt-ohjelmointikielellä. Ohjelma generoi XML-lähdetiedostoja käyttäen eNodeB kontrollisanomia. Työkalun käyttö poistaa manuaalisen työn tarpeen tilanteista, joissa olemassa olevat kontrollisanomat muuttuvat tai tulee kokonaan uusia sanomia. Työkalu tekee sekunneisssa työn, jonka tekeminen manuaalisesti kestäisi tunnista jopa useisiin päiviin. Työn lopuksi analysoidaan ohjelman kehitystyötä sekä sen käyttö- ja jatkokehitysmahdollisuuksia.

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Oulu, 27 of May 2012
Teemu Heikkilä

CONTENTS

DEFINITIONS AND ABBREVIATIONS

1G	1st generation mobile communications
2G	2nd generation mobile communications
3G	3rd generation mobile communications
4G	4th generation mobile communications
3GPP	3rd Generation Partnership Project
AN	Access Node
API	Application Programming Interface
AT	Acceptance Test
ATE	Automated Test Environment
ATETT	ATE Testing Tool
BTS	Base Transceiver Station
CI	Continuous Integration
CTA	Common Testing Application
CP	Control Plane
CPU	Central Processing Unit
DE	Definitions Element
DOM	Document Object Model
DSP	Digital Signal Processor
DB	Database
DL	Downlink
EDGE	Enhanced Data Rates for GSM Evolution
eNodeB	E-UTRAN Node B
EPC	Evolved Packet Core
EPS	Evolved Packet System
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GERAN	GSM/EDGE Radio Access Network
GPL	General Public License
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GUI	Graphical User Interface

HSDPA	High Speed Downlink Packet Access
HSUPA	High Speed Uplink Packet Access
HSPA	High Speed Packet Access
HTML	Hyper Text Markup Language
HW	Hardware
IDE	Integrated Development Environment
IF	Interface
IFS	Interface Specification
IP	Internet Protocol
IT	Integration test
I/O	Input/Output
Iu	UTRAN-CN interface
Iub	BTS-RNC interface
L1	Layer 1
L2	Layer 2
L3	Layer 3
LTE	Long Term Evolution
MAC	Medium Access Control
ME	Messages Element
MME	Mobile Management Entity
MT	Module Test
NMT	Nordic Mobile Telephone system
NodeB	In UMTS equivalent to the BTS
NSN	Nokia Siemens Networks
OMT	Object Modeling Technique
PC	Personal Computer
PCRF	Policy and Charging Resource Function
PS	Packet Switched
P-GW	Packet Data Network Gateway
QoS	Quality of Service
Qt	C++ framework
R6	Release 6
RB	Radio Bearer
RNC	Radio Network Controller

RNS	Radio Network System
RRM	Radio Resource Management
Rx	Receiver
R&D	Research and Development
SAX	Simple API for XML
SDK	Software Development Kit
SCM	Software Configuration Management
SDLC	Software Development Lifecycle
SGML	Standard Generalized Markup Language
SGSN	Serving GPRS Support Node
SMS	Short Message Service
ST	System Test
SUT	System Under Test
SVN	Subversion
SW	Software
SWi	Software Integration
S-GW	Serving Gateway
TCP/IP	Transmission Control Protocol / Internet Protocol
Tx	Transceiver
UE	User Equipment
UI	User Interface
UL	Uplink
UML	Unified Modeling Language
UMTS	Universal Mobile Telecommunication System
UP	User Plane
USIM	UMTS Subscriber Identity Module
UT	Unit test
UTRAN	UMTS terrestrial radio access network
Uu-LTE	Air interface between UE and BTS
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network
W3C	Worldwide Wide Web Consortium
XHTML	eXtensible HTML
XML	Extensible Markup Language

1 INTRODUCTION

The LTE (Long Term Evolution) technology is currently the latest radio network technology used in the universal mobile telecommunication system (UMTS). The eNodeB (Evolved Universal Terrestrial Radio Access Network Node B) is an access node (AN) that provides wireless connection between the user equipment (UE) and the core network of the LTE.

The eNodeB system of Nokia Siemens Networks (NSN) consists of hardware and embedded software. The software (SW) is build from individual SW components. When the SW components are combined together, they provide all functionalities that are required by the eNodeB. The SW components are performed on the digital signal processors (DSP) of the eNodeB. The LTE DSP SW integration (SWi) is the first testing phase where all the SW components are integrated and tested together. It is a low level integration test phase where the eNodeB system is not controlled by an upper control layer.

The LTE DSP SWi uses an automated testing environment (ATE) in the eNodeB SW integration. In the ATE, the upper control layer's functionality is replaced with the ATE testing tool (ATETT). The ATETT controls the eNodeB system using the eNodeB control messages.

The ATETT is the main testing tool used in the ATE of LTE DSP SWi. All the new eNodeB control messages for the ATETT are created manually. The format of the messages is difficult for a human. Additionally, the amount of the messages is around one thousand and the overall size of the content of the messages' is near 25Mbytes. In general, manual working is very slow, extremely laborious and a risk level for human errors is high.

Currently, the eNodeB control messages influence a bottle neck effect in the LTE DSP SWi every time when the SW interfaces change between the DSP SW applications. This happens because the eNodeB control messages are not available for testing within the expected time frame.

In the incremental SW projects of NSN, the project management continuously measures the velocity time for new features. The velocity time measures how quickly the features are implemented and integrated to be a part of the eNodeB system. The overall velocity time increases in the situation where the SW product chain contains a bottle neck. When the bottle neck occurs in an early phase of the product chain, the impact on the total velocity time is significant.

In case when the LTE DSP SWi is not able to execute the required tests within the required time frame, all the later testing phases are set on hold until the LTE DSP SWi is completed. It leads into a situation where other testing phases have less time for testing. As a consequence, the errors in the SW are found later than expected, near the final release date. Hence, it is important that the velocity time is kept through the SW organization at the required level at all testing levels.

1.1 Scope of thesis

The main scope of this thesis is to decrease the velocity time for the DSP SW builds at the LTE DSP SWi testing level. The minimum time requirement is set into two hours per a DSP SW build regardless the size of the change in the DSP SW. The main problem has been the changes in the application programming interface (API) of the DSP SW applications because they cause manual work for the LTE DSP SWi. NSN’s SW organization provides the API information of the DSP SWs in two forms: traditional interface specification (IFS) and extensible markup language (XML). In this thesis the XML data is taken in use, since it is already available.

A solution to replace the manual work is studied by an application. The application is capable of processing the XML data and is able to convert the data in the form of the eNodeB control messages for the ATETT. The development process of the application provides a common testing application (CTA) and an XML conversion plug-in for it.

The CTA is a common interface for multiple small size tools, and the XML conversion plug-in is a tailor-made tool whose main functionality is to generate the eNodeB control messages for the ATETT. The main function of the applications is to support the current and future testing activities of the LTE DSP SWi.

The main focus of the thesis is in the implementation work of the CTA and the XML conversion plug-in. The content of the eNodeB control messages as well as the XML source data files contain confidential information of the company. Because the applications will process the confidential material, the requirements for the applications are presented at a high level by using user scenarios and figures by using the unified modelling language (UML). Only the key functionalities of the implementation are opened at a more detailed level. However, the thesis does not focus on how the tool is connected to the ATE.

The subject of the thesis supports a continuous need to improve the quality, testing and integration performance of the LTE DSP SWi. The C++, Qt, XML and UML languages are selected to be a part of this thesis due to technical and personal reasons. Studying the languages and using them in practice in the application development process improved the thesis writer’s professional skills in the areas that are needed in the work duties on a daily basis. The selected coding languages are technically suitable languages to the application required to handle a considerable amount of data with high performance.

The LTE technology, the eNodeB functionality in general, the SW integration work and the testing are all essential to this thesis since all of them are tightly related to the LTE DSP SWi engineers’ work.

1.2 Structure of thesis

After introducing the research topic and describing the aim of the study in the introduction chapter, chapter 2 shortly goes through the evolution of the radio network from the first generation (1G) up to the LTE technology. Additionally, it describes at a more detailed level the main reasons why the LTE technology is needed. The main benefits of the LTE technology are introduced and compared to one of the previous network generations. Chapter 3 presents the definition of testing and different testing techniques. The testing of the LTE DSP SWi is described at the general level. Secondly, ATE and ATETT of the LTE DSP SWi are presented only at the general level. Chapter 4 focuses on the application development project. Firstly, the tools and languages used in the project are presented. Secondly, the chapter presents the main functionalities of the CTA including its common plug-in interface. Finally, the chapter presents the main functionalities of the XML conversion plug-in. Chapter 5 presents the result and proposals. Chapter 6 presents the evaluations of this thesis.

2 EVOLUTION OF UMTS NETWORKS

The number of subscribers in the UMTS network is growing fast. The number of mobile subscribers increased with more than one million new subscribers per day in 2008 and the number of subscribers is still growing. In 2008 more than four billion subscribers were connected to UMTS. Since then, the number of subscribers is much higher. (1, p.1.)

The trend is that the systems that have been used for wire line connections are replaced with the systems that use a wireless connection. A fast growing amount of subscribers connected to the UMTS, the data hungry applications used in the mobile devices, requires all the time more and more data capacity and even faster data throughput rates. These are the reasons why a new generation of mobile networks is needed time to time. It leads the information technology into the situation that forces them to continuously development the performance of the current networks and creating totally new technologies whose architecture and techniques provide even a higher performance than the currently known technologies. These reasons also lead to the definition of the LTE which is the first (4G) fourth generation telecommunication network. In the standardization process for the new technologies, the 3rd generation partnership project (3GPP) has had a critical role over the company’s boundaries. (1, p.3-4.)

This chapter gives a general introduction about the basics of the UMTS networks evolution up to the foundation of the LTE. This chapter presents the main characteristics of the LTE technology and show the LTE related parts of the UMTS network. The eNodeB’s roles in the UMTS network and the LTE radio protocol stack are presented. Overall, this chapter helps to understand what kind of system the LTE DSP SWi team is testing and how it is related to this thesis work.

2.1 Evolution of mobile networks and target for LTE

The 1G is the name for the analogue or semi-analogue mobile networks. The nordic mobile telephone system (NMT) is an example of the 1G based mobile network and it was developed only for voice services. The second generation (2G) mobile network also known as the global system for mobile communication (GSM) was the first mobile network that had a capability to transfer data. The third generation (3G) mobile networks introduced a high speed downlink packet access (HSDPA) and the high speed uplink packet access (HSUPA) technologies in Release 6 (R6). The R6 improved data rates up to 14Mbps in the downlink and 5.8Mbps in the uplink. After the HSPA had been introduced, the traffic in the networks changed from the voice dominated to the packed data dominated. A typical case of the relation between the voice and data traffic in the networks is illustrated in Figure 1. (1, p.2-3.)

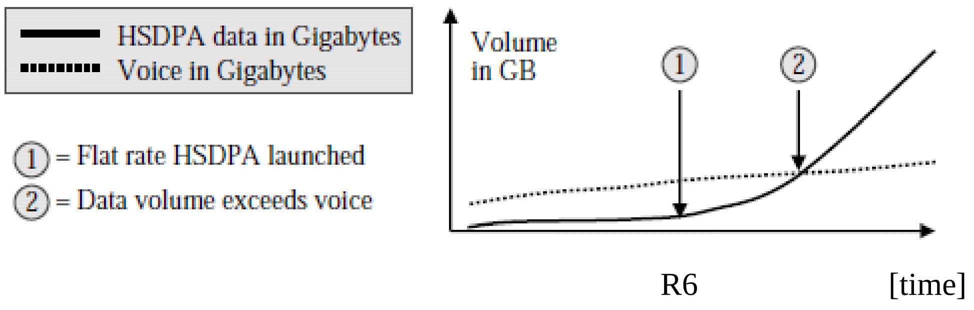


FIGURE 1. HSDPA data volume exceeds voice volume (1, p.3.)

The HSPA is fast enough to be used in providing services over the networks that has value for the end users. The applications used in mobile devices as smart phones or laptops increases the data transfer in the networks very much. The internet browsing, an interactive gaming, streaming services and file transfers are few examples of the service. (1, p.2-3.)

The 4G was based on the standard of the LTE Release 8. The LTE networks and all the earlier mentioned network generations from the 1G up to the 3G follow the standards made under the 3GPP. When the 3GPP started defining the requirements for the LTE, it considered the questions presented in Figure 2. Simultaneously with the wireless the technologies, technology on the wire line side is improving and the network applications utilize all the available network resources to improve the services for subscribers. Similar improvements are required from the LTE networks as well. The applications that work in the wire line networks, has to work without problems in the LTE networks. The improvements require that the LTE technology utilizes the available radio spectrum as well as it is possible. (1, p.4.)

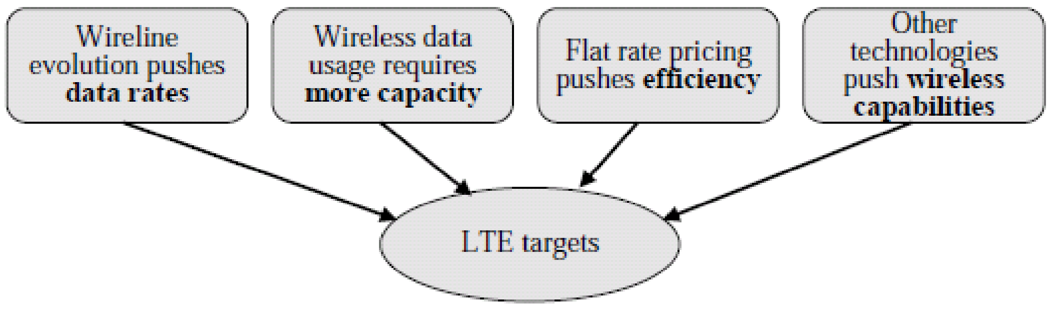

Wireline evolution pushes **data rates**
Wireless data usage requires **more capacity**
Flat rate pricing pushes **efficiency**
Other technologies push **wireless capabilities**
LTE targets

FIGURE 2. Reasons for LTE development (1, p.5.)

The requirements that the 3GPP project has defined for the LTE are relative to the requirements defined for the HSPA in the R6. The comparison of the LTE and the HSPA is presented in Figure 3. The principle is that the LTE delivers a better performance than any existing mobile network as well as the other wireless techniques such as the wireless local area network (WLAN). The improvements in the latency time make the managing of the UEs more efficient and decrease the UE's battery consumption as well as the optimized UE power efficiency itself. (1, p.4.)

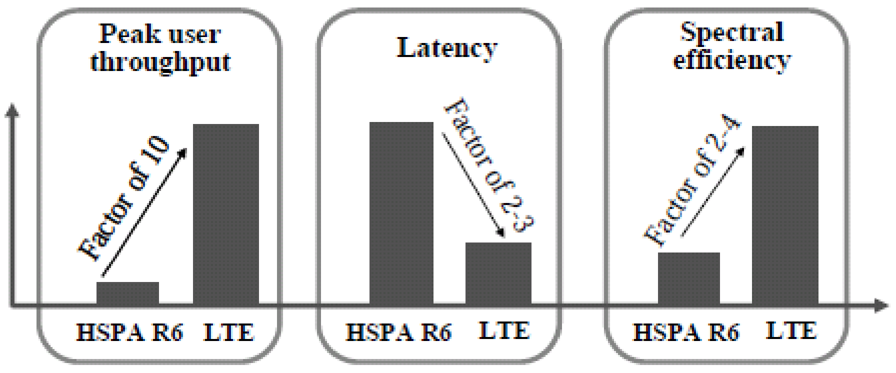


FIGURE 3. LTE performance targets compared to HSPA (1, p.5.)

The performance requirements for the LTE are as follows:

- Spectral efficiency two to four times more than with HSPA Release 6
- Peak rates exceeds 100 Mbps in downlink and 50Mbps in uplink
- Enables round trip time<10ms
- Packet switch optimized
- High level of mobility and security
- Optimized terminal power efficiency
- Frequency flexibility with from below 1.5MHz up to 20MHz allocations

(1, p.4-5.)

2.2 E-UTRAN

All types of the ANs in the UMTS network architecture are located beyond the evolved packet core (EPC) as presented in Figure 4. The UMTS access networks consist of four main divisions: UE, AN, EPC and the service domain. (1, p.25.) The evolved universal terrestrial radio access network (E-UTRAN) presents the 4G type of the ANs in the UMTS. The enhanced data rates of the 2G for the GSM evolution (EDGE) radio access network (GERAN) and the universal terrestrial radio access network of the 3G (UTRAN) present the previous generation's access networks before the 4G exists.

At the architectural level, the improvements done in the LTE are done in the evolved packet system (EPS) layer. The EPS layer consists of the UEs, the E-UTRAN and the EPC layers. These three layers represent the connectivity layer that is based on the internet protocol (IP). All services including voice are served on top of the IP in the LTE. The architecture of the EPS is optimized for the IP based data. (1, p.25-26.)

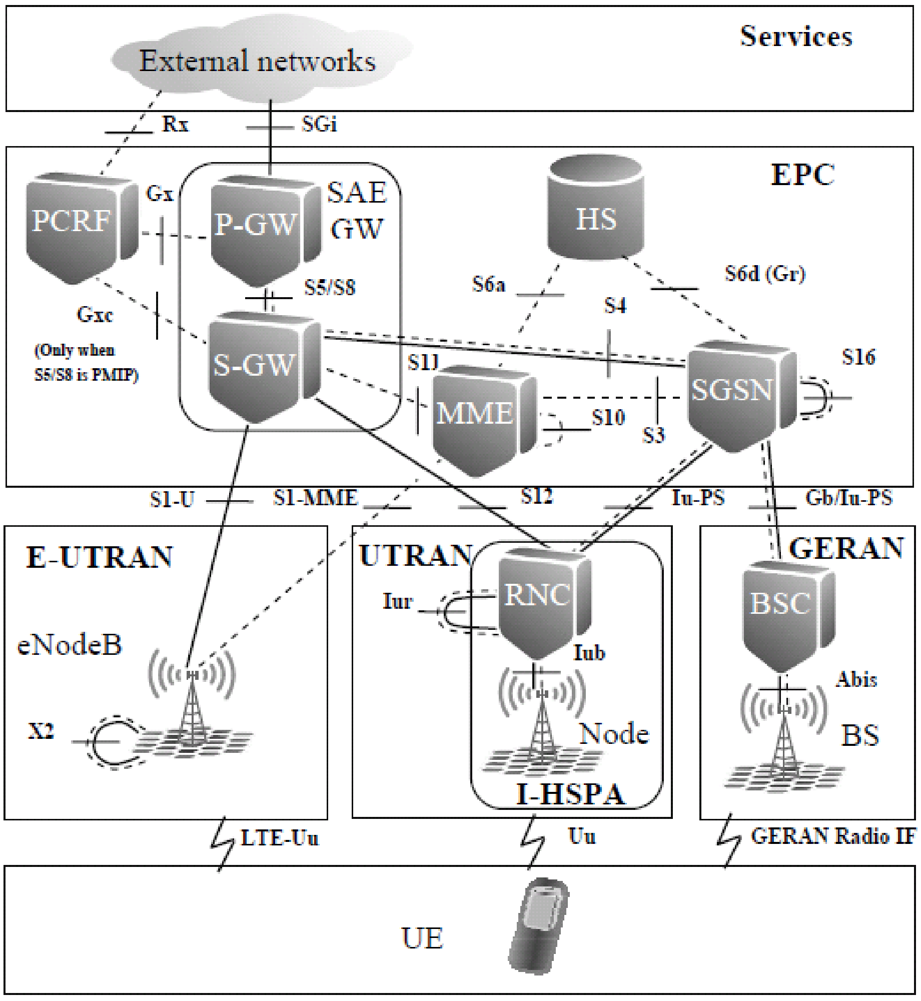


FIGURE 4. UMTS high level system architecture for radio access networks (1, p.41.)

The eNodeB is an AN for the the UE in the E-UTRAN. The E-UTRAN normally consists of numerous eNodeBs interconnected together via the X2 interface. The S1 interface connects the eNodeB to the EPC. The LTE-Uu means the physical layer 1 (L1) and that presents the air interface between the UE and the eNodeB. Network layer 2 (L2) of the eNodeB is a bridge between the UE and the EPC in the functionality's point of view. In other words, the eNodeB provides a wireless connection for the UE to the fixed part of the network and its services. (1, p.27.)

The main functionalities of the logical nodes in the EPS are shown in Figure 5. The radio resource control (RRC) controls the radio interface of the eNodeB. Based on the RRC requests, the eNodeB configures the radio bearers (RB), radio admission control, allocates the requested resources, constant monitoring the usage of the resources, prioritizing and scheduling traffic according to the required quality of service (QoS) etc. The mobility management (MM) of the eNodeB controls and analyses the radio signal level measurements of the UE while makes similar measurements itself. Based on result of the measurements the eNodeB manages the required signalling during the handover process for the UEs between the radio cells. (1, p.27.)

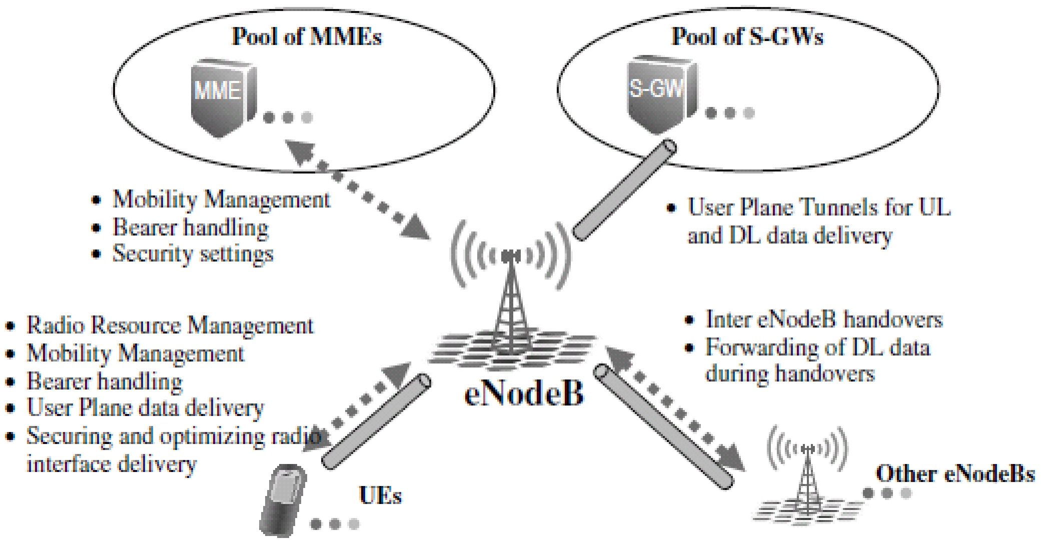

Pool of MMEs
MME
Pool of S-GWs
S-GW
• Mobility Management
• Bearer handling
• Security settings
• User Plane Tunnels for UL and DL data delivery
• Radio Resource Management
• Mobility Management
• Bearer handling
• User Plane data delivery
• Securing and optimizing radio interface delivery
eNodeB
• Inter eNodeB handovers
• Forwarding of DL data during handovers
UEs
Other eNodeBs

FIGURE 5. eNodeB connections to other logical nodes in EPS and main functions (1, p.28.)

The radio protocol of the E-UTRAN is dividable in two terminations towards the UE: user plane (UP) and control plane (CP). Both the UP and CP protocol stacks are shown in Figure 6. The protocol stack of the UP consists of the packed data convergence protocol (PDCP), the radio link control (RLC), the media access control (MAC) and the physical (PHY). The protocol stack of CP consists of the RRC. (2, p.15.)

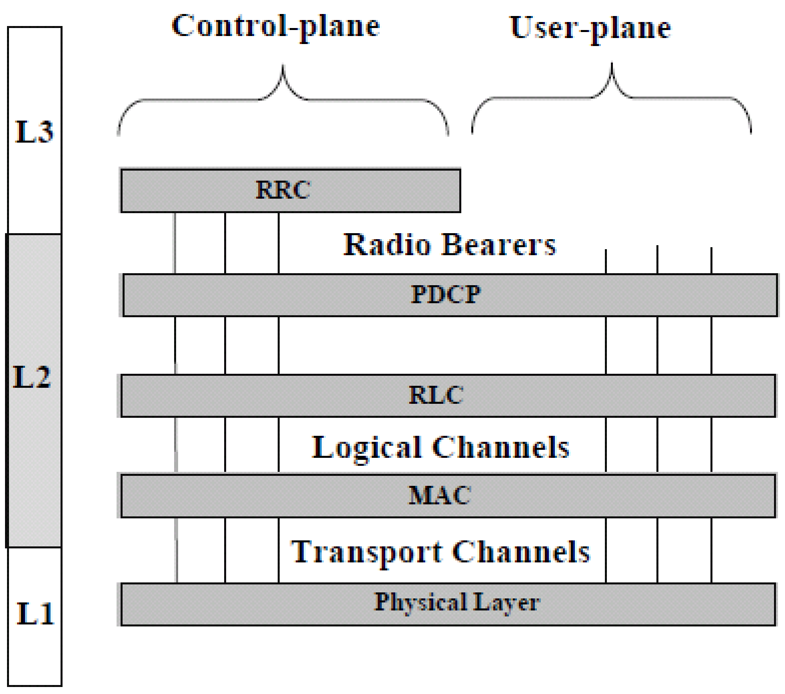


FIGURE 6. LTE radio protocol stack (3, p.138.)

A full constructed E-UTRAN system contains both the UP and the CP. It means that the eNodeB is controlled by the RRC. As Figure 6 shows, the RRC is a part of layer3 (L3), and all the UP related protocols are spread on L1 and L2 layers. The LTE DSP SWi testing focuses on the eNodeB functionality testing only at the level of the UP and the CP is not present. The ATE contains only L1 and L2 layers. The lack of L3 requires that ATETT is used to replace the RRC and the L3 functionalities.

The RRC system controls the eNodeB by using the eNodeB configuration messages. The ATETT uses the eNodeB control messages to control eNobeB in the same way as the real RRC does. Additionally, ATETT is capable of encoding, and it decodes the messages in a different format. After the message decoding operation of the ATETT, the eNodeB control messages are in a more readable and understandable format for a human. The CTA with the XML conversion plug-in provides the eNodeB control messages in the format that is suitable for the ATETT.

3 SOFTWARE TESTING

It has been a well-known fact for years that in a typical programming project approximately 50 percent of the project time and more than 50 percent of the total cost are expended in testing the software being developed. Nowadays, even though there are available new development methods, advanced program languages with more intelligent built-in tools, well-educated programmers, the software testing is still one of the main elements in the software development. (5, p.4.)

The defects are caused by a poor SW quality in the SW. It is important to investigate the root causes for these errors in order to prevent them and improve the quality of the SW. A SW defect can be an error in the source code, a procedural error, a documentation error, or a SW data error. The causes for all these errors are made by humans. (8, p.19.)

This chapter gives an introduction about the SW testing. The chapter starts with the basic definition of testing and a general knowledge of what the meaning of the testing is, followed by the testing methods and the main phases of testing.

3.1 Definition of software testing

The software testing provides multiple definitions for testing in general. The main idea behind the testing is always the same. *"Software testing is a process, or a series of processes, designed to make sure -- code does what it was designed to do and that it does not do anything unintended."* The definition for testing by Myers: *"Testing is the process of executing a program with the intent of finding errors"* (5, p.8-10.)

A need for testing is based on the fact that defect free systems do not exist. The aim of the testing is to find defects in the SW and add more value to it. The value of the testing means raising the quality or reliability of a SW. Raising the reliability of the program means finding and removing errors. In the testing there is a universal rule that it is impossible to find all defects. It comes reality because organizations never have enough of human resources, time, money etc. to test everything. (4, p.3.)

The defects in the SW are discovered if the outcome of the SW does not respond the expected. A basic test case consists of the known input data and a validity checker for the output data. A simple testing situation is illustrated in Figure 7. The functionality and validity of the behavior of the system under testing (SUT) can be verified by giving runtime input data (X) to the implementation under testing (IUT). The correctness of the SUT behavior can be verified from the outcome data (Y) given by IUT. (6, p.10.)

In this thesis work, both the Input X and the Output Y data can be perceived to be the eNodeB control messages. Several types of the eNodeB control messages exist but most of those are pairs of two messages containing a request message and the response message for it. The request message presents the input X data, and when the eNodeB (SUT) receives the request message, it is expected that the eNodeB responses to it with the response message which is the Output Y.

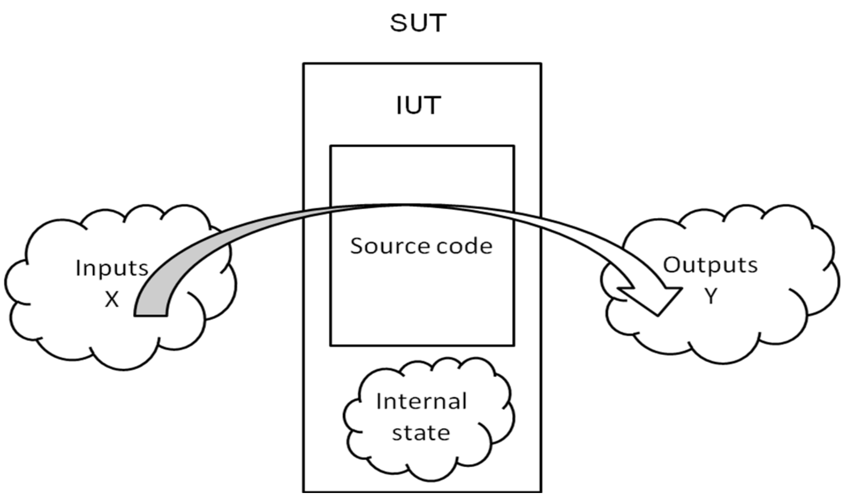


FIGURE 7. Illustration of the software testing (6, p.11.)

The *failure rate* is presented in Figure 8 as a function of time for software. In theory the failure rate curve for SW should take the form of the *idealized curve*. In an early phase when SW is new it contains more undiscovered faults and the failure rate is high in the beginning. When more and more failures are discovered and corrected without introducing new errors, the curve flattens. The *actual curve* presents a more realistic failure rate when new changes are implemented in the SW. After the changes have been made, there is a high probability that new defects are introduced causing to spike in the *failure rate*. All defects caused by the previous change are not discovered and corrected when another change is requested causing the actual curve spike again. As a consequence of this, the minimum level of the failure rate begins to rise. Every failure indicates an error in the process from design to implementation. The quality of the SW is deteriorating due to the change. (7, p.8.) The SW testing methods presented later on strive to reduce the magnitude of the spikes and the slope of the actual curve.

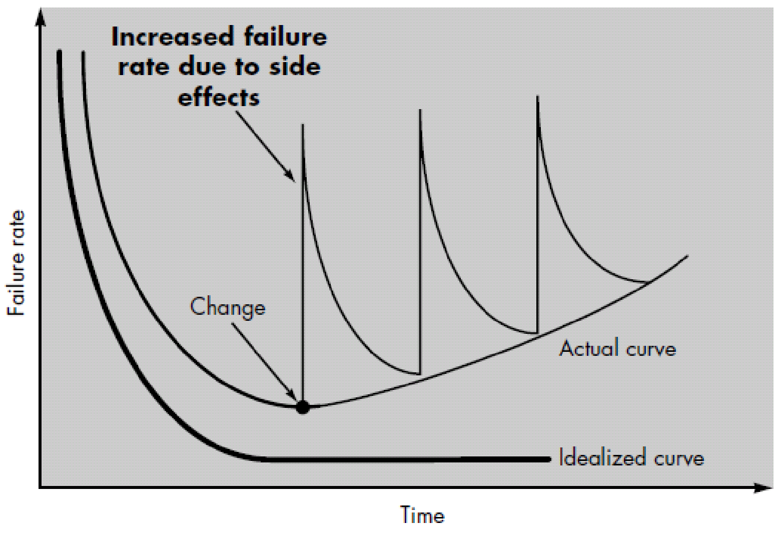


FIGURE 8. Idealized and actual failure curves for software (7, p.8.)

The software testing models used in software projects are presented in the next chapters. The models are commonly used to find defects effectively in as early a phase of a SW project as possible.

3.2 Software development process model 1: Waterfall model

The waterfall model is a classic SW development life cycle (SDLC) model. The classic waterfall model was suggested by Rouce in 1970. The waterfall model is the oldest and most widely used paradigm of the SDLC. The most common illustration of the waterfall model is presented in Figure 9. It is a linear sequential model and suggests a systematic sequential approach to the SW development that begins at the system level and progresses through the requirements, analysis, design, coding, testing, and support. (8, p.123-125.)

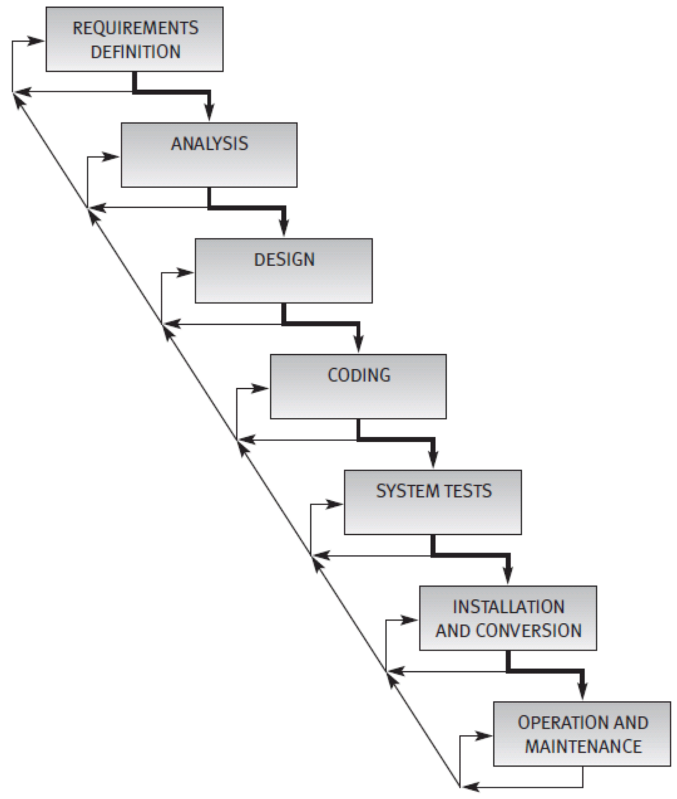


FIGURE 9. Waterfall model (8, p.124.)

The basic idea in the waterfall model is to split the main phases of the SDLC in separate steps. The number of the steps is not fixed and the amount of them depends on the scale of the project. In complex, large-scale projects some of the presented steps could be split to be smaller and, on the contrary, in small-scale projects the steps can be even merged. The progress onto the next phase requires an approval of the outcome from the previous phase. If the approval is not granted, the required corrections need to be done before progress is possible. (8, p.125.)

Weaknesses of using of the waterfall model:

1. Real projects rarely follow the sequential flow that the model proposes. Although the linear model can accommodate iteration, it does so indirectly. As a result, changes can cause confusion as the project team proceeds.
2. It is often difficult for the customer to state all the requirements explicitly. The linear sequential model requires this and has a difficulty in accommodating the natural uncertainty that exists at the beginning of many projects.
3. The customer must have patience. A working version of the program(s) will not be available until late in the project time-span. A major blunder, if undetected until the working program is reviewed, can be disastrous.

(7, p.30.)

3.3 Software development process model 2: V model

The V model has similarities with the waterfall model but it is a further developed version of it. The SW testing is done during the SW development process and is not left to the end of the project, as it is done in the waterfall model. (9.) That leads to foundation of the V model. The V model responds to the weaknesses listed in the previous chapter well. The V model is a commonly used process model in the software projects of NSN.

The individual steps of the V model process are from top-to-down almost the same as in the waterfall model. Difference in the V model is that instead of going down like in the waterfall in a linear way the process steps are bent upwards at the coding phase to form the typical shape of the V as presented in Figure 10. The reason for this is that for each of the design phases it was found that there is a counterpart in the testing phases which correlate each other. (10.)

The process of the V model begins with the requirements gathering. In a close co-operation with a customer the overall objectives for the software are defined. The purpose is to continuously outline the areas where the further definition is required. After a change in the code every of the testing phase results are evaluated and used to refine the requirements for the software to be developed. Iteration occurs as the change is tuned to satisfy the needs of the customer while at the same time understanding what needs to be done is improved. (7, p.30-31.)

In the V model the testing is incorporated into the entire SDLC. The left side of the V model represents the steps of the requirement work and creation of the system specifications. The right side of the V model represents the integration of parts and validation steps. (11.)

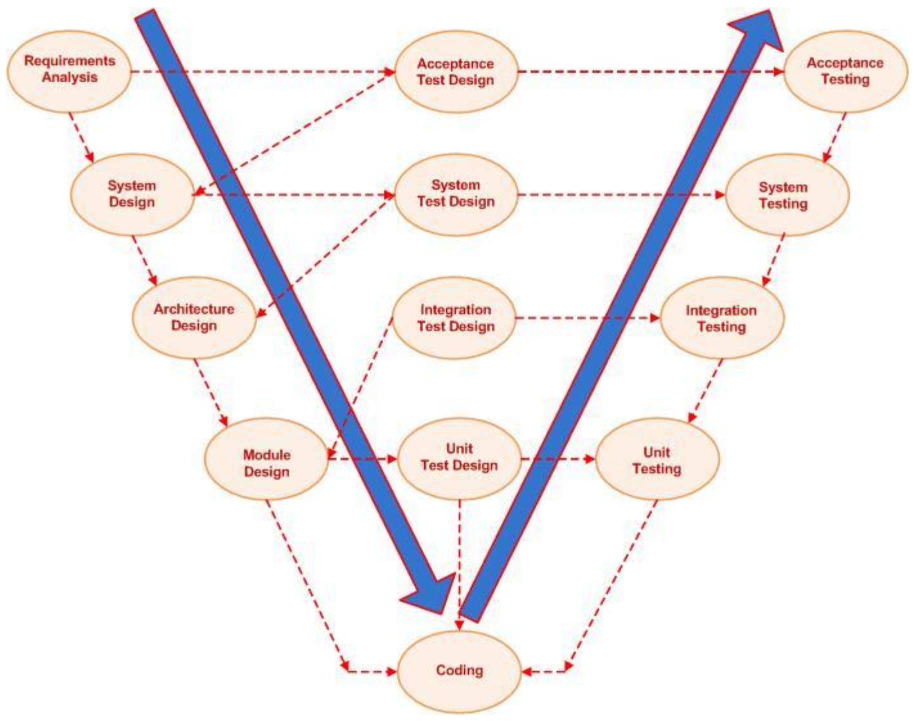


FIGURE 10. The V model of software testing (14.)

The unit testing (UT) level is the first testing phase. Entering this level requires that 80% of the requirements must be completed. The UT is also often called a module test (MT) because it tests the individual units of the source code that comprise the application. The UT is a series of stand-alone tests, conducted by the developer. Each of the tests examine an individual component that is a new or has been modified. In the NSN’s SW process the UT and the MT are separated testing phases. The system testing (ST) described in the source material is more or less a part of the MT as the system designates one of the eNodeB’s SW applications in the NSN’s SW process. (9, p.8.)

In the NSN’s SW process the MT testing level pertains under the UT in the V model’s testing steps. Entering this level requires that the UT for each of the SW modules has to be completed and passed. The tests of this level verify all of the SW components and SW modules that are new, changed, affected by a change, or needed to form the complete SW application. The testing of the individual SW application may require involvement of other SW applications but this should be avoided as much as possible to minimize outside factors. Working this way reduces the risk of the externally-induced problems. On this level of testing the *stubs* are commonly used to replace the other SW applications required in the system. The main targets of the MT are the validation and verification of the functional design specification and that all the SW modules work together.

The integration testing (IT) level is the second phase of testing in the V model. In this level all the individual SW modules and SW applications are combined together to form the complete system. Entering this level requires that the MT for each of the SW modules has to be completed and passed. The IT’s focus is to test the interactions between all the SW modules that are new, changed or affected by a change. Contrary to the MT level, the IT requires involvement of the other systems and interfaces with the other SW applications. (9, p.9.) The IT is discussed in more detail in the next chapter.

The ST level is the third phase of the testing in the V model. Entering this level requires that the status of the IT has to be in the required level. The ST, in the NSN’s SW process designates that at the first time the eNodeB is connected to be one of the network elements under the EPC. In this phase the eNodeB becomes a part of the E-UTRAN where the RRC starts to control the eNodeB’s baseband.

The acceptance testing (AT) level is the fourth and the last testing phase of the V model. It is also often called the end-user testing. A software vendor often uses real end-users in the AT to test the provided SW. In the NSN’s case it means that the AT is done as a field trial in close co-operation with a mobile operator. In the field trial a new version of the eNodeB SW is launched in a limited area of the operator’s mobile network. Before the final release of the eNodeB SW all of the defects found from the eNodeB SW have to be corrected. (9, p.10.)

3.4 Integration testing

In the IT level all of the individual modules and applications are combined together to form a complete system as shown in Figure 11. In the eNodeB SW project the system consists of the applications and numerous SW modules. Inside each of them it is necessary that the testing process contains the IT level. The use of the UT and MT is not only sufficient to get the stability and functionality of the SW in the required level before entering the ST level. They are not enough because many of the defects are related to the integration of the modules and applications. If the IFS made for the SW is not formally described, everyone has to make their own interpretation of it. There is always a big risk to defect the system if these interpretations are related to the interactions between the modules or applications made by others. (4, p.46.)

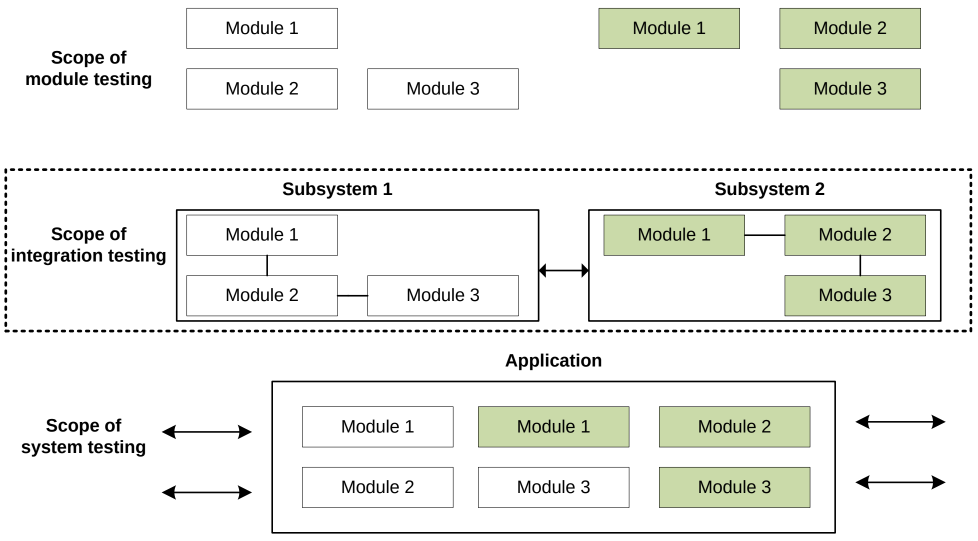


FIGURE 11. Scope of IT in testing process (12, p.629.)

An integration strategy is a decision about the different modules integration into a complete system including both the software and hardware. It is important to decide which integration strategy to use. The reason behind this is that the eNodeB system has dependencies between the different software modules, applications, hardware parts and the hardware and software. At certain moment all these parts have to be ready for the integration. The moment when all the parts are ready for integration depends on the followed strategy. The decision about the one strategy to follow should be made as early as possible because it has a strong effect on the scheduling of project activities. (4, p.46.)

There exists three different integration strategies: *Big bang*, *Bottom-up* and *Top-down*. The strategies are not mutually exclusive and there are exists variations of these three. (4, p.46.)

3.4.1 Non-incremental integration

In the "*Big bang*" integration strategy all of the modules are integrated and the system is tested as a whole as it is done when the waterfall model is followed. In this strategy the choice is made not to integrate until the release time and then all the branches are integrated at once as presented in Figure 12. The main advantage is that instead of using the stubs or drives, real modules are used. The main disadvantages of this strategy are that it is difficult to find the cause of defects and the integration can only start if all the modules are available. The Big bang integration can only be successful if a large part of the system is stable, only a few new modules are added, the system is rather small, the modules are tightly coupled and it is too difficult to integrate the different modules stepwise. (4, p.46.)

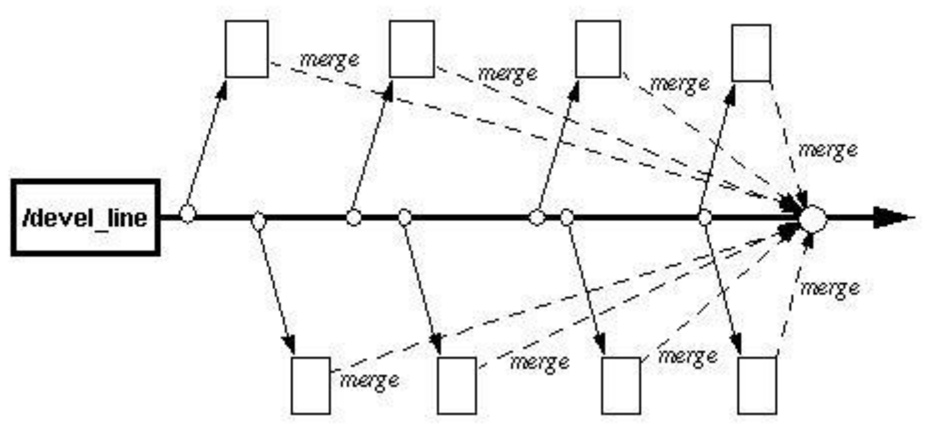


FIGURE 12. "Big-bang" integration at the end (13.)

3.4.2 Incremental integration

The *incremental model* software is developed and tested in small but usable pieces, called '*increments'* as shown in Figure 13. In general each increment builds on those that have already been delivered. The first increment is often called as core product. Next coming iterations modify always the previous increment version to meet better the needs of customer and the delivery of additional features and functionality. Based on the fact in complex systems the software evolves over a period of time. Requirements of product often change as development proceeds, making a straight path to an end product unrealistic. Because the evolutionary nature of software used process models should be iterative. (7, p.34-35.)

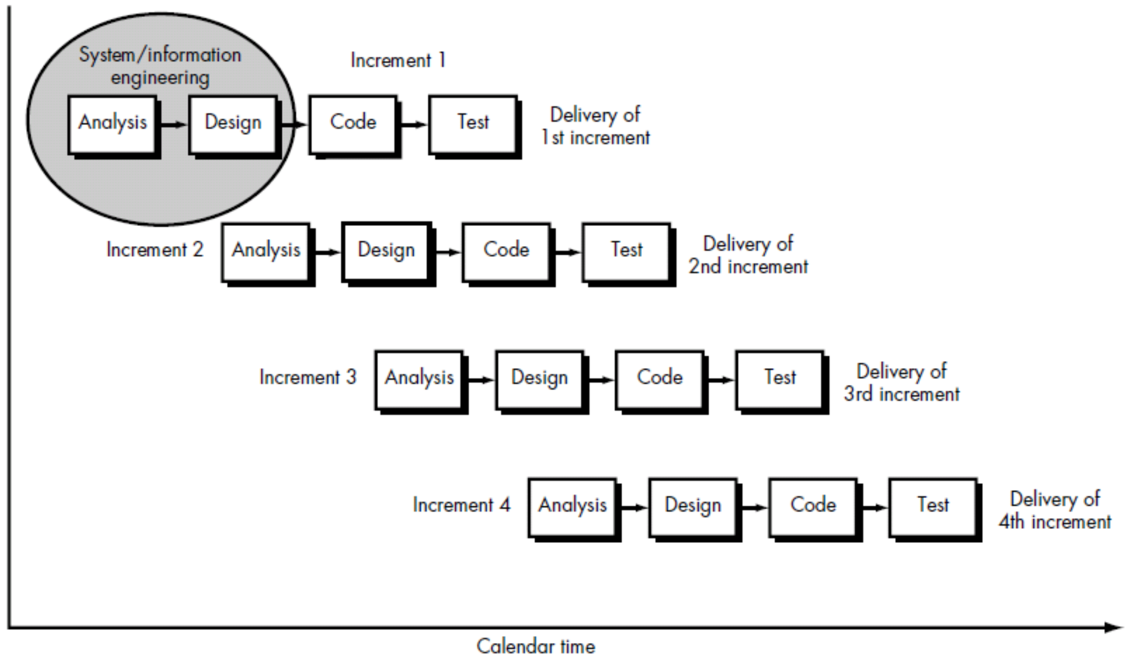


FIGURE 13. Incremental model (7, p.35.)

The strategy of the incremental testing usually follows the main steps of the V model. The basic idea is that the SW is tested in modules, as they are completed (*unit tests*); then integrated to the test groups of the tested modules with the newly completed modules (*integration tests*). This process continues until all the package modules have been tested. Once this phase is completed, the entire package is tested as a single entity (*system test*). Basically every phase of testing contains integration work. The incremental testing can be performed by using either of one the basic strategies, *bottom-up* or *bottom-down*. Both of the testing strategies are illustrated in the next two chapters using an identical SW project composed of 11 modules. (8, p.182.)

The *bottom-up strategy* presented in Figure 14 is useful for almost every system. The strategy starts with the low-level modules with the least number of dependencies using *drivers* to test these modules. The strategy can be used to build the the system stepwise or first build up the subsystems in parallel and then integrate them into a complete system. The main advantage of this strategy is an early detection of the interface problems and the isolation of them is made possible. The mentioned advantages also result in cost savings compared to the problems that are discovered when the complete system is ready. The main disadvantage is that many drivers have to be developed and used in carrying out this strategy. The maintenance of the drivers could be a very time consuming process because of the iteration of modules and tests (4, p.47.). The use of the drivers is explained in more detail later on in this chapter.

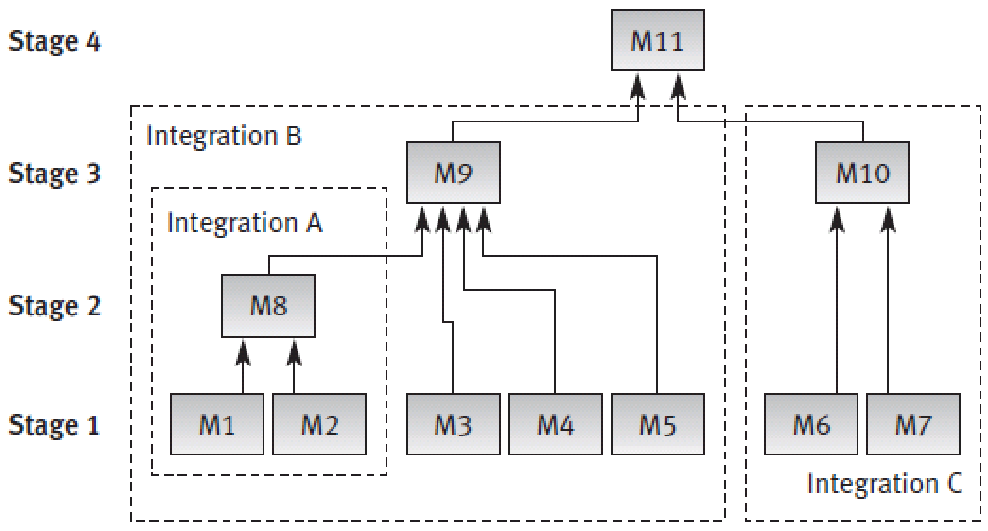


FIGURE 14. Bottom-up testing (8, 183.)

The *top-down strategy* is presented in Figure 15. In the strategy the control structure of the system takes the lead. The control structure is developed in a top-down sequence. This order offers the ability to integrate the modules top-down starting with the top-level control module. At every new integration stage the connected modules at the corresponding level are integrated together and tested. The main advantage of this strategy is that the entire system can be verified partially or as a whole. The main disadvantage of this strategy is that if the requirements are changed and the change has an impact on the low-level modules it may lead to changes in the top-level. Another disadvantage is the conciderable number of *stubs* needed to test every integration step. (4, p.47.)

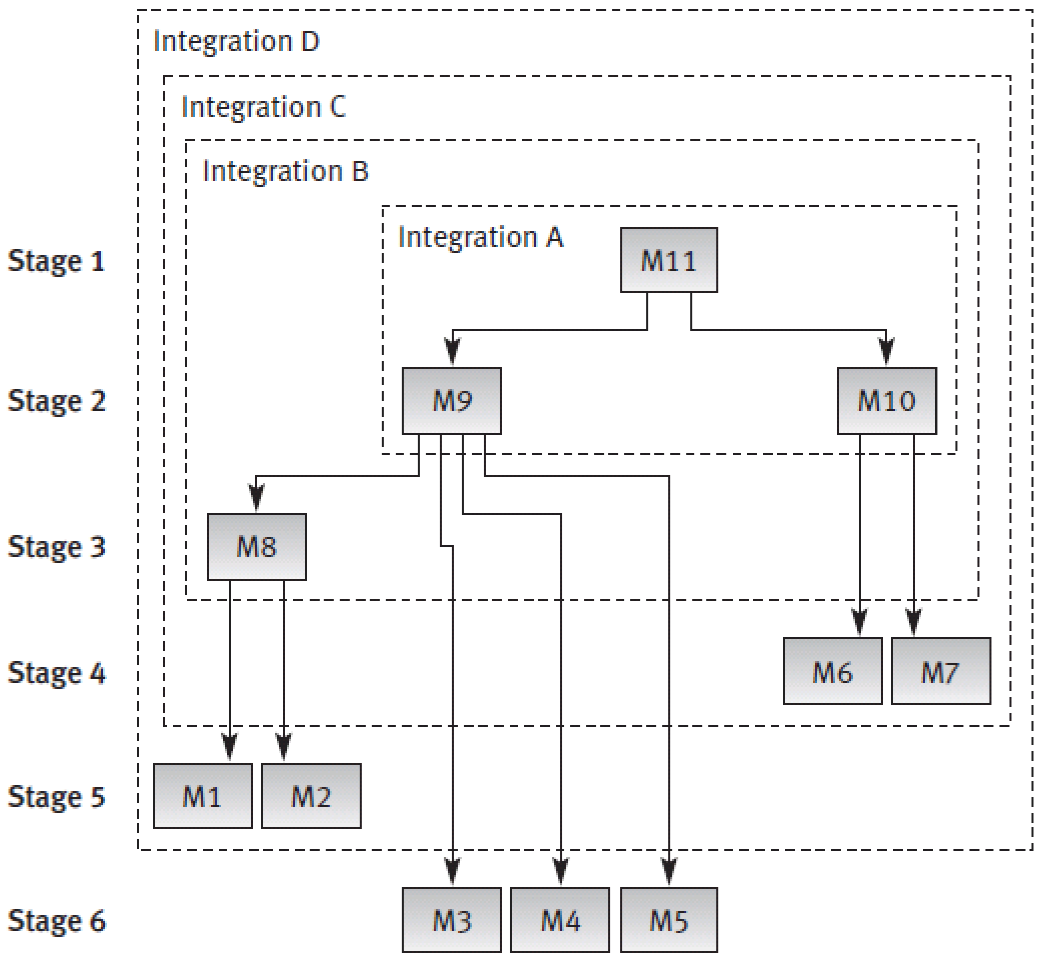


FIGURE 15. Top-down testing (8, p.183.)

The Stubs and *drivers* are defined as the SW replacement simulators that are required for the modules not available when performing UT or IT. In the top-down strategy the testing stubs are used to replace the unavailable lower level modules as presented in Figure 16. The main function of the stubs is to provide the result of calculations the subordinate module is designed to perform. (8, p.184.)

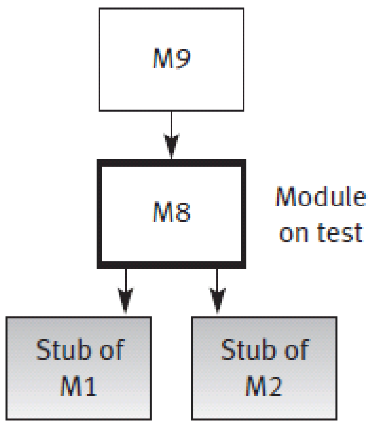


FIGURE 16. Use of the stubs in implementing top-down tests (Stage 3. in Figure 16). (8, p.185.)

In the bottom-up strategy the testing requires the drivers instead of stubs. A driver can be seen as a substitute module for the stub but of an upper level. It activates the module tested as presented in Figure 17. The driver is used for passing the test data onto the tested module and accepting the results calculated by it. Drivers are required in the bottom-up testing until the upper level modules are developed. (8, p.185.) The ATETT is a one type of driver used to control the eNodeB system. Two of the main reasons why the drivers are used in the LTE DSP SWi testing level are:

- They isolate the lower level SW modules out of control by the RRC system.
- They permit to test the lower level SW modules before the upper layer SW are available.

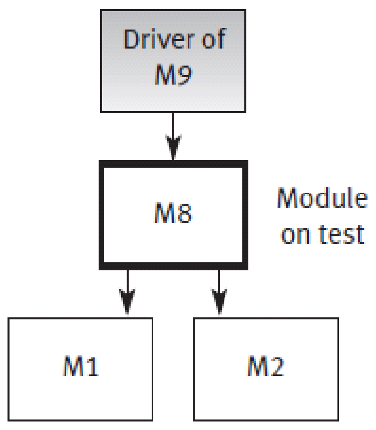


FIGURE 17. Use of the drivers in implementing of bottom-up tests (Stage 2. in Figure 14). (8, p.185.)

3.5 Testing types

Various types of the SW testing exist as functional verification of requirements testing, performance, regression, security etc. All the testing types can be categorized to one or two of the main categories: *black-box*-, *white-box*- and *gray-box* testing. (15, p.11.)

3.5.1 White-box testing

The *white-box* test design techniques are based on the knowledge of the system's internal structure. The white-box testing process is illustrated in Figure 18. The unit testing and code coverage testing are an example of the white-box testing where test design is based on the code, program descriptions and technical design. The testing type requires some working knowledge of the code and design. The main focus in this type of testing is that the system successfully satisfies its functional requirements. (15, p.12.)

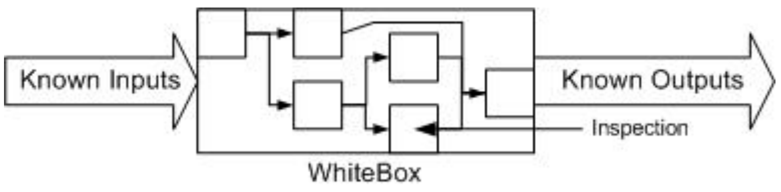


FIGURE 18. White-box testing (16.)

3.5.2 Black-box testing

The *black-box* test is also known as the "*user interface*" test. The black-box testing process is illustrated in Figure 19. Its test design techniques are based on the functional behavior of systems. It doesn't require explicit knowledge of the implementation details as the white-box testing does. In black-box testing the system is a "*black box*" while the inner working of the system is not needed to know. The system is subject to *input* and the result *output* is analyzed if it conforms to the expected system behavior based to requirements of the system. The system behavior is verified only by viewing the output of the user interface. (15, p.12.)

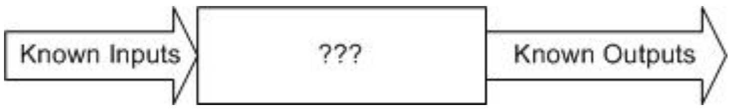


FIGURE 19. Black-box testing (16.)

3.5.3 Gray-box testing

The *gray-box* test design is used to increase black-box testing effectiveness. This design overcomes the problem of not discovering all defects in a system. while using the black-box testing. The simple reason for this is that all the errors may not be reported to the user interface due to the error-reporting mechanism of the software. The gray-box test design requires knowledge of the components used to build the system . Deeper understanding of the architecture and components of an application allows a tester to pinpoint test outcomes to different areas of the application. The gray-box testing is based on the multiple outcomes, and by analyzing the results tester is able to found out the parts of the application that are failing. (15, p.12.)

3.6 LTE DSP SW integration

NSN's eNodeB SW projects based on the V model and the SW and hardware (HW) are developed further using the incremental model. Additionally chosen decision is made to follow the bottom-up strategy where lower level modules are developed before the control elements.

NSN's LTE DSP SWi testing is a very good example of an integration testing in a large scale SW project and for a large size system. The eNodeB system consist of both embedded HW and a very complex DSP SW that the LTE DSP SWi tests.

Because the use of the incremental model and the multiple combinations of HW and SW the integration testing cycle measured in time is very short in all of the test levels. Based on the fact mentioned earlier, in complex systems the software evolves over a period of time. Requirements of the product often change during the development process. The mentioned issues lead to the situation where also the requirements of DSP SW APIs change from time to time.

In the LTE DSP SWi testing level the test engineer works most of the time by using all three of the testing types presented in the chapter 3.5. The eNodeB control messages (*request*, *response* and *indication* messages) present the input and the output of the SUT (eNodeB system) as it is presented in Figure 20. It is specified that the eNodeB has to respond to all received eNodeB control messages with a response message. The response message contains specific information which depends on the received request message. The information in the response is used to verify if the structure of the request message is valid or not. In the scope of this thesis only the message structures are considered . The testing type is the black-box testing since it considers only the input and the output data of the eNodeB.

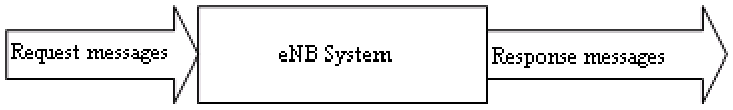


FIGURE 20. The eNodeB control messages are used as input and output testing data.

The eNodeB control messages have a major role in LTE DSP SWi testing because of the type of used ATE. The ATE of the LTE DSP SWi contains only the L1 and L2 layers and not the L3 which controls the L1 and L2 layers in entity systems. The lack of the L3 and the higher network layers defines the type of the ATE. The high level illustration of the LTE DSP SWi type of the ATE is presented in Figure 21.

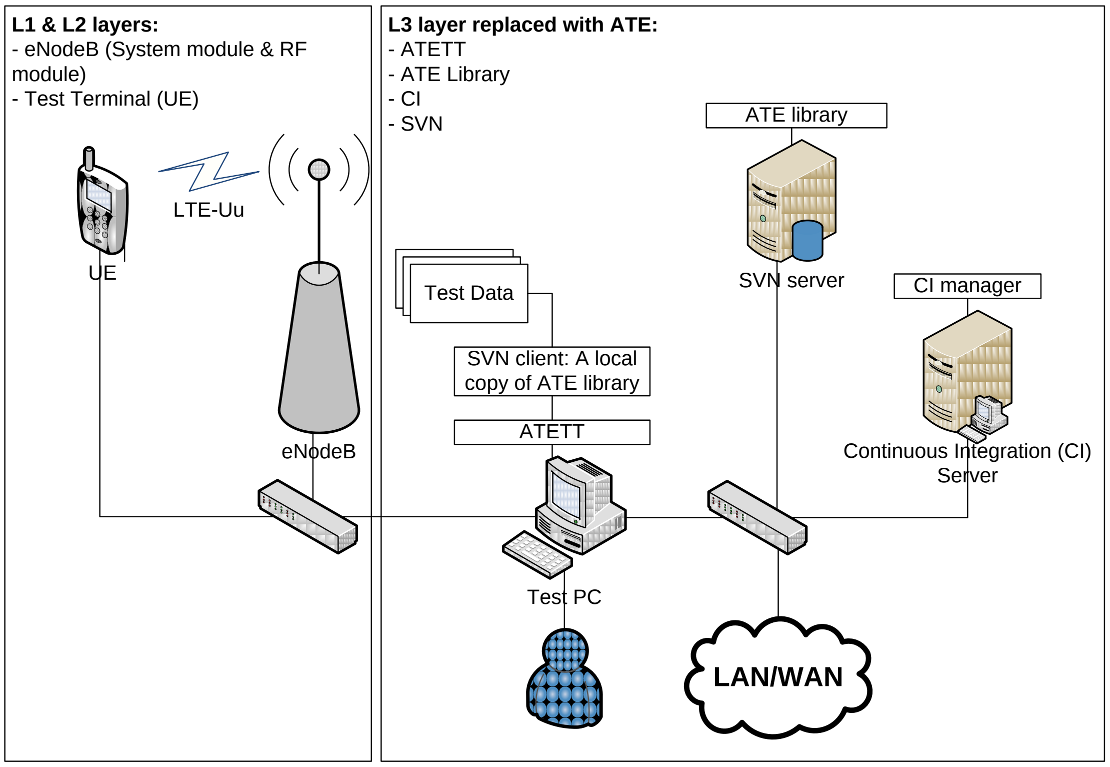


FIGURE 21. The LTE DSP SWi type of test environment

3.6.1 ATETT

The ATETT is the main testing tool used in the LTE DSP SWi. It is a testing SW and it is developed in NSN by an internal test environment team. The ATETT is used mainly in low level integration to execute the tests and test environment configurations. It also provides all the needed interfaces in LTE DSP SWi test environment including support for the automation.

The ATETT is a testing SW and it is also one type of driver used in the LTE DSP SWi testing stage to replace the RRC functionality in a required level. All the eNodeB control messages between the eNodeB and ATETT application are handled through a TCP connection. Figure 18 presents an example of the use of the driver in the SW testing that follows the bottom-up strategy.

The IFS of ATETT specifies an own scripting language and a format for the eNodeB control messages. All of the scripts, eNodeB control messages and other testing related data are stored in the ATE testing library for maintenance.

3.6.2 ATE library

The ATE library is a database where the entire test data made for eNodeB testing purposes by LTE DSP SWi team is collected. The main purposes of using the ATE library is to get all the files used in testing maintained, under version control and to get the latest test data available for every tester globally.

The ATE library is split into two main branches; tests and services. The services branch contains all the eNodeB control messages. The test branch contains all the test case scripts. The test scripts use the eNodeB control messages to setup the eNodeB with different kind of configurations as comprehensively as possible. The main purpose is to verify the correct functionality of the eNodeB in every situation.

3.6.3 Test automation in LTE DSP SW integration

The ATE of the LTE DSP SWi is partially automated. The current automation is based on continuous integration (CI) which is a commonly used practice in the Agile SW development. The aim of the automated CI testing in LTE DSP SWi testing is to provide a quick result for every DSP SW build. It is required that the first test result of each build has to be available within two hours.

4 APPLICATION DEVELOPMENT PROJECT

The definition for software by Myers: *"Software is (1) instructions (computer programs) that when executed provide desired function and performance, (2) data structures that enable the programs to adequately manipulate information and (3) documents that describe the operation and use of the programs."* In general, SW is used to produce information. SW delivers the computing potential embodied by the computer HW. SW can be used as an example to transform, produce, manage, acquire, modify, display, or transmit information. In general, SW has multiple using purposes and one of them is to transform data so that it is more useful in a local context. (5, p.4-6.)

This chapter presents the implementation project of the PC application made for the LTE DSP SWi testing purposes. The chapter goes through the key languages, tools used during the project. The requirements and key functionalities of the CTA and XML conversion plug-in are presented.

4.1 Used tools and languages

This chapter presents all tools and languages which were used either in the development process of the tool or are in some other way tightly related to this work.

4.1.1 Qt programming language

The first version of the Qt framework was the Qt 0.90 and it was released in 1995 by Haavard Eirik and Chambe-Eng. The Qt was based on the C++ programming language. At the beginning, the Qt framework only contained a cross-platform graphical user interface (GUI) toolkit. The cross-platform approach of the Qt means that a programmer can use a single source tree for applications that can be run on Windows 98 to XP, Mac OS X, Linux, Solaris, HP-UX, and many other versions of Unix with X11. The cross-platform framework is still one of the main strengths of the Qt. The later releases of the

Qt framework extend the framework with: signals and slots mechanism, Unicode, multithreading, databases, internationalization, networking and XML. (17, p.xi, xv-xvi, 451-452.)

The Qt is available under various licenses. A commercial license of the Qt is required in a case of commercial applications. The general public license (GPL) version of the Qt is available for non commercial open source programs. (17, p.xii.) The application made for the company's internal use only can be done under the GPL, as the application in this thesis for NSN.

The Qt software development kit (SDK) combines the Qt framework including the class library with tools (simulator, local and remote compilers, internationalization support, device toolchains etc.). The SDK is needed in the creation of the applications. The content of the Qt SDK is presented in Figure 22. The newest release of the Qt library is version 4.8. (18.)

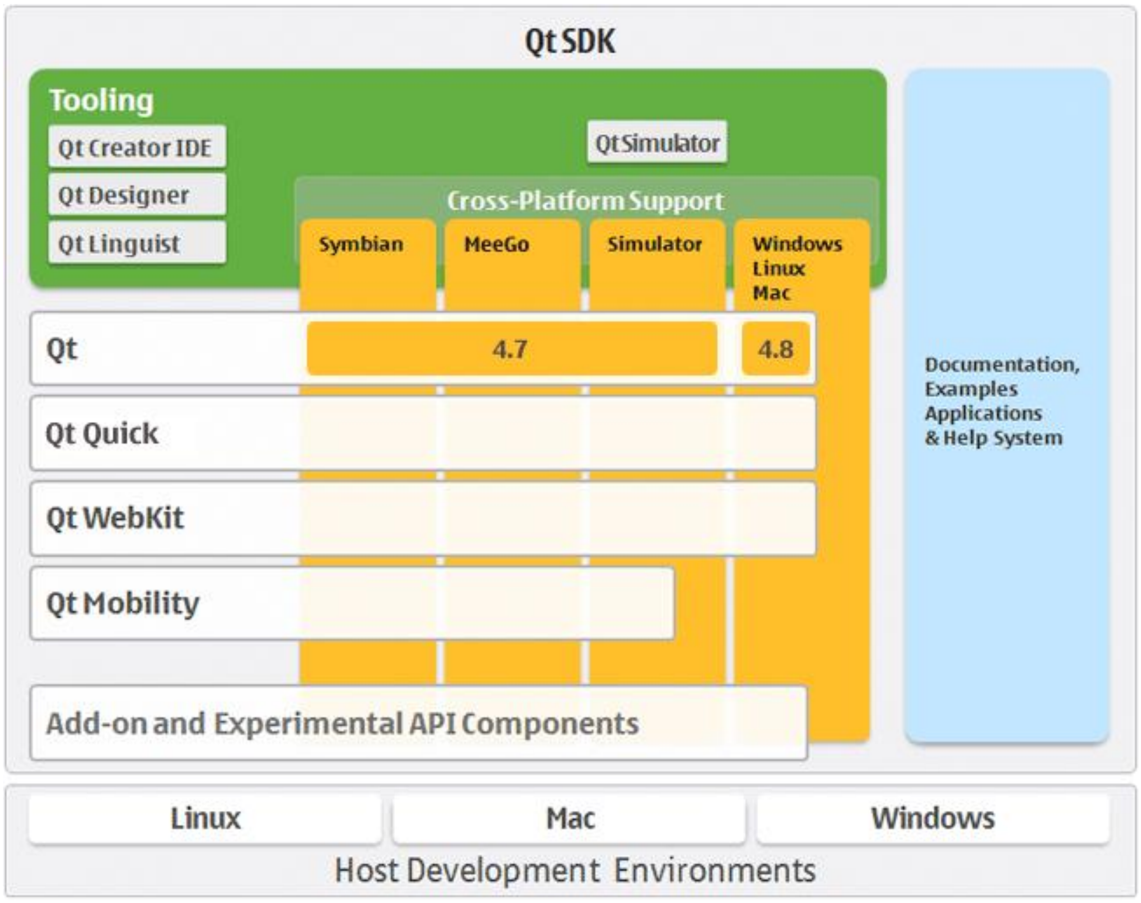


FIGURE 22. The content of Qt SDK (19.)

The Qt Creator is an integrated development environment (IDE), and it is one of the tools that the SDK contains. It is a cross-platform IDE tailored to the needs of Qt developers. It is designed for developing Qt applications and user interfaces once and deploying them across several operating systems. (20.)

A list of the main functionalities of the Qt Creator is as follows:

- C++ and JavaScript code editor
- Integrated UI designer
- Project and build management tools
- GDB and CDB debuggers
- Support for version control
- Simulator for mobile UIs
- Support for desktop and mobile targets

(20.)

In this thesis, the following were the main reasons why the Qt programming language was chosen to the programming language of the PC application:

- Support for XML data handling. The main functionality of the XML conversion plug-in is to convert the source data from the XML format to the format of the eNodeB control messages. Because the source data is in the XML format, most of the functionalities of the application are related to the XML processing.
- The SW organization of NSN has a mixed set of platforms in use that contains Windows and Linux PCs. From that reason it was natural to select a programming language that supports both of the platforms.

The Qt library version 4.7 and the Qt Creator 2.2.0 version were used in the application development project. The Qt library version provides two different types of APIs for processing XML data:

- SAX (Simple API for XML)
- DOM (Document Object Model)

(17, p.339.)

The main difference between the SAX and the DOM is that an XML document is read in the memory when the DOM is used. The DOM represents the entire XML document as a three of the XML node objects. After the document is read in the memory, applications can then parse and modify it. Approach of the SAX is simpler than that of the DOM, and it can only be used to read the XML document. The SAX does not read the entire XML document in the memory. (17, p.339, 344.) In the implementation of the XML conversion plug-in, the DOM was used. It provided a good base for a dynamical XML parser.

4.1.2 XML modeling language

The first version of XML was introduced in 1998 by a group of companies and organizations that called themselves the world wide web consortium (W3C). XML is a programming language based on the standard generalized markup language (SGML). SGML is a metalanguage whose primary task is to define other markup languages.

SGML is parent for both XML and the hypertext markup language (HTML), and this relation is presented in Figure 23. The extensible HTML (XHTML) is a reformulation of HTML using XML. XML is a markup language that defines a subset of SGML meant to work more efficiently with networked applications. (21, p.15-16.)

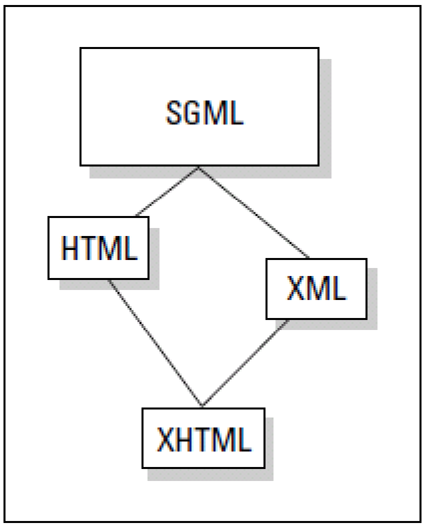


FIGURE 23. Relations of the markup languages (21, p.15.)

XML is a software- and hardware-independent ‘tool’ for carrying information. The main differences between HTML and XML are that HTML is about displaying information whileXML is about carrying information. Another difference between these languages is that the tags in XML are not defined by any XML standard. The tags are invented by the author of the XML documents. In HTML, the tags used are predefined by the HTML standard unlike in XML. (22.)

A markup language uses tags that can be placed in the text of a document to determine and label the parts of that document. The tags are important in electronic documents because computer applications use them when processing documents. The tags used to determine the exact boundaries for a certain part of document. If the tags are missing, the program have to has with the entire document as a unit. (23, p.2-3.)

A markup language is a language used to label, categorize and organize data or document content. The markup describes a document or data structure and organization.

The content, such as text, images and data, is the content of the markup. (20, p.14) XML is not itself a markup language. It is a set of rules for building markup languages. It makes it possible to make up an individual markup language to express the information in the best way possible. (23, p.12.)

A software application that contains an XML processor is able to process XML. It means that the application is able to read an XML file and do something with it. The basic idea is that the XML processor is used to read XML files and transforming them into an internal representation for other applications or subroutines to use. This is called an XML parser and it is one of the main components of every application that processes XML data. (23, p.8.)

XML has a major role in this thesis because the source data that the XML conversion plug-in converts is in the XML format. The Qt library version used in the application development project offers two different types of XML APIs, which was presented in the previous section (4.1.1).

4.1.3 UML modeling language

The first version of the UML was introduced in 1997 by Booch, Rumbaught and Jacobson. UML is a language or notation intended for analyzing, describing and documenting all aspects of a SW intensive system. It is further developed from the object modeling technique (OMT) (A method found by J. Rumbaught), *Booch* (A method founded by G. Booch) and *OOSE* (A method founded by I. Jacobson). Since the year 1997 the language has been developed with a dynamic set of new features, and minor releases are released by referring to them as UML1.x. Currently, the newest versions of UML are known as UML2.x and the released versions of it are designed to extend the UML1.x. (24, p.1.)

UML is an industry standard mechanism that provides a comprehensive set of SW modeling instruments. The set contains: graphical elements, including notation for classes, components, nodes, activities, ports, workflow, use cases, objects, states and the relationships between all these elements. (24, p.1-2.)

A modeling represents in general a highly creative work and it is a method used to search the best solutions for a certain module to achieve the goals and the requirements of the project under construction. During the modeling work the designers have to investigate the needs, preferences, structure and design for the project. The predefined needs and preferences are called requirements. The requirements include areas such as functionality, appearance, performance and reliability. Using the iterative approach in co-operation with the developers the model designers try to reach a deeper understanding of the system and can finally create models of the systems that achieve the goals and requirements of the system and its users. Communicating a model in a clear way to many people represents a core feature of UML. (24, p.2-3.)

There is no simple way to model a complex system. It is impossible to represent the entire system clearly in a single picture that all understand without confusion. A single graph cannot capture all the information needed to describe a system. A system has many different aspects: functional (its static structure and dynamic interactions), nonfunctional (timing requirements, reliability, deployment etc.), along with organizational aspects (work organization, mapping to code modules etc.). A system description requires a number of views, where each view represents a projection of the complete system that shows a particular aspect. Each of these views requires a number of diagrams that contain information emphasizing a particular aspect of the system. The diagrams contain graphical symbols that represent the model elements of the system. (24, p.21.)

A list of different views in UML is as follows:

- *Use-case view*: A view showing the functionality of the system as perceived by external actors.
- *Logical view*: A view showing how the functionality is designed inside the system, in terms of the system's static structure and dynamic behavior.
- *Implementation view*: A view showing the organization of the code and the actual execution code.

- *Process view*: A view showing the main elements in the system related to the process performance. This view includes the scalability, throughput, and basic time performance and can touch some very complex calculations for advanced systems.
- *Deployment view:* A view showing the deployment of the system into the physical architecture with computers and devices called nodes.

(24, p.21.)

UML is a powerful tool when it is used in planning the architecture of the SW. In the SW project of this thesis it was mainly used to draw use-case views and logical views.

4.1.4 SVN version control

The version control is used to manage the changes in the information. People who are using computers to manage information that changes are often people who need the version control. The version control is a widely used system by the SW developers who typically spend their time making small changes in software and then undoing or checking some of those changes the next day. It helps the developers of a team to successfully commit new changes without losing anything into the existing files when the developers are working concurrently using the same repository and sometimes even simultaneously on the very same files. (25, p.1.)

In the application project of this thesis the TortoiseSVN subversion and its basic features were used. TortoiseSVN is one of the subversion version types available. The TortoiseSVN is a free open-source Windows client for the Apache Subversion version control system. The subversion manages files and directories over time which is a basic functionality in every version control system. It can operate across networks which allow it to be used by people on different computers. The files are stored in a central repository. The repository is much like an ordinary file server, except that it remembers every change ever made to the files and directories. This feature allows the users to recover older versions of the files and examine the history of how and when the data changed and who changed it. Figure 24 illustrates the architecture of the subversion system. (26, p.xi)

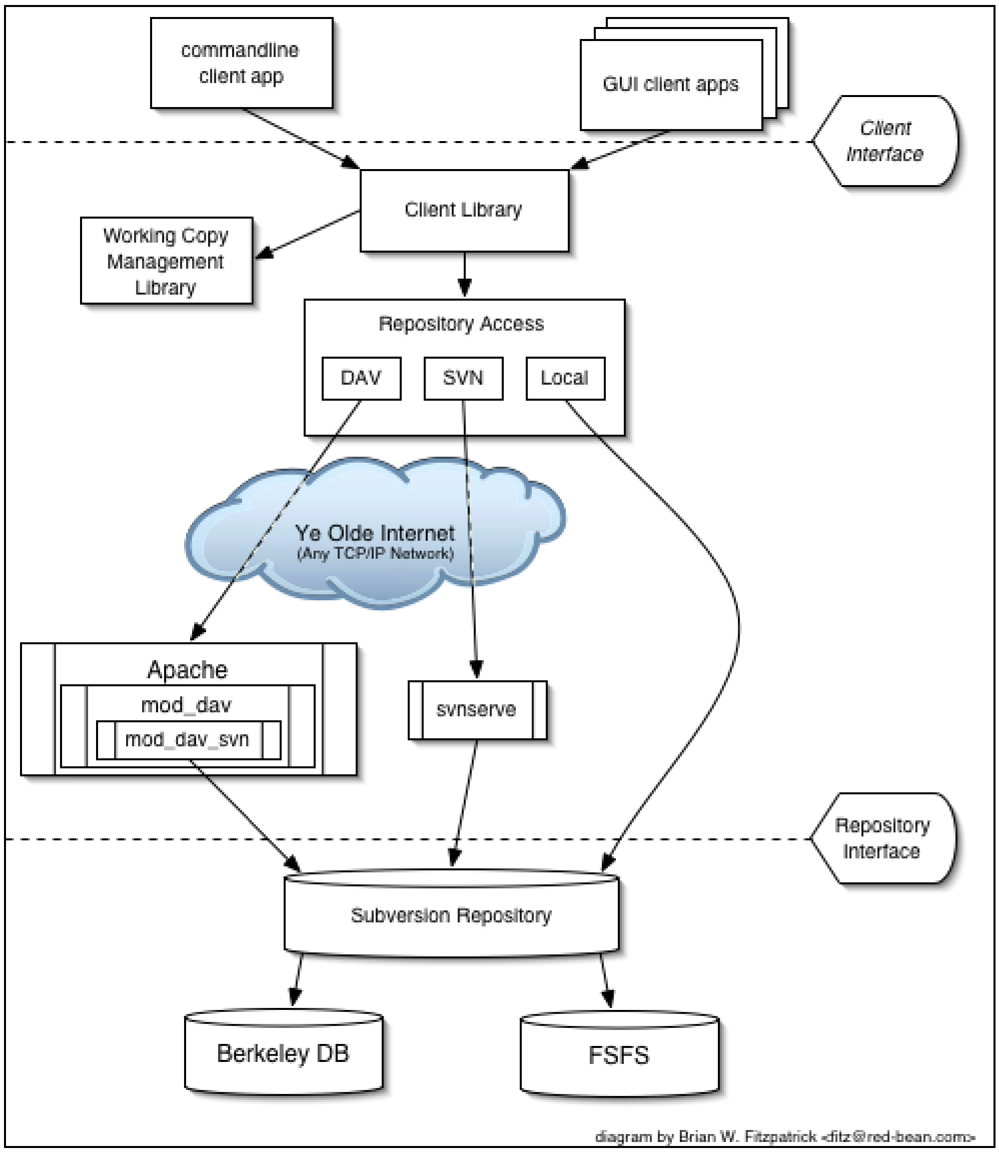


FIGURE 24. Subversion architecture (25, p.4.)

A SVN repository is possible to branch into separate branches. The branching makes possible to develop multiple SW iterations in parallel. The branching isolates the SW iterations from other iterations. Use of the branching, guarantees that a change made in a certain iteration of the SW does not have influence to the other the SW iterations in the same SVN repository. The branching of a repository is illustrated in Figure 25. The original line of development (trunk) that exists independently of other lines (branches) shares a common history. A branch always begins life as a copy of trunk, and moves on from there generating its own history. (25, p.42.)

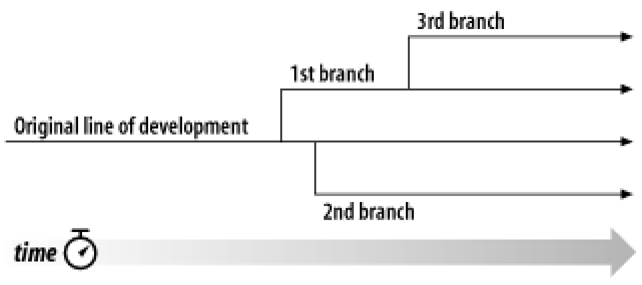


FIGURE 25. Branches of SW development (25, p.42.)

At the beginning of the project three branches were created. This was done because the trunk branch was used to develop and maintain the common interface of the CTA. Two other branches were reserved for two independent software plug-ins that were planned to be developed. Another one of these two was the XML conversion plug-in.

After the first working version of Common testing tool and its interface for plug-ins was ready, source codes from the trunk branch were merged to the other two branches. After the merging operation the development process of the plug-ins continued independently. The branching was used to control the influence of changes. The changes were made to certain branch and then merged between the branch and the trunk. The changes were tested before merging.

The branch that was used to develop the XML conversion plug-in contained 43 different revisions in the end of SW project. It means that 43 changes committed in the SVN repository before the functionality of the CTA's and the XML convert plug-in was in the required level and functionality worked without errors.

4.2 CTA

The CTA is a PC application. The CTA is made by using the Qt programming language and class library of it. Testing PCs used in LTE DSP SWi testing contain both Windows and Linux operating systems. The CTA must work on top of both of them. That is why it was very useful to choose Qt cross-platform development environment and framework.

Name of CTA refers in that the application is developed into the testing purposes and ‘common’ comes because it is extendable with software plug-ins. The CTA provides a common interface for numerous of individual testing software (plug-ins). It does not itself provide any testing functionalities without plug-ins. Basically, the CTA acts as framework for its plug-ins. The CTA provides only the main window (widget) with very simple visual layout from user point of view. The layout consists of common graphical user interface (GUI) containing only basic menus.

The main idea behind the CTA and its common plug-in interface was respond to two of the known problems related to small size tools developed inside the NSN’s SW organization:

1. SW engineers develop numerous small size tools to help their daily work. Most of these tools are used only by developer itself and in some cases by few other persons.
2. The small size tools are lost many times during the time because the tools are usually stored only in the hard drive of certain laptop or PC.

The CTA can be used to collect under its common interface all such small size tools that are usable for more than one person inside the SW organization. In general, the common widget where all individual tools provide their own GUI is more user friendly approach than 100 small tools spread around the SW organization.

4.2.1 User scenario of CTA

A use-case diagram presented in Figure 26 is used to show the number of the external actors and their connection to the use cases that are provided by the CTA. The use-case diagram describes the functionality of the CTA and its plug-in interface which provides an API for all software plug-ins.

A user of the CTA can select between the available plug-in software which of the plug-in tools s/he wants to start using. The CTA only shows the available plug-ins.

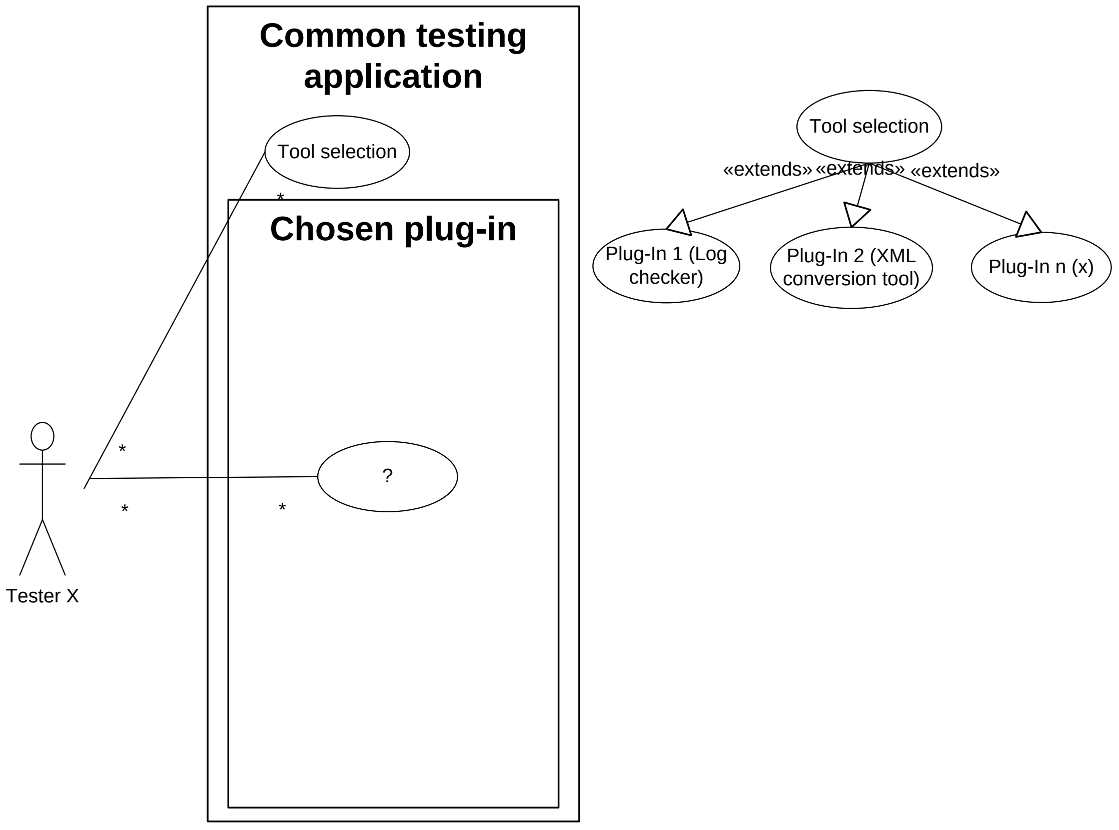


FIGURE 26. The UML use-case diagram of the testing application extendable with plug-ins

4.2.2 Plug-in interface of CTA

The software written using C++ consists of one or more compilation units. Each of the compilation units is a separate source code file. Once all the source files have been compiled, the object files can be combined together to create an executable program (.exe) using a special program called the linker. The compilation process is illustrated in Figure 27. (17, p.452.)

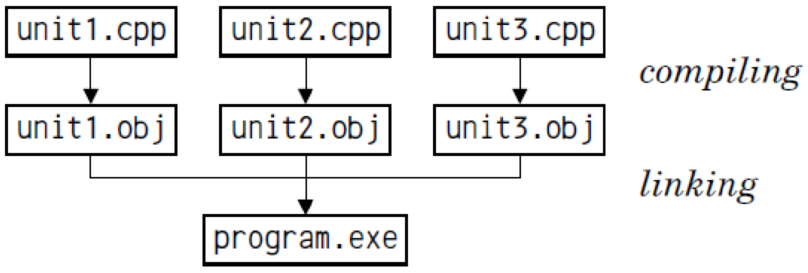


FIGURE 27. The C++ compilation process on windows platform (17, p.452.)

The executable can only consist of object files, but they often link even against the libraries that implement a ready-made functionality. There are two main library types:

- Static libraries are put directly into the executable as if they are object files. This ensures that the library cannot get lost but increases the size of the executable
- Dynamic libraries (also called shared libraries or DLLs) are located at a standard location on the PC and are automatically loaded at the application's startup.

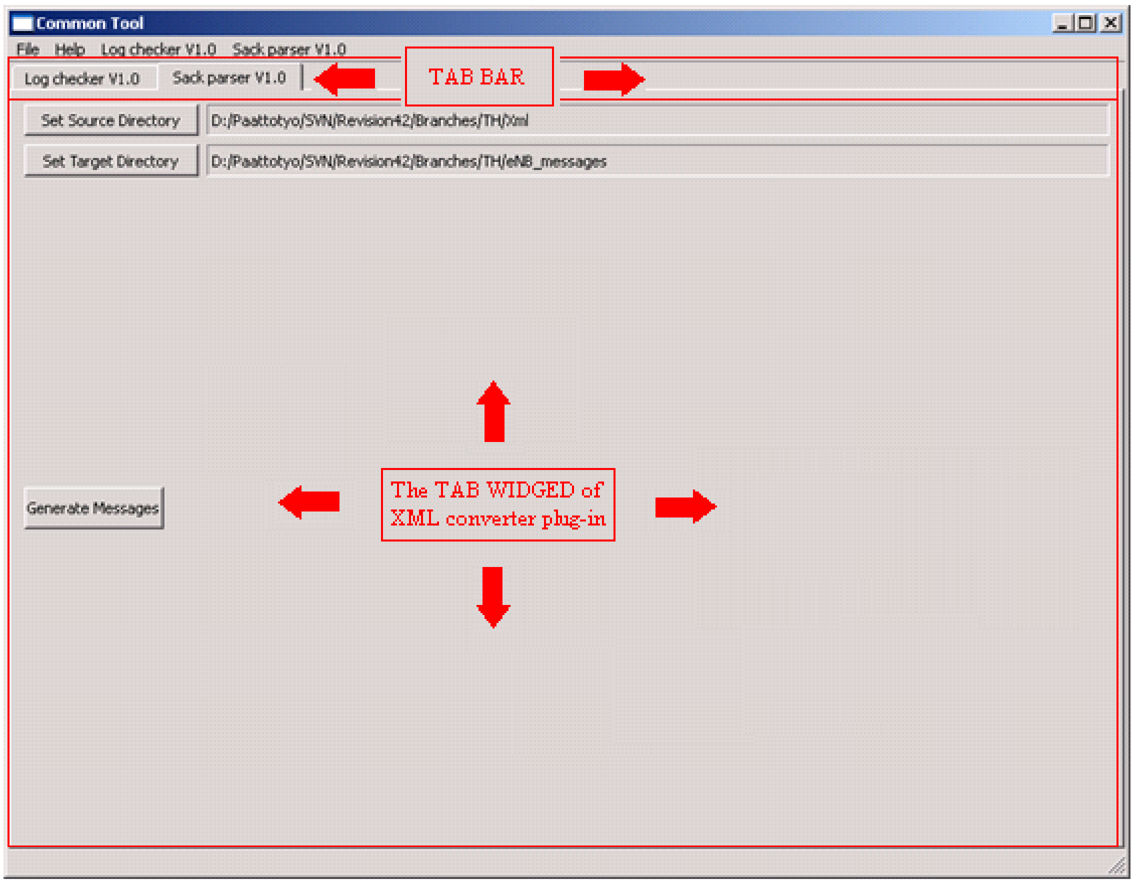
(17, p.456.)

The CTA and its API are made to be a plug-in aware. Qt supports two types of the plug-ins. The first plug-in type extends the Qt library and the other type extends the applications written in Qt. The XML conversion plug-in represents the plug-in type that extends the functionality of the CTA. All the plug-ins used via the CTA use the plug-in interface of it.

In practice, a single plug-in of the CTA's is a DLL file. When the execution of the CTA starts, all the plug-ins that are currently available in a predefined directory will be loaded in use. The plug-ins dynamically extends the functionality of the CTA’s and implements one more interface into it. A plug-in interface is a class that only contains pure virtual functions. This interface is inherited from the class that implements the plug-in. The class is stored in the shared library and therefore it can be loaded by the application at the run-time. When the plug-in is loaded, it is dynamically cast with the interface using Qt's meta-object system. (27.)

The CTA consists of a single TabDialog class that provides an individual tab for each plug-in. The use of tap dialogs provides a clear and efficient way for the testing application to communicate with the user. The information that the CTA’s GUI provides can be split between the plug-ins by using a number of tabs in a dialog. (28.)

The tabs of the testing application are implemented to provide the plug-in specific GUIs which have no relation between them. The Qt library’s QTabWidget class was used in the implementation. It provides a stack for tabbed widgets. The tab widget provides a tab bar that contains an individual tab for each of the plug-ins. The "page area" display pages were related to each tab. The tab bar of the testing tool and the page area of the XML conversion plug-in are presented in Figure 28. Each of the tabs is associated with a plug-in specified widget (page). Only the page of the selected plug-in is shown in the page area and all the other pages are hidden. The user can start to use different plug-in software by clicking on its tab. (29.)



D:/Paattotyo/SVN/Revision42/Branches/TH/Xml

D:/Paattotyo/SVN/Revision42/Branches/TH/eNB_messages

FIGURE 28. The GUI of the CTA with two tab widgets (two plug-in extensions) - The XML convert plug-in application (Sack parser V1.0) is selected in use

4.3 XML conversion plug-in for CTA

The XML conversion plug-in is developed to extend the functionalities of CTA. It is used to generate the eNodeB control messages. The main functionality of the plug-in is to transform the XML source data to the format of the eNodeB control messages defined by the IFS of the ATETT.

4.3.1 User scenario of XML conversion plug-in

A user of the XML conversion plug-in could be any one of the testers who works in the LTE DSP SWi team. When the DSP SW application interface(s) of the eNodeB system changes, all the testers in the team know what to do and start to follow the protocol made for the situation. The protocol currently contains many manual actions. The use of the CTA with the XML conversion plug-in removes one of the manual actions and the laborious one, from the point of view of the LTE DSP SWi.

The XML conversion plug-in is one of the software that is used to extend the CTA. It provides all the functionalities that are needed to generate the eNodeB control messages from the source XML files. A high level illustration of the CTA is presented in Figure 29.

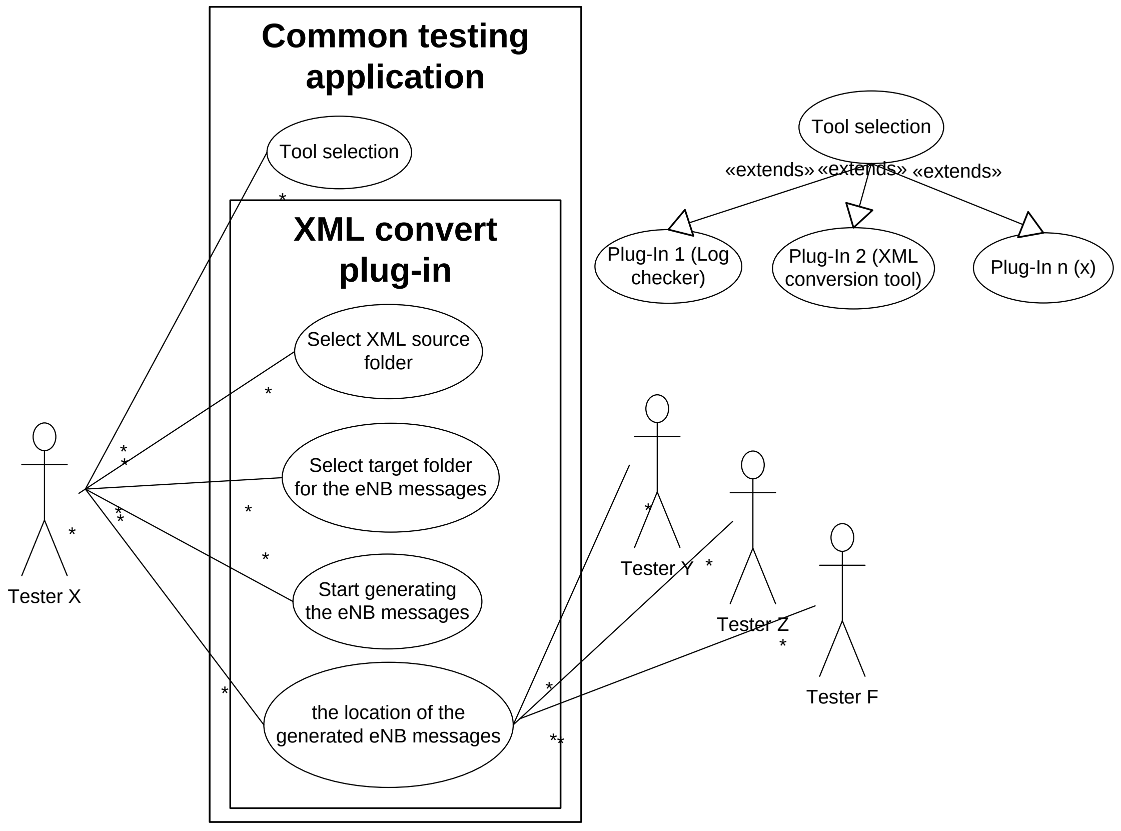

Common testing application
Tool selection
XML convert plug-in
Select XML source folder
Select target folder for the eNB messages
Start generating the eNB messages
the location of the generated eNB messages
Tester X
Tester Y
Tester Z
Tester F
Tool selection
«extends»
«extends»
«extends»
Plug-In 1 (Log checker)
Plug-In 2 (XML conversion tool)
Plug-In n (x)

FIGURE 29. The UML use-case diagram of the testing application extended with the functionality of XML conversion plug-in

4.3.2 Input data for XML conversion plug-in

Inside the NSN’s LTE SW project, XML is used to transform the existing data according to the rules (refactoring). The content of the XML source data is based on the IFS of C-Based messages. The XML conversion plug-in uses the XML source data and convert it in the format of the eNodeB control messages. The amount of the XML source data is considerable. It consists of 27 separate XML files whose total size is ~3.3Mbytes.

The content of the XML data files consist of the definitions of the information of the messages. The definitions can belong to *messages, definitions and interfaces*. The *messages* elements only contain the structure definition of the messages. The *interfaces* elements store the relation information between the messages and DSP SW applications. The *definitions* elements store the information about the content of the messages. The content is a set of parameters which each have a definition of type, size and default value. Typically, a message contains 1-1000 parameters. An example of the XML source file’s structure with a simplified illustration can be seen below:

```
- <system name=" "
        - <component name=" ">
                - <definitions>
                              <typedef name=" " type="u32" />
                       - <enum name=" ">
                       <enum-member name="1" value="0" />
                       <enum-member name="2" value="1" />
                        </enum>
                       - <struct name="SDRbList">
                              <member name=" " type="Tx" />
                              <member name=" " type="Sy" />
                        </struct>
                       - <union name="UUlResCtrlParamContainer">
                                <member discriminatorValue="0" name="" type="S1" />
                                <member discriminatorValue="1" name="" type="S2" />
                        </union>
                       <constant name=" " value=" " />
                 </definitions>
                - <messages>
                       - <message name="  ">
                         <member name=" " type="T1" />
                       </message>
               - <messages>
               - <interfaces>
                              - <interface name=" " >
                               <message name=" " />
               </interface>
               <interfaces>
        </component>
</system>
```

The definitions contain the type definitions for each parameters and it can be one of the following:

- *Constant (const)*: Constants are expressions with a fixed value. (30)
    - An example use of the constant in the XML source file:

      <constant name="MAX_NUM_OF_FAULT_INFO" value="11" />

- *Typedef*: C++ allows definition by developer using own types based on other existing data types. It is possible to do by using the keyword typedef. (30)
    - Typedef is declared in C++ using the following syntax:

      typedef existing_type new_type_name;.
    - An example use of typedef in the XML source file:

      *<typedef name="**T**BoardId" primitiveType="32 bit integer unsigned" />*

- *Structure (struct)*: Data structure is a group of data elements. The data elements are grouped together under one name. These data elements, known as members, can have different types and different lengths. (30)
    - Data structures are declared in C++ using the following syntax:

```
struct structure_name {
member_type1 member_name1;
    member_type2 member_name2;
    member_type3 member_name3;
    ...
} object_names;
```

    - An example use of struct in the XML source file:

```
- <struct name="SAaTime">
     <member name="year" type="u32" />
     <member name="month" type="u32" />
     <member name="day" type="u32" />
     <member name="hour" type="u32" />
     <member name="minute" type="u32" />
     <member name="second" type="u32" />
     <member name="millisec" type="u32" />
</struct>
```

- *Union*: All the elements of the union declaration occupy the same physical space in the memory. Union's declaration and use is similar to the one of structures but its functionality is different. The size of union is the one of the greatest element of the declaration. (30.) As seen in example below, the union contains two different structures. The structures are selectable by defining the discriminator value.
    - Union structures are declared in C++ using the following syntax:

```
union union_name1 {
    member_type1 member_name1;
    member_type2 member_name2;
    member_type3 member_name3;
    ...
} object_names;
```

    - An example use of the enumeration in the XML source file:

```
- <union name="UUlResCtrlParamContainer">
       <member discriminatorValue="0"
                    name="vendor1UlResCtrlParams"
                    type="SVendor1UlResCtrlParams" />
       <member discriminatorValue="1"
                    name=" vendor2ParamContainer1"
                    type="SVendor2ParamContainer1" />
  </union>
```

- *Enumeration (enum):* Enumerations create new data types to contain something that is not limited to the values of fundamental data types. (30.)
    - Enumeration is declared in C++ using the following syntax:
      ```
      enum enumeration_name {
        value1,
        value2,
        value3,
        …
      } object_names;
      ```
    - An example use of the enumeration in the XML source file:
      ```
        - <enum name="EFaultId">
            <enum-member name="EFaultId_ChangeFanAl" value="0" />
            <enum-member name="EFaultId_FanPowerAl" value="1" />
        </enum>
      ```

Following list of exceptions is required to be taken into account when parsing the content of XML files:

- Dimension: Models arrays on typedefs, structures and union members. Used to define if certain parameter or block occurs more than once.
- Optional Members: Generates additional structures if member *hasXyz* as flag. The flag used with messages that contain dynamical structures. *hasXyz* parameter is used to indicate this information to the DSP SW.
- Variable Size Arrays: Additional length field. The used DSP processor and buss type in HW of eNodeB has own limitations e.g. how big variables the eNodeB DSP SW is able to handle. This is used to round the limitation.
- Value Ranges: Used in validation functions to check all message members. The value ranges can be printed also into message templates during the message generation process. The ranges are added there in the form of comment lines after each parameter to give extra information for the user.
- Default Values: Usable with new parameters.

The implementation of the XML source files contained few solutions which I did not find any good argument. The XML files contained all required information to generate the eNodeB control messages. Nevertheless, there are few implementations that could be done better than currently. Earlier in this section was stated that the XML source data contains the definition of the *messages*, *definitions* and *messages*. The first and the second of the notifications below are related to the definitions of the *messages*. The third of the notifications is related to the definitions of the *definitions.*

All the XML source files are generated automatically with a special XML generator tool. The XML source files contain exceptions, because the way of the XML generator implementation is done. All the exceptions have to be taken into account while implementing an application that is used to parse the XML source data. It makes implementation of XML parsers' for the eNodeB control messages more complex. Next three notations are found during the development project of the XML conversion plug-in. All the three required additional functionalities implemented in the parser of the XML conversion plug-in.

Description of notation 1 with text and using an example below: The size attribute of the XML dimension element contains a constant parameter. The constant is used to define if a certain parameter or structure in the eNodeB control message occurs more than ones. The MAX_NUM_OF_XMBR is constant value and defines how many times the eNodeB control message contains TXmbr parameter:

```
- <component name="MAC">
        - <messages>
                - <message name=" ">
                        <member name="Xmbr" type="TXmbr">
                                <dimension isVariableSize="true"
                                size="MAX_NUM_OF_ XMBR" />
                        </member>
                </message>
        </messages>
</component>
```

Proposal for the notation 1 explained with text and using an example below: The definition of the XML message element defines three indexed parameters. The individual member elements are used instead of that the dimension element defines how many parameters are required. The XML conversion plug-in or any other tool used to parse the XML source data does not need extra functionality to handle the dimension. In example the value of MAX_NUM_OF_ XMBR is three.

```
- <component name="MAC">
        - <messages>
              - <message name=" ">
                       <member name=" Xmbr [1]" type="TXmbr" />
                       <member name=" Xmbr [2]" type="TXmbr" />
                       <member name=" Xmbr [3]" type="TXmbr" />
               </message>
        </messages>
</component>
```

The Xmbr parameter inside the eNodeB control message:

```
Xmbr[1] (4) = 0x00000000               //1st
Xmbr[2] (4) = 0x00000000               //2nd
Xmbr[2] (4) = 0x00000000               //3rd
```

Description of notation 2 with text and using an example below: The XML message element does not contain a child element for hasXmbr parameter. Since the member element contains the attribute optional with value ‘true’, it indicates that in the eNodeB control message has to exist one additional Boolean type parameter before the next parameter item.

```
- <component name="MAC">
        - <messages>
              - <message name=" ">
                       <member name="Xmbr" comment="hasXmbr"
                        optional="true" type="TXmbr" />
               </message>
        </messages>
</component>
```

Proposal for the notation 2 explained with text and using an example below: The XML message element should contain an own member element for the parameters which is used to indicates that next parameter or structure is optional. Hence the XML conversion plug-in or any other tool used to parse the XML source data does need extra functionality to handle these Boolean parameters.

```
- <component name="MAC">
        - <messages>
              - <message name=" ">
                       <member name="hasXmbr" type="TBoolean" />
                       <member name="Xmbr" type="TXmbr" />
               </message>
        </messages>
</component>
```

The Xmbr parameter inside the eNodeB control message:

```
hasXmbr (4) = 0x00000000    //Indicates does the message contain Xmbr parameter
Xmbr (4) = 0x00000000       //Exists only if hasXmbr is true (true | false)
```

Description of notation 3 with text and using an example below: The definition of the XML message element contains only one member element. When the message parser requests the type definition for TXmbr parameter, the XML typedef element can contain an additional XML dimension element. Size attribute of the dimension is used to indicate that instead of one u32 the TXmbr requires use of two u32s. It means that the XML conversion plug-in has to generate TXmbr parameter two times into the eNodeB control message.

```
- <definitions>
      - <typedef name="TXmbr" type="u32">
            <dimension size="2" />
        </typedef>
- <component name="MAC">
      - <definitions>
            <typedef name="TXmbr" type="u32">
                  <dimension size="2" />
            </typedef>
        </definitions>
      - <messages>
          - <message name=" ">
                  <member name=" Xmbr" type=" TXmbr" />
            </message>
        </messages>
</component>
```

Proposal for the notation 3 explained with text and using an example below: The definition of the XML message element defines two indexed parameters instead of one without the index. Hence the XML conversion plug-in or any other tool used to parse the XML source data does not need functionality to handle the parameter value dimensions.

```
- <component name="MAC">
      - <definitions>
              <typedef name="TXmbr" type="u32" />
        </definitions>
      - <messages>
            - <message name=" ">
                  <member name=" Xmbr [1]" type=" TXmbr " />
                  <member name=" Xmbr [2]" type=" TXmbr " />
              </message>
        </messages>
</component>
```

The Xmbr parameter inside the eNodeB control message:

Xmbr[1] (4) = 0x00000000 //1st part of the parameter
Xmbr[2] (4) = 0x00000000 //2nd part of the parameter

4.3.3 Output data of XML conversion plug-in

The eNodeB control messages contain two headers and those are located in the beginning of the each message. An actual payload data section comes after the headers. The first hearer is used in the testing purposes. The second header defines where the message is transmitted inside the eNodeB and the signal number (msg_nr) is used in the DSP SW level to separate the messages from each other. The length of the messages indicates DSP SW the end of an individual message.

Basically all the parameters are equally important from the DSP SW point of view but the headers, the length parameter and the msg_nrs parameter of the messages has a critical role when the XML conversion plug-in generates the eNodeB control messages. The length need to be calculated and need of padding bytes have to be taken into account. The msg_nrs are parsed out from the XML source data.

An example capture of eNodeB control message which shows the first header structure of the message. The header structure consists of 8 bytes. It is presented in the message format of the ATETT in below:

protocol_id (1) = 0x00
msg_type (1) = 0x00
length (2) = 0x0000
msg_nr (2) = 0x0000
spare (2) = 0x0000

All the eNodeB control message parameters have own line in ATETT's message. Each line starts with a name of parameter. The second item is a number in brackets which reveal the size of the parameter in bytes. Last item after an equal sign are digits. The amount of digits depends on the size of the parameter. The digits are shown in the hexadecimal format and one digit presents four bits. One byte is eight bits and that is the reason why 1 byte is shown with two digits. The maximum amount of digits is eight

bytes. It leads into the fact that one parameter value in the message can carry up to 32 bytes. Example of 32bits value:
nameOfParameter (4) = 0x00000000

When all the XML source files are converted into the target directory, the directory will contain around thousand individual eNodeB control message and overall size of the messages content is near to 25Mbytes.

4.3.4 Data structure padding

Data structure alignment is the way data is arranged and accessed in the computer memory. It consists of two separate but related issues: *data alignment* and *data structure padding*. When a modern computer reads from or writes to a memory address, it will do this in word sized blocks (e.g. 4 byte blocks on a 32-bit system). (31.)

Data alignment means putting the data at a memory offset equal to some multiple of the word size, which increases the system's performance because it simplifies the calculation of starting point for memory addresses. (31.)

Data structure padding is done for same reason as the data alignment. Padding bytes are only inserted if a data structure is not a multiplication of with the size of the biggest member of the data structure. There have to be inserted some meaningless padding bytes between the end of the last data structure and the start of the next one. (31.)

Data structure padding part of XML conversion’s source code is shown below. Padding issue was one of the difficulties while programming. When the ATETT message parser construct eNodeB control message and if the message contains one or more structures it requires structure data handler to check that if the structures need padding bytes. If the padding bytes are required the structure data handler also recalculates the message length and corrects it with the amount padding bytes.

```
/* Check the size of biggest member*/
quint32
ISARTypeStruct::getSize(qint32 &biggestMemberSize, bool returnTotalSize)
{
   ISARTypeDatabase * database = ISARTypeDatabase::instance();
   quint32 size = 0;
   SMemberParamData memberData;
   for (int iter = 0; iter < m_members.count(); iter++) {
      memberData = m_memberTypes[m_members[iter]];
      QString memberType = memberData.memberType;
      ISARType *  member = database->getType(memberType);
      if (member != 0) {
         qint32 sizeCheck = 1;
         quint32 tmpSize = member->getSize(sizeCheck) *
                getMemberSizeUint(memberData.memberDimensionValue);
         size += tmpSize;
         if(sizeCheck > biggestMemberSize) {
            biggestMemberSize = sizeCheck;
         }
      }
   }


   /* No alignment for values bigger than 16 bits*/
   if (0 < biggestMemberSize && biggestMemberSize <= 16) {
      qint32 modulo = (size % biggestMemberSize);
      if (modulo != 0) {
         qint32 padding = biggestMemberSize - modulo;
         for(int iterm = 0; iterm < padding; iterm++) {
            addMember("size_padding_" + QString::number(iterm),"u8");
         }
         size += padding;
      }
   }
   return size;
}
```

The XML source files do not contain information about the padding bytes even though those are required to be in the eNodeB control messages. The padding bytes are added normally by the code compiler. When the XML conversion plug-in parses the XML message elements, it has to add the needed padding bytes in the eNodeB control message or the structure of the message is not well aligned. The DSP processors of the eNodeB do not accept unaligned control messages. It takes a while to learn how and which phase of the execution the XML conversion plug-in has to add the padding bytes in the messages. The implementation of the padding byte algorithm was also challenging.

4.3.5 Main functionality of XML conversion plug-in

Figure 30 illustrates how the XML conversion plug-in works logically at a high level using the UML logical view. The *Generate Messages* button is selectable only if both of the directories are set. QStatusBar is used to inform the user about the status and what to do next. If the *Set source directory* is only set, the status bar informs the user to "*Set target directory*". If the Set target directory is only set, the status bar informs the user to "*Set source directory*". When each of the directories is set, QLabel is used to show the defined folder path. When both of the directories are set, "*Ready to start - Push the Generate messages button*" is shown in the status bar. When the *Generate Message* button is pushed, the status bar shows "*Parsing ongoing*" as long as messages are created. After the messages have been created, the status bar shows "*Messages created*".

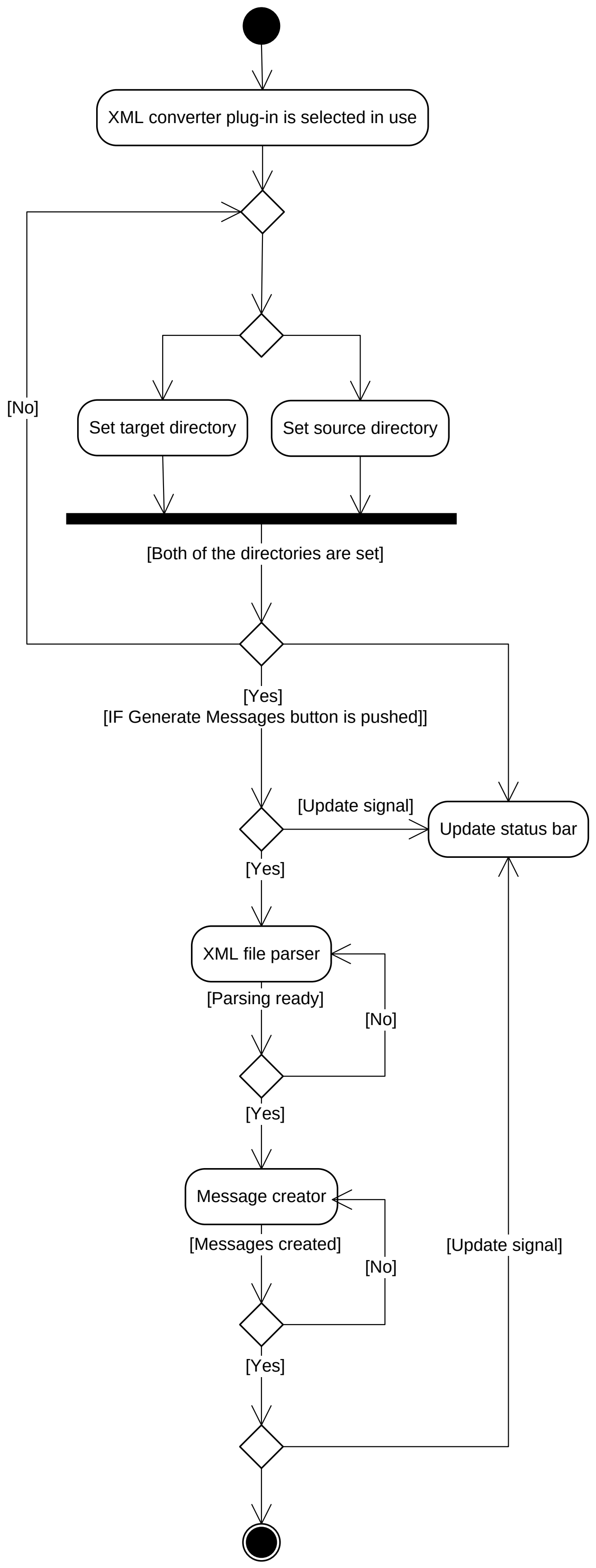
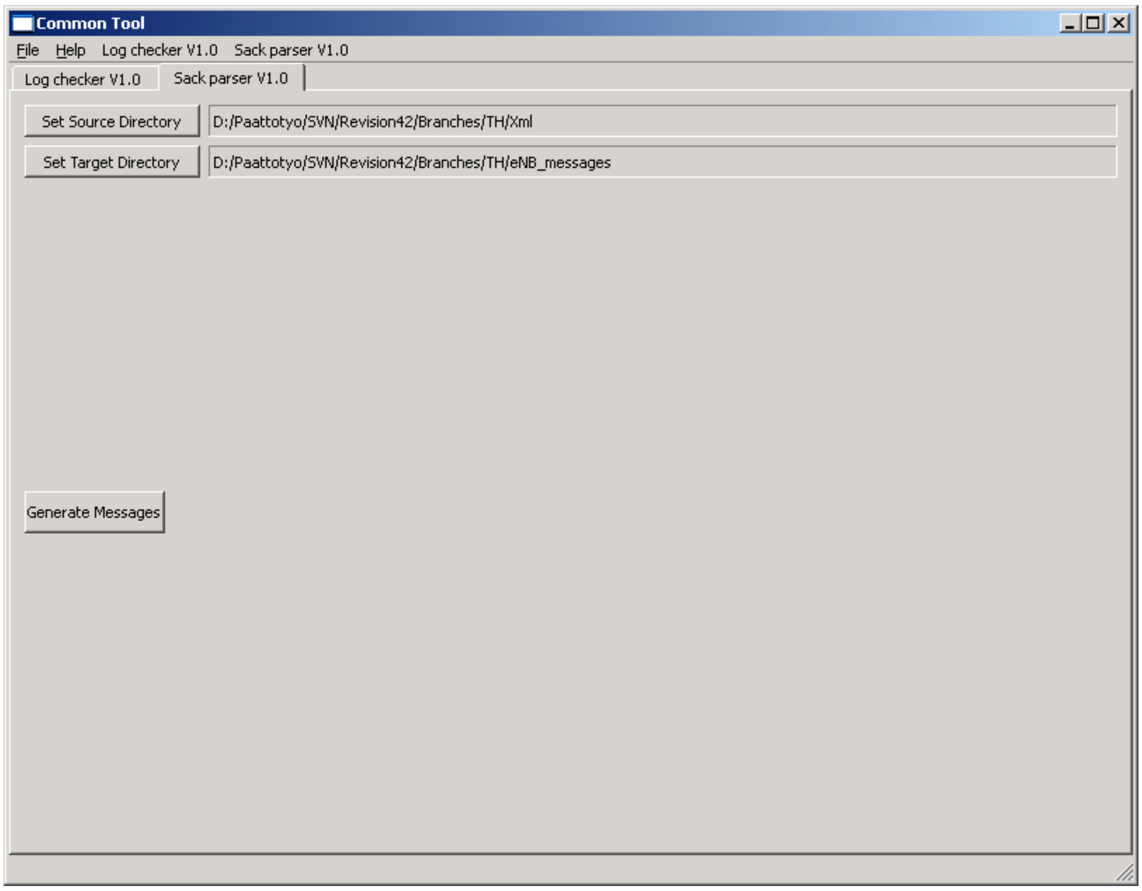


FIGURE 30. The UML Logical-View diagram – High level illustration of XML conversion plug-in

The CTA shows the GUI of the XML conversion plug-in in its own tab when it is selected as presented in Figure 31. The GUI in the tab is the only visible part of the XML conversion plug-in. The layout of the GUI is kept as simple as possible.



D:/Paattotyo/SVN/Revision42/Branches/TH/Xml

D:/Paattotyo/SVN/Revision42/Branches/TH/eNB_messages

FIGURE 31. The GUI of XML conversion plug-in is load in the tab of common testing tool

Using the UML logical view, Figure 32 illustrates how the XML conversion plug-in works during the actual XML conversion process. The conversion process illustrates the functionality of the plug-in after the required user actions have been done. The process is divided into two main phases:

- Parsing of *definitions* elements (DE)
- Parsing of *messages* elements (ME)

In the first phase of the parsing, the focus is to collect the required data located under the XML DEs into a type database. Initially in the first phase, the XML conversion plug-in creates a file list of the XML files in the selected source directory. The plug-in selects the first file from the list and then loads the file in the PC's memory in the form of the XML (DOM three). After this, the actual parsing process for the XML file is able to start. The parsing process continues file by file as long as all the files in the list are parsed and the parameter definitions of them are saved into the database. If the parser recognizes that the XML file under the parsing contains the ME element, the name of the XML file is added into the second file list. The second file list is used during the second phase of parsing when the MEs are parsed.

In the second parsing phase, the second file list is used to recognize the files which contain the MEs. The plug-in avoids the parsing process for the files that does not contain the MEs with this implementation. By following the file list, the second parsing phase goes through all the files that contain the MEs. As earlier discussed, the first parsing phase collected the definition data for all the parameters. Now, in the second phase of the parsing process the focus is on the structures of the messages. The content of the MEs only defines the structure information of the messages. Because of that, during the second parsing process, the definition data for the messages' parameters is read from the database. One ME consists of several message child elements. The parser parses one of the message elements at a time. The constructing of the ATETT message starts when the parsing process of a single message element is completed and the required data for one eNodeB control message is collected. The ATETT handler is used to modify the data of the message in the format of the ATETT message and to generate the actual eNodeB control message files into the defined destination directory. The process of the second parsing phase is repeated as many times as all the files in the list are parsed and the messages are generated.

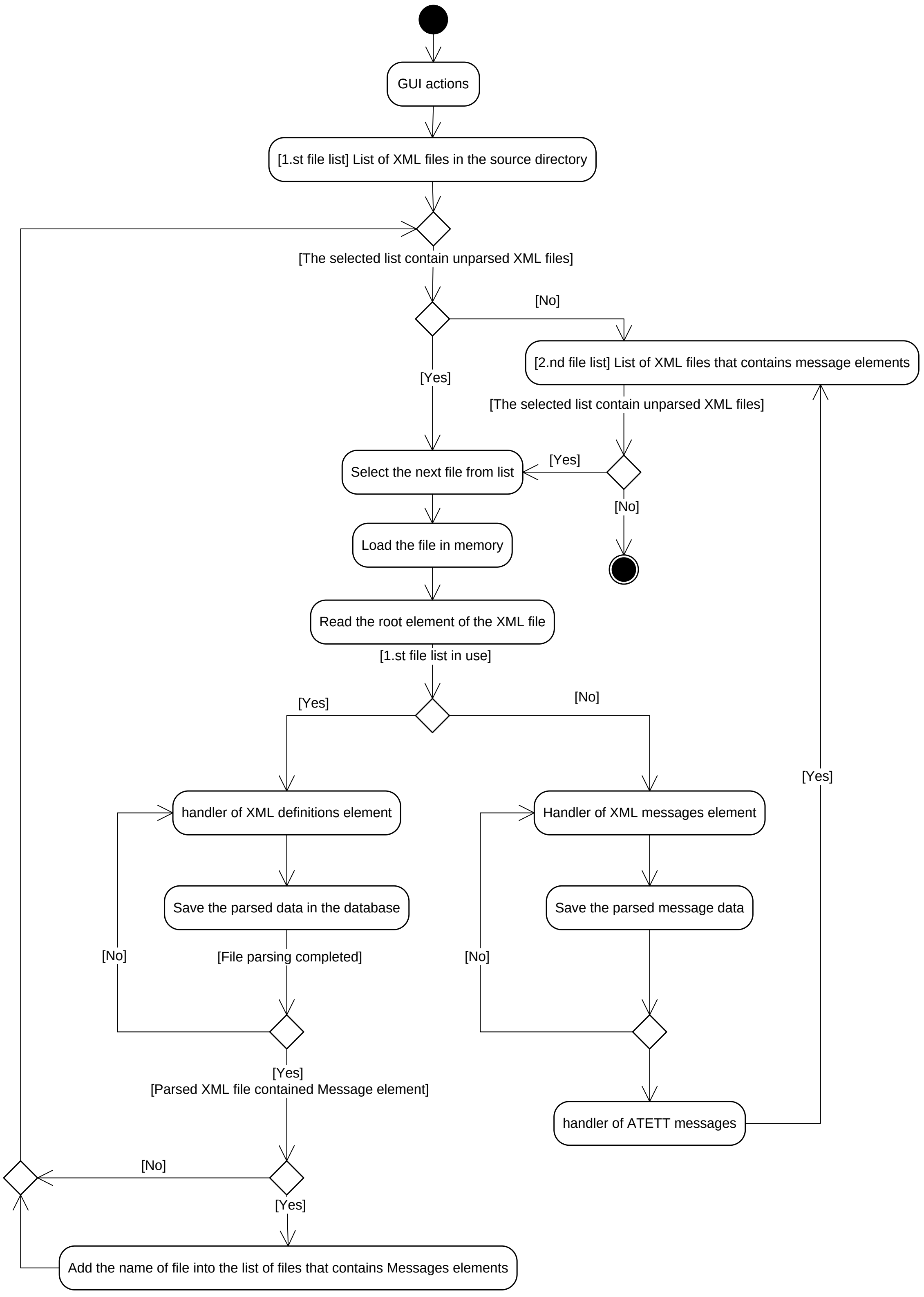

GUI actions
[1.st file list] List of XML files in the source directory
[The selected list contain unparsed XML files]
[No]
[2.nd file list] List of XML files that contains message elements
[Yes]
[The selected list contain unparsed XML files]
Select the next file from list
[Yes]
[No]
Load the file in memory
Read the root element of the XML file
[1.st file list in use]
[Yes]
[No]
[Yes]
handler of XML definitions element
Handler of XML messages element
Save the parsed data in the database
Save the parsed message data
[No]
[File parsing completed]
[No]
[Yes]
[Parsed XML file contained Message element]
handler of ATETT messages
[No]
[Yes]
Add the name of file into the list of files that contains Messages elements

FIGURE 32. The UML Logical-View diagram – The actual conversion process of the XML conversion plug-in

Using the UML logical view, Figure 33 illustrates in a more detailed level how the XML conversion plug-in saves the definition data during the actual XML conversion process. The same process was illustrated in the Figure 32 using only two state objects. The objects were named as following: *handler of XML definitions element* and *save the parsed data in the database.*

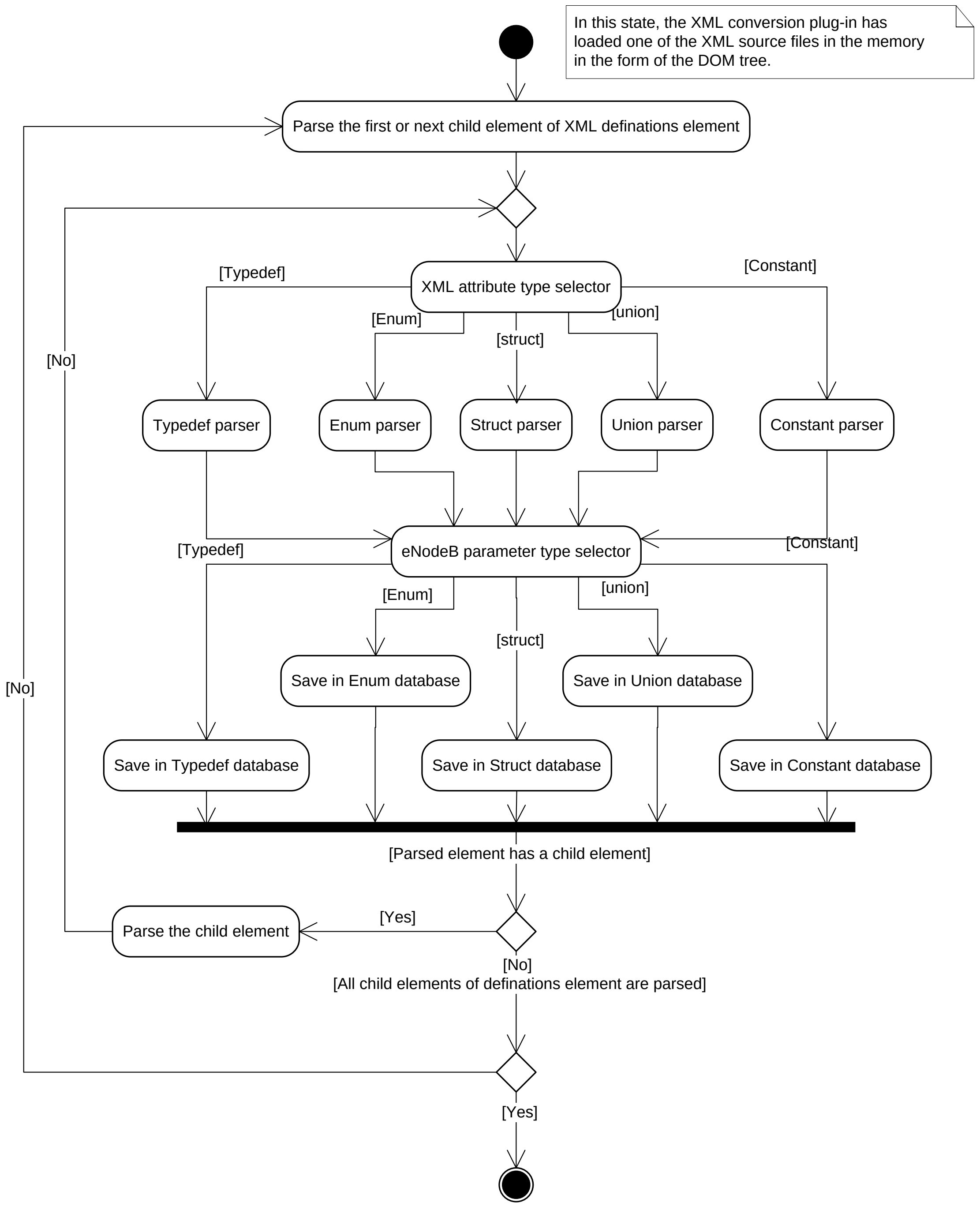

In this state, the XML conversion plug-in has loaded one of the XML source files in the memory in the form of the DOM tree.
Parse the first or next child element of XML definations element
XML attribute type selector
[Typedef]
[Enum]
[struct]
[union]
[Constant]
[No]
Typedef parser
Enum parser
Struct parser
Union parser
Constant parser
eNodeB parameter type selector
[Typedef]
[Enum]
[struct]
[union]
[Constant]
[No]
Save in Enum database
Save in Union database
Save in Typedef database
Save in Struct database
Save in Constant database
[Parsed element has a child element]
[Yes]
Parse the child element
[No]
[All child elements of definations element are parsed]
[Yes]

FIGURE 33. The UML Logical-View diagram – The saving process of the definition data of the XML conversion plug-in

Using the UML logical view, Figure 34 illustrates in a more detailed level how the XML conversion plug-in reads and use the definitions data from the databases during the actual XML conversion process. The same process was illustrated in the Figure 32 using only three state objects. The objects were named as following: *handler of XML messages element, save the parsed message data* and *handler of ATETT messages.*

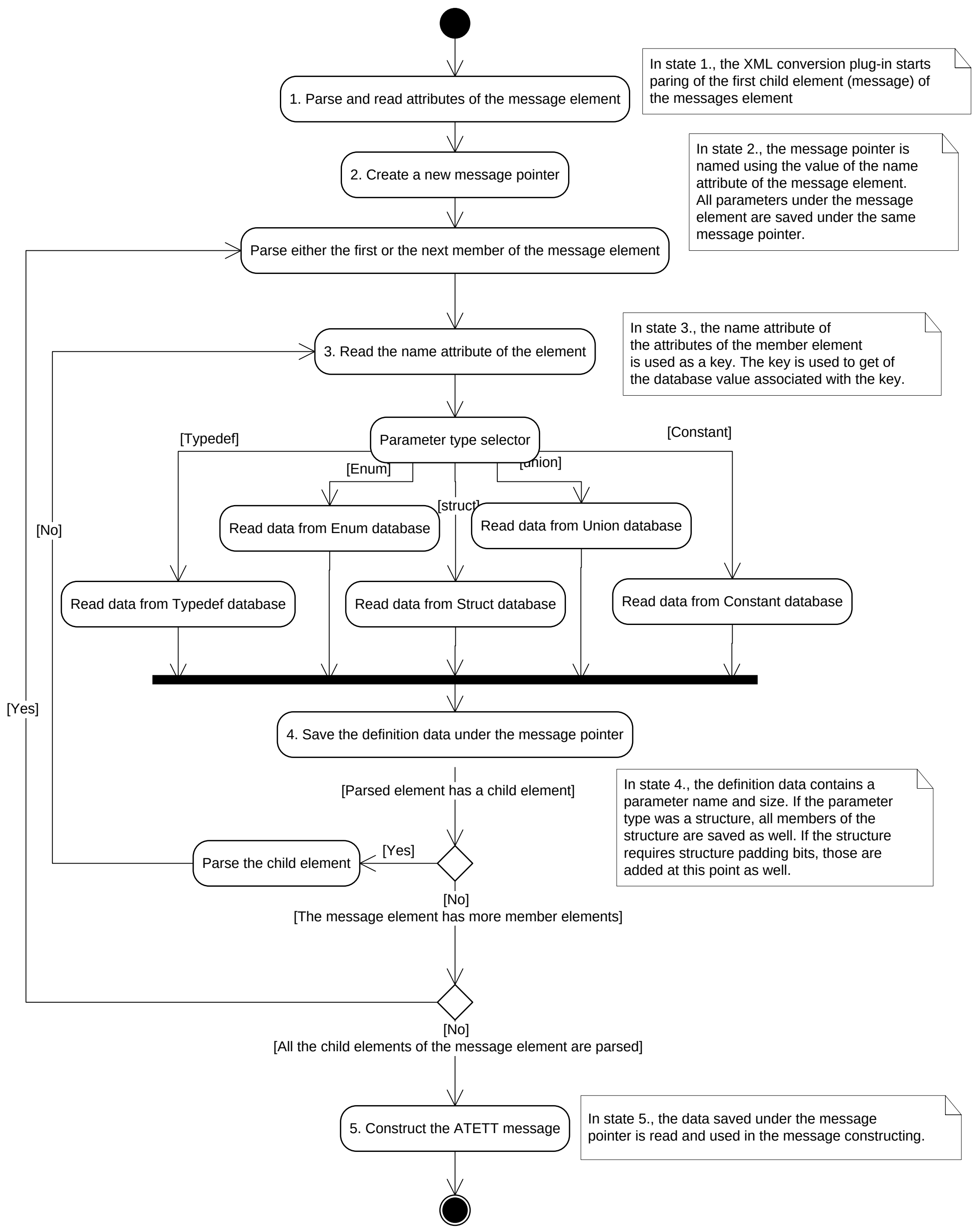

1. Parse and read attributes of the message element
In state 1., the XML conversion plug-in starts paring of the first child element (message) of the messages element
2. Create a new message pointer
In state 2., the message pointer is named using the value of the name attribute of the message element. All parameters under the message element are saved under the same message pointer.
Parse either the first or the next member of the message element
3. Read the name attribute of the element
In state 3., the name attribute of the attributes of the member element is used as a key. The key is used to get of the database value associated with the key.
Parameter type selector
[Typedef]
[Enum]
[struct]
[union]
[Constant]
Read data from Enum database
Read data from Union database
Read data from Typedef database
Read data from Struct database
Read data from Constant database
[No]
[Yes]
4. Save the definition data under the message pointer
[Parsed element has a child element]
In state 4., the definition data contains a parameter name and size. If the parameter type was a structure, all members of the structure are saved as well. If the structure requires structure padding bits, those are added at this point as well.
Parse the child element
[Yes]
[No]
[The message element has more member elements]
[No]
[All the child elements of the message element are parsed]
5. Construct the ATETT message
In state 5., the data saved under the message pointer is read and used in the message constructing.

FIGURE 34. The UML Logical-View diagram – A detailed level message data construction process of the XML conversion plug-in

5 RESULTS AND PROPOSALS

Chapter 5 presents the main benefits that the usage of the CTA and XML conversion plug-in provides compared to the time when the eNodeB control message for the ATTET was created manually.

5.1 Improvement in the testing velocity time

The SW quality assurance agreement determines that all the DSP SW builds must be tested within two hours after it has been released. The ATE of the LTE DSP SWi with the CI master system was capable of fulfilling the time requirement set for the LTE DSP SWi if the released DSP SW build did not contain considerable interface changes. When the DSP SW build contained considerable changes, the LTE DSP SWi was not capable of meeting target and test it within the given two hours' time frame.

During the time when the LTE DSP SWi did not have the XML conversion plug-in, the eNodeB control messages for the ATETT were created manually. The working need varied from a half an hour to many days. In the worst cases the changes required that many engineers of the LTE DSP SWi assigned to do the eNodeB control messages.

The use of the XML conversion plug-in, guarantees that the eNodeB control messages for the ATETT are always available in time. The plug-in helps the LTE DSP SWi to meet the time requirement. Also, the accuracy in time when the test results of the LTE DSP SWi are available is better since the XML conversion plug-in is used and the eNodeB control messages do not affect the additional delays anymore before the LTE DSP SWi is capable of starting the testing.

The eNodeB control messages are ready for the ATTET and testing purposes in few seconds when a tester starts the message conversion process by pushing the "*Generate message"* button of the GUI of the XML conversion plug-in.

5.2 Quality improvements in LTE DSP SWi testing

One eNodeB control message can contain more than four thousand parameters. When the messages were done manually, a big risk existed that during the change work the engineer made writing typos or interpreted the DSP SW IFS wrongly. Any kind of an error which is avoidable is unnecessary. Errors in the eNodeB control messages always cause an extra work load for an engineer and as well for developers. One of the main tasks of the LTE DSP SWi testing is to verify that the interfaces of the DSP SW applications work as specified. If the eNodeB control messages used in testing contains errors, the focus from SUT and IUT testing change on the testing of the control messages and that is not acceptable. The eNodeB control messages generated using the XML conversion plug-in do not contain errors.

5.3 Implementation status of CTA and XML conversion plug-in

Both the CTA and the XML conversion plug-in basic functionality work as specified. The current implementations do not contain any errors.

5.4 New plug-in proposals for CTA

There are not known limitations in the amount of plug-ins used via the CTA. When more plug-ins are developed, it is possible that unplanned problems occur related to the common interface of the CTA. The initial version of it is as simple as possible and it may require more functionality in the future. If the common plug-in interface has to be changed, new interface versions have to be backward compatible. Two new ideas already exist for new plug-ins which are presented below:

Plug-in 1. The main functionality of the plug-in is to send and receive the eNodeB control messages. The plug-in reads and utilizes a message sequence log of the ATETT as an input data. The message sequence logs are always available after the initial test execution has been done.

Extra value that the plug-in provides: The use of plug-in provides a very efficient and simply approach to repeat the test executions of the LTE DSP SWi for the eNodeB system. Repeating a test does not require test scripts when the plug-in utilizes the existing test logs. The logs contain all required test data from the message sequence to the values of the message parameters. This approach in testing would be practical when the intention is to repeat the test exactly as the original test execution has been done. The error reports of eNodeB SW usually contain only the message sequence log and the description of the error. Considering the fact that only the message sequence log is attached in the error report, the plug-in would be a powerful tool for a tester when s/he verifying the correction for the reported error.

Plug-in 2. The main functionality of the plug-in is to check the used eNodeB configuration setups. Currently all tests in the LTE DSP SWi are executed using the ATETT. The use of the ATETT and script language of it sets their own limitations in the verification of the eNodeB functionalities.

An extra value that the plug-in provides: The Qt and the C++ programming languages make it possible for testers to create more sophisticated verification algorithms than the current tests based ones on the script language can provide. A practical example of this plug-in is that the plug-in could be used to analyze a considerable amount of the system logs from the defined directory. The plug-in goes through all the system log files in the directory and searches an error and other relevant information which a tester is determined to be interested in. When all the logs are processed, the plug-in creates a summary report of the findings it has made.

5.5 Functional extensions for the applications

This chapter presents all known limitations functionally and few functional extension proposals

The current implementation of the XML conversion plug-in supports the generation for the eNodeB control message templates that are suitable for the ATETT only. The object oriented C++ and the modularity of the source code make the functionality of the XML conversion plug-in extendable with a small effort. In the future it is possible to extend the plug-in to support other output data formats, too. For example, many of the testing applications contain an XML processor and are capable of handling XML data nowadays. A natural message format for the tools that contain the XML processor is the XML.

5.5.1 The error management of the applications

The error management of the CTA as well as the XML convert plug-in is not as good as it should be. Both of the applications provide only QDebug prints in error situations. Basically, the debug checkers already exist in the source code which provides detailed level information about what went wrong. The functionality of these debug prints should be changed to show the error information in a pop-up window.

5.5.2 eNodeB control message filter in the XML conversion plug-in

The XML conversion plug-in does not provide a possibility to limit which of the eNodeB control messages the user wants to generate. The XML conversion plug-in always generates all the messages that the XML source data defines, and the amount of the messages is around one thousand messages and the data size is ~25Mbytes. An option to select the wanted messages which the user wants to generate at the level of the DSP application would be a very useful feature to have.

6 CONCLUSION

The main focus in this master’s thesis was to provide an application that removes the need of manual work with the eNodeB control messages. The CTA is application developed using the Qt programming language. The application is implemented with a common interface that makes it extendable with plug-ins.

During the study, the XML conversion plug-in for the CTA was developed. The plug-in contains all the functionalities needed to generate the eNodeB control messages by using the XML source files as input. The performance of the plug-in guarantees that the changes in the eNodeB control messages does not have a negative influence into the testing velocity time of the LTE DSP SWi. The XML conversion plug-in is capable of generating all the control messages in few seconds.

The development project of the CTA and the XML conversion plug-in proceeded as it was planned except the delay in the time schedule. The implementation work was ready two months behind the original time schedule. The original time schedule for the development project delayed due to many reasons. The main reasons for the delay are listed below:

1. The implementation work was done outside of the normal working hours.
2. With limited programming experience the problem solving took more time than expected. Unexpected problems occurred during the development process with the structure padding.
3. The change of the employer was undersigned during the Master’s thesis. It affected both the development process of the application and the writing part of the thesis.

The CTA and XML conversion plug-in will be used continuously in the LTE DSP SWi. The LTE DSP SWi will achieve significant time savings in long-term by using the applications even when the development project lasted for six months. In this perspective, developing an application to do a task on behalf of a human is an excellent method to reduce manual work. In general, an application can provide extra value if it is used to replace manual work in those tasks that are regular and need constantly some actions.

The development process of the CTA and the XML conversion plug-in was an interesting project. The project was very challenging since many of the questions that are discussed in this thesis were out of the thesis writer’s personal comfort zone. The practice started from the basics of the C++ language. The investigation of the content of the XML source files was started in the next phase. In addition, the method to construct the information in the files was studied. It took a while only to understand in general how to use the information collected in the XML files. The XML source data consists of nearly 30 separate XML files. The structure of the XML source files is described with the XML schema file that contains 40kB information. The amount of data in the schema describes how much effort was needed to understand the structures of the XML source files.

After the structures of the XML source files had been studied, the application development project was able to continue. The project continued by learning how to parse the XML data with an application made by Qt. The modular class architecture for the XML conversion plug-in was created in the beginning of the actual coding process with guidance of the supervisors. The well planned SW architecture helped the coding process through the project.

The TortoiseSVN subversion was used in the application development phase. It is invaluable in the SW development. When a developer does not have much experience s/he probably makes more errors, and does not always know which of the changes caused the error. Problem solving can take a great deal of time when the code contains many changes. The power of the subversion is that the developer can save the project as many times as needed. If needed, the developer can always return into the revision that is not influenced by the changes. The use of the subversion basically follows the same principles than the incremental SW development. Every time when something useful is made, it is saved in the subversion.

The application development project lasted six month. It is such a long time that requires good documentation or it is difficult to remember all the reasons for the decisions made during the project. The subversion makes it possible to write a comment for all committed changes. Many times the committed changes contain multiple changes simultaneously and the change easily becomes too large. When the size of the commit is too large it is difficult to write a comment that describes the change explicitly. In the beginning of the application development process the problem with too large commits was emphasized.

Overall, the application development process was a project that developed coding skills, acquainted in the Qt, SVN, UML and XML languages. All this is valuable knowledge for people who work in SW related working position.

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APPENDICES

XML SOURCE DIRECTORY EXAMPLE APPENDIX 1/2

```
Directory of D:\…\SVN\Revision42\Branches\XmlConversionPlugIn\Xml

15.04.2012  13:46    <DIR>     .
15.04.2012  13:46    <DIR>     ..
27.03.2012  08:26    <DIR>     .externalToolBuilders
25.01.2011  14:37                              .project
26.10.2011  15:45                1KB           L3.xml
27.03.2012  08:27    <DIR>       configuration
09.11.2011  12:48               194KB          MAC1.xml
11.10.2011  12:52                89KB          Tool1.xml
05.11.2011  16:19               93KB           externals.xml
03.11.2011  12:04               92KB           globals.xml
01.09.2011  11:02               3KB            LTE.xml
24.05.2011  02:39               4KB            LTE1.xml
05.07.2011  14:18               4KB            LTE2.xml
04.11.2011  14:52                178KB         MAC2.xml
11.10.2011  12:52               1KB            MAC3.xml
22.07.2011  16:07               1KB            MAC4.xml
24.05.2011  02:39               38KB           MessageId_Lte.xml
27.10.2011  15:59               1610KB         HW1.xml
03.11.2011  12:04               13KB           PHY.xml
24.05.2011  02:39               3KB            PHY1.xml
03.11.2011  12:04               141KB          PHY2.xml
28.10.2011  08:26               57KB           PHY3.xml
08.11.2011  14:50               63KB           HW2.xml
03.11.2011  12:04               5KB            SW1.xml
19.09.2011  16:24               52KB           ATE.xml
24.05.2011  02:39               15KB           HWSW.xml
03.11.2011  12:04               1KB            TUP.1xml
08.11.2011  10:11                91KB          TUP2.xml
24.05.2011  02:39               1KB            TUP3.xml
17.10.2011  19:13               58KB           MAC5.xml
              27 File(s)   3341KB
               4 Dir(s)
```

CTA’s Qt PROJECT .PRO FILE EXAMPLE APPENDIX 2/2

```
# ------------------------------------------------------------
# $Rev:: 31                                                   $:
# $Author:: teemuhei                                          $:
# $Date:: 2011-10-21 14:20:51 +0300 (pe, 21 loka 2011)        $:
# ------------------------------------------------------------

QPRO_PWD = $$PWD
TEMPLATE = lib
CONFIG += qt
CONFIG += plugin
OBJECTS_DIR = ../lib
DESTDIR = ../../bin/plugins
TARGET = xmlConversionPlugin
DEPENDPATH += .
INCLUDEPATH += ../include
HEADERS = ../include/pluginInterface.hpp
HEADERS += xmlConversionPlugin.hpp \
    xmlFileParser.hpp \
    typeConstant.hpp \
    xmlParser.hpp \
    typeUnion.hpp \
    typeStruct.hpp \
    typeTypedef.hpp \
    typeDatabase.hpp \
    typeEnum.hpp \
    type.hpp \
    typePrimitive.hpp \
    atettMessages.hpp
SOURCES = xmlConversionPlugin.cpp \
    typeDatabase.cpp \
    typeConstant.cpp \
    xmlFileParser.cpp \
    xmlParser.cpp \
    typeUnion.cpp \
    typeStruct.cpp \
    typeTypedef.cpp \
    typeEnum.cpp \
    typePrimitive.cpp \
    atettMessages.cpp \
    isarType.cpp

QT += xml
```