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APPLIED SCIENCES

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THE PROCESS OF DEFINING THE RADIO FREQUENCY HARDWARE VERIFICATION WAY OF WORKING MODEL AT NOKIA CORPORATION

THE PROCESS OF DEFINING THE RADIO FREQUENCY HARDWARE VERIFICATION WAY OF WORKING MODEL AT NOKIA CORPORATION

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Bachelor's Thesis
Autumn 2019
Information Technology
Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
Degree Programme in Information Technology, Software Development

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Title of bachelor´s thesis: The Process of Defining the Radio Frequency Hardware Verification Way of Working Model at Nokia Corporation
Supervisor: Anne Keskitalo
Term and year of completion: Autumn 2019 Number of pages: 50

The target of this bachelor's thesis was to describe and prove the methods that were used to set up and manage the work of updating the WoW material for Radio Frequency Verification process areas. The acquired knowledge base gathered for the project, the methods that were used to conduct the study and the ways in which the project was implemented to achieve the target, are described in this report.

The thesis work was commissioned by Nokia Corporation in the Spring of 2019. The target of the project was to present the HW Verification WoW in a unified way. To achieve the target, it was decided to set up a Sharepoint page collection and templates to collect the material. A semi-structured face-to-face interview technique was used to collect information and to form a high-level picture of each of the areas. The project was planned and conducted using project management principles.

The project consisted of six different scheduled stages that were monitored by the project manager. This project and its results were perceived very important by the Nokia management. The main results of the project were the process descriptions from each area, the templates created for the process, the Sharepoint pages created for the material and the lessons learnt. The next stage would be to use the templates and the results to define the WoW of all areas in the RF area.

Keywords: Mobile Networks, Verification, Lean, Way of Working

PREFACE

My career at Nokia started as an operations trainee in November of 2018. This past year has been very educational and eye-opening for me. I would like to thank my co-worker Riikka Turpeinen for guiding and always believing in me. Thank you Eija Mikkonen and Pekka Kivioja for mentoring me through this Thesis process.

Also, a special thank you for all you strong women in my class whom I have had the honour of sharing this journey with. And most of all, I would like to thank my family, especially my children and my husband, for their patience. Minea and Sonja, these past three years can be set as an example of how you can do anything you want to do if you just set your mind to it.

Kempele, 23.9.2019
Anni Haaranen

CONTENTS

ABBREVIATIONS AND DEFINITIONS

3GPP	3rd Generation Partnership Project
5G PPP	5G Infrastructure Public Private Partnership
AMPS	Advanced Mobile Phone System
BTS	Base transceiver station
CoDe	Competence and development
DMAIC	Define, measure, analyse, improve, control
DMADV	Define, measure, analyse, design, verify
DoD	Definition of Done
EDGE	Enhanced Data Rates for GSM Evolution
ETSI	The European Telecommunications Standards Institute
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HW	Hardware
IMT	International Mobile Telecommunications
ISO	International Organization for Standardization
ITU	International Telecommunications Union
LeSS	Large-Scale Scrum

LTE	Long Term Evolution standard
MBSE	Model-Based Systems Engineering
MMS	Multimedia Messaging Service
Mobile Network Cell	Area of land that is typically hexagonal, has at least one transceiver cell tower, and use various radio frequencies
Mobile Network Cell Site	Cellular-enabled mobile device site where antennae and electronic communications equipment are placed.
MTBF	Mean time between failures
MTSO	Mobile Telephone Switching Office
NMT	Nordic Mobile Telephone System or Nordiska Mobiltelefongruppen
PDCA	Plan–do–check–act
RAN	Radio Access Network
R&D	Research and Development
SAFe	Scaled Agile Framework
SBD	Set-Based Design
SIPOC	A graphic model to describe suppliers, inputs, process, outputs and customers
SMED	Single Minute Exchange of Die
SMS	Short Message Service
SW	Software

TPS	Toyota Production System
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
W-DCMA	Wideband Code Division Multiple Access
WoW	Way of Working

1 INTRODUCTION

The target of this study was to describe the theoretical framework and process of streamlining and global updating of Way of Working in Hardware Verification at Nokia Corporation. At the beginning of the process the previously made WoW material was outdated and insufficient due to newly formed processes. Most of the material was available but it was outdated and thus, in some areas, not followed. There was some obscurity concerning the interfaces between teams and that caused confusion inside the organisation. Although everyday work was running smooth, there was a huge need to get the preconditions and deliverables available. This thesis work in Nokia revolved around collecting the Way of Working material from verification, integration and supporting tasks for program management through collaboration with different teams. However, due to time issues, the work was focused on the verification area.

Companies usually have a set business framework, which includes goals and strategies, policies, organization and culture, relationship contracts and arrangements, business processes, roles, tools, systems, goals, measures and incentives. It is important that the framework is visible and acknowledged by all the employees to achieve a business success. The description of the Way of Working is one part of making the processes visible and understandable for all employees and the material is a dependable and updatable.

The first phase of this project was to form a high-level picture of the area by shadowing each of the areas in question. While shadowing the author became acquainted in the day-to-day activities of each process by using a semi-structured face-to-face interviewing method. After the project kick off meeting in June of 2019, status update meetings were held every two weeks to ensure that the process was progressing as planned. One important part of the project was to define a template in Sharepoint Online for the WoW material and define an update schedule and a revisioning plan.

The theoretical part of this thesis describes Nokia as the commissioning company, some history of mobile networks technology development, some of the technologies currently being developed and manufactured in Nokia Oulu office, the current quality standards in information technology, working methods in Nokia and the methods that were used to conduct this assignment. There is also information about the area of which the WoW project was implemented in, including hardware verification and Nokia processes in general. Multiple and dependable references were used to

acquire theoretical base for the project and study. In the last chapter of this thesis, there is information of how the project proceeded and what are the next steps and the author's suggestions on how the project could be used in the future.

Updating and bringing this material to an easy-to-find form has become an important tool for the commissioning company, as the material is now easy-to-update and use during hiring, onboarding or when learning about the processes.

2 NOKIA CORPORATION

Nokia Corporation is a multicultural and multinational corporation with approximately 102,000 employees in over 100 different countries. Nokia has the reported annual revenue of about 22.6 billion euros (2018) and has a long history as an industrial and technological company. Over the years Nokia has produced for example cables, paper products, rubber tires and boots. Nokia is of course most famous for producing mobile phones. The headquarters of Nokia is in Karaportti, Espoo. Nokia's other Finnish sites are in Helsinki, Tampere and Oulu. (Nokia Corporation 2018a, cited 16.5.2019.)

Nokia's description for its business is described as follows: "Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers with the industry's most complete, end-to-end portfolio of products, services and licensing. We adhere to the highest ethical business standards as we create technology with social purpose, quality and integrity. Nokia is enabling the infrastructure for 5G and the Internet of Things to transform the human experience." (Nokia Corporation 2018b, cited 16.5.2019).

Oulu is one of the Nokia's key locations and can be considered a globally unique radio research, development and manufacturing centre. The Oulu site has more than 40 years of experience on working with Radio products. The site cooperates actively with other technology centres and further improves its quality, productivity and attractiveness in the long term. It uses the radio ecosystem in trialling the latest technologies and solutions with the customers. The current focus of Oulu site is 5G. More than 400 employees work to develop the 5GPP standardization, System-on-Chips, new 5G radio products HW and SW as well as verification and manufacturability. The site, located at the Rusko campus, has around 2,350 employees, of which some 1,500 work for R&D, 650 for Operations and 140 for other functions. (Nokia Corporation 2018a, cited 16.5.2019.)

This WoW description is affecting the area which is responsible for verification testing, type approval testing and failure analysis of radio products in Oulu. Nokia hardware verification is one of the six areas in the recently formed Research and Development Center Oulu tribe. The execution efficiency and maximized laboratory asset use are ensured by continuous testing tool development, test automation and developing the Laboratory as a Service. The Radio Frequency Research and

Development tribe in Oulu also drives the unified test automation platforms with R&D and production. Due to vastly operated verification activities in this area, there is perhaps the best visibility about the maturity of the project throughout the product development pipeline. There are about 180 people working in this area in Oulu site.

3 MOBILE NETWORKS

The development of mobile networks has proceeded in a series of generations starting from 1G all the way to the 5G, which is currently being deployed. The development has been regulated by organizations, such as 3GPP and IEEE. (Al Agha, Pujolle, Ali-Yahiya 2016, 2.)

Mobile networks, also known as cellular networks, are communication networks consisting of cells. A cell is an area of land that normally has three cell towers or base transceiver stations. Neighbouring cells can be used to help avoid interference, by using a different set of frequency. This equipment provides the network coverage for the cell in question and it can be used to transfer data, such as voice and pictures, between devices. The cells can be joined together to cover wide geographic areas to enable more usability. Combining enables the communication between mobile devices, such as mobile phones, computers and tablets and fixed transceivers, throughout the whole area without any breakage in connection. (Wikipedia 2019c, cited 10.7.2019.)

One example of a cellular network is a mobile phone network which must use cells to enable the limited frequencies to be enough for all users. Interference can be minimized by using the computerized control of frequencies and with the use of low power transmitters. Mobile phone operators use the network to supply connectivity to the clients. Radio base stations, a core circuit switched network, a packet switched network and a public switched network together form a simple cellular mobile-radio. (Wikipedia 2019c, cited 10.7.2019.)

An increasing number of people are using mobile devices and almost 90 % of all data traffic is generated by using smartphones. The estimation of usage is 95 percent at the end of 2024, which is an annual growth of 0,31 %. (Telefonaktiebolaget LM Ericsson 1994-2019, cited 11.7.2019.) This increase in mobile data traffic creates a request for more efficient and faster technologies. In the following chapters the existing and future technologies in the field of mobile networking and development of those technologies at Nokia, will be introduced. There are some estimates on the growing need of network bandwidth in figure 1.

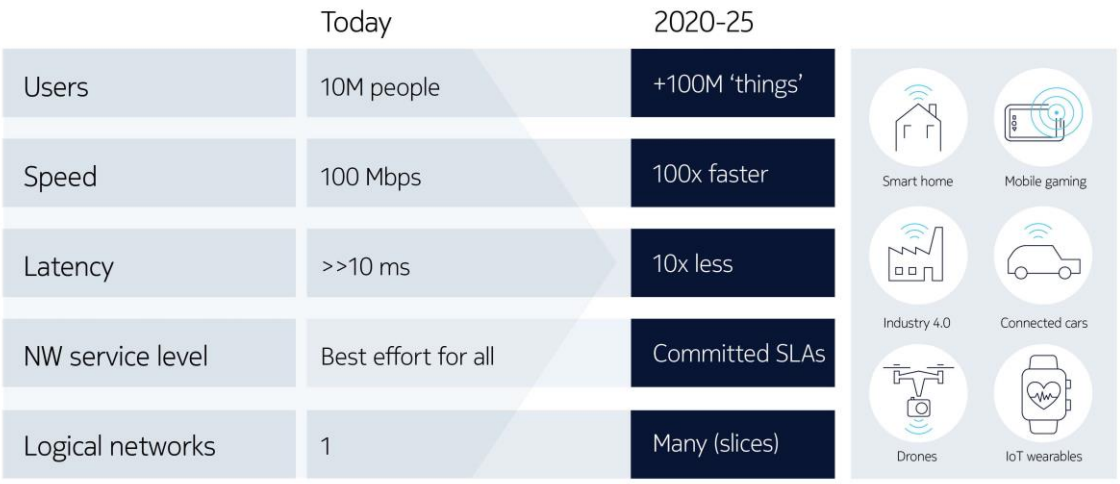

FIGURE 1. Specifications of mobile network capabilities now and in the future. (Nokia 2018c, cited 11.7.2019.)

3.1 **Mobile Network technology**

A simple mobile network consists of a radio base station subsystem forming of radio base stations, a core circuit switched network, a packet switched network and the public switched network. A base station consists of an antenna, a controller and receivers. It is the centre of the cell and is used to communicate over channels assigned to the cell. A cell phone and base station establish two types of channels between each other; control and traffic. The traffic channel is used to transport voice, data and the control channel is used to maintain and establish connections. (Al Agha, Pujolle, Ali-Yahiya 2016, 21.) The base station is connected to the MTSO, which is designed to manage several base stations and establish connections between mobile nodes (cellular telephone, handheld, laptop computer or router). The MTSO allocates channels for calls. (Al Agha, Pujolle, Ali-Yahiya 2016, 21.)

Nokia has been an important part of the mobile network development since Mobira (acquired by Nokia) launched the world's first international mobile network which allowed roaming in 1981. (Wikipedia 2019h, cited 15.7.2019.) Nokia AirScale Radio Access is one of the latest base stations Nokia has been developing and manufacturing. It is the "industry-first first commercial end-to-end 5G solution enabling operators to capitalize early on 5G." (Nokia 2019f, cited 15.7.2019). The base station is compatible with GSM, WCDMA, FDD-LTE, TD-LTE and 5G technologies and it has three bands in one radio. AirScale is a Single ran radio, which is compatible with Flexi Base Stations and

it can be used for Distributed RAN, Centralized RAN and Cloud RAN both indoor and outdoor deployment scenarios. Advanced 4th The Oulu factory, which produces 1,000 4G and 5G base stations per day, was selected as an Advanced 4th Industrial Revolution (4IR) Lighthouse recipient. One of the most important values at Nokia are customer satisfaction, respect for individuals, achievement and continuous learning. These values are carried out to ensure the quality in everything that is done in the company. (Nokia 2019h, cited 15.7.2019.)

3.2 **Previous generations**

The development of mobile networks began from the first-generation (1G) which was analog-based and focused on the voice service. The first fully automatic cellular system (1G) was the NMT which was developed through Nordic collaboration. It was first launched in 1981 with variants NMT-450 and NMT-900, the numbers indicating the frequency bands that were used. The NMT-900 network in Finland was shut down in 2001 and NMT-900 a few years later. (Al Agha, Pujolle, Ali-Yahiya 2016, 2-4.)

The successful launch of NMT was important to Nokia and led to the development of the GSM, second-generation (2G) digital systems which was first deployed in Finland in 1992. Besides from switching from analog-based to digital-based technology, the GSM differs from the NMT by using the TDMA and slow frequency hopping. In 1991 the GSM operated on the frequency band of 1800 MHz and in 1995 when SMS messaging and data services were launched, the first 1900 MHz network was launched. Over time the GSM was developed to include data communications via GPRS (2000) which enabled MMS and EDGE technologies (2003). Some of the 2G networks have been shut down in Australia and United States. (Wikipedia 2019e, cited 11.7.2019.)

The third-generation (3G) mobile network UMTS was first launched in Finland in 2004 using the W-CDMA technology. It was designed to be a successor for the GSM and focused on data transfer and services, such as mobile television, GPS, real time audio and video systems. (Prasad 2014, 3.) The goal was to improve the quality of audio and services. The UMTS network operated on frequencies 2100 MHz and 900 MHz in Finland and at 1900 MHz and 850 MHz in the United States. (Al Agha, Pujolle, Ali-Yahiya 2016, 4-5.)

Fourth-generation (4G) technologies have brought a great increase in download and upload speeds and types of content that can be used in mobile devices. Bringing the IP solutions to 4G networks made delivering of voice, data and multimedia possible for users anytime and almost all over the world. Improving of data carriage has made higher-level data services, such as streamed video and audio, video messaging, mobile tv, and gaming available for mobile users. The LTE standard, which is based on the GSM/EDGE and UTMS/HSPA, brought a significant increase in performance and speed using a radio interface together with the core network improvement. (Al Agha, Pujolle, Ali-Yahiya 2016, 6.) The first public LTE service was launched in 2009 in Oslo and Stockholm by TeliaSonera. (Wikipedia 2019g, cited 11.7.2019.)

3.3 **5G**

The fifth-generation cellular network technology or 5G is the newest and most advanced mobile network technology which provides fast broadband access and "air latency" of 144 milliseconds. These features together provide almost endless possibilities of usage such as IoT, self-driving cars, automatic monitoring devices for health care, advanced industrial automatics and virtual reality in the future. 5G offers real financial value too; Rajeev Suri has estimated that the 5G technology can improve the profitability of the United States by 30-35 %. Nokia is currently one of the six companies to manufacture and sell 5G radio hardware and 5G systems for carriers. (Wikipedia 2019a, cited 11.7.2019.)

The 5G generation is expected to be launched in full and the standards will be ready in 2020, but the development of the technology is already in full speed. To implement all the visions of different use cases, technologies, like RAT (Radio Access Technology), evolved versions of LTE HSPA and other technologies must, be still developed. (Prasad 2014, 98.) Besides the technology, there are challenges to solve during the development, such as security, ecological views and energy consumption and ethical questions. (Rodriguez 2015, 324.)

Nokia is one of the leading companies in developing and researching 5G technology and Nokia's Oulu site is one of the Nokia's key locations. It can be considered a globally unique radio research, development and manufacturing centre. The Oulu site has a slogan "Home of the Radio", which describes the scope of the work that is done there. The Oulu location has more than 40 years of experience on working with Radio products and the main focus is currently on 5G. Cooperation is

done actively with other technology centres and universities to improve the quality and productivity in the long term. More than 400 employees work at Nokia developing 5GPP standardization, System-on-Chips, new 5G radio products HW and SW and in verification and manufacturability. (Nokia Corporation 2018a, cited 16.5.2019.) In figure 2, there are some ideas on how the 5G technology can be used in the future.

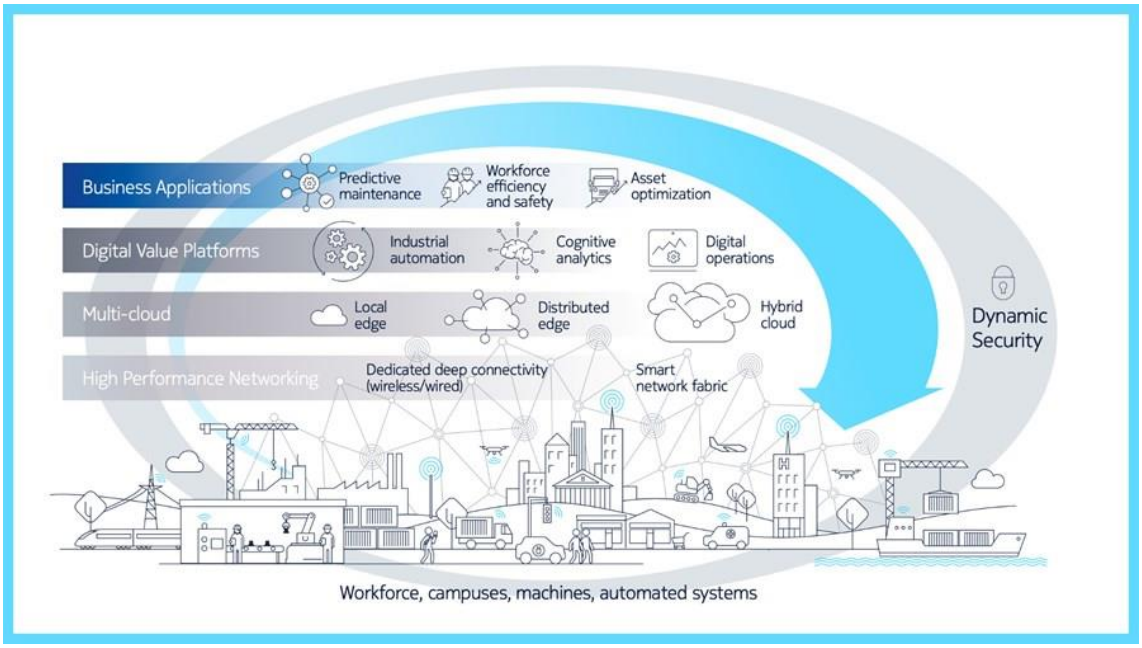

FIGURE 2. Future possibilities of 5G network. (Decisive Media Limited 2019, cited 12.7.2019.)

4 PRODUCT RELIABILITY, TESTING AND PROGRAM MANAGEMENT

Previously made mistakes in the field of engineering have resulted in the improvement of reliability predictions through a failure analysis. Failure automatically leads to improving the next version of the product utilizing the lessons learnt, but with data collection and analysis the procedure has become more efficient. Cost and schedule pressures, emerging of mass production and the need for component standardization have led to specific inspections during the manufacturing process and following of quality-control procedures to control reliability. (Smith 2005, 3-4.)

Three common factors can be seen in projects which have proven to be dependable and secure. Fewer parts and component means that there is less to be broken and this it makes the product more reliable. Using redundant parts to avoid a system failure due to a breakage of one part, increases both reliability and capital costs. The third factor is product design which makes the product more durable to stress and thus significantly increases reliability. In short, these actions vastly increase reliability; reducing complexity, taking account fault tolerance, reducing stress factors, qualification testing and reviews, failure feedback, controlling material, control of work methods and standards, instructions on maintenance and operating, feedback from field failures and replacing items which are known to wear out. (Smith 2005, 8-9.)

To ensure quality, all phases must be tested properly against given specifications or requirements. Product requirements are secured using many kinds of tests, for example white-box testing, black-box specification and type approval testing. Black-boxing is used to test the application software without knowing the structure of it. A type approval or certificate of conformity means that reliability predictions, reviews, quality methods and test strategies are subjects of agreement and audit. The type approval is granted if a minimum set of regulatory, technical and safety requirements are met. Usually these requirements are various electrical parameters, such as power and noise characteristics, frequency measurements and stability. A type approval characteristic must be met before the product can launched on the market. (Smith 2005, 11.)

High-reliability testing is carried out by using a sufficient number of items and testing them for a certain amount of time. These numbers depend on the decided MTBF percentage. These testing times can be accelerated with the help of relays, pistons, rods and cams without changing the

mechanics. Acceleration enables the accumulation of vast amount of data in significantly shorter time received in normal conditions. (Smith 2005, 160-161.)

4.1 3GPP

The ITU started the development of a global broadband multimedia international mobile telecommunications system (IMT) more than 30 years ago. The 3GPP and 3GPP2 organizations were born as a result of this initiative in December of 1998. (Al Agha, Pujolle, Ali-Yahiya 2016, 2.) The 3GPP is a unison of seven organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC) from different continents and its role is to provide "…their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies" (3GPP 2019a, cited 15.7.2019). The project provides complete system specification, including radio access, the core transport network, service capabilities with codecs, security and quality of service. Technical Specification Groups and the Working Groups together produce "…Technical Specifications, to be transposed by relevant Standardization Bodies (Organizational Partners) into appropriate deliverables (e.g. standards)" (3GPP 2019b, cited 15.7.2019).

Each mobile development milestone can be addressed through 3GPP Releases in addition to the mobile generations. The Releases are complete when all features and functionalities are ready. To ensure that the progress is continuous and stable, there are several releases being developed simultaneously. It is also very important to ensure that the system is backwords and forwards compatible. A good example of this type of development is ensuring the compatibility between the LTE and LTE-Advanced, where the "…LTE-A terminal can work in an LTE cell and an LTE terminal works in the LTE-A cell." (3GPP 2019a, cited 15.7.2019). Ongoing Releases of 3GPP radio technologies and systems are visible in figure 3.

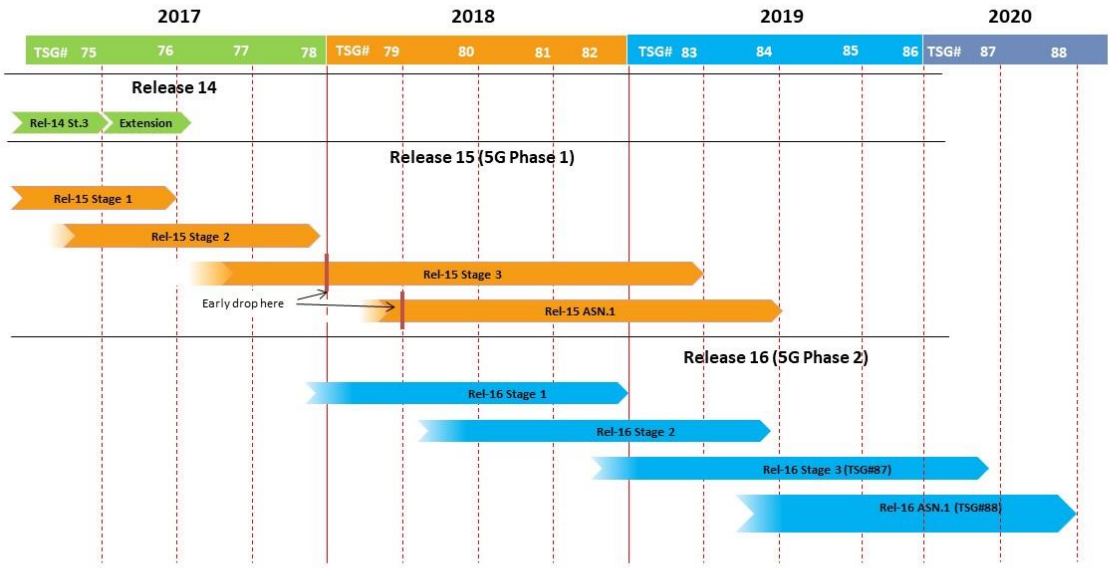

FIGURE 3. Ongoing Releases of 3GPP radio technologies and systems. (3GPP 2019, cited 15.7.2019).

4.2 **ETSI**

ETSI is one of the seven partner organizations in 3GPP and its mission is "To provide platforms for interested parties to work together to produce standards for ICT systems and services that are used globally." (ETSI 2019a, cited 15.7.2019). ETSI is a not-for-profit organization which is funded through membership contributions, the European Commission (EC) and the European Free Trade Association (EFTA), commercial activities and collaborations activities. (ETSI 2019a, cited 15.7.2019.)

ETSI standards are free and available for everyone and they are developed, tested and validated widely. Ongoing ETSI activities can be seen in figure 4. ETSI supports "…European regulations and legislation through the creation of Harmonised European Standards. Only standards developed by the three ESOs (CEN, CENELEC and ETSI) are recognized as European Standards (ENs)." (ETSI 2019a, cited 15.7.2019). Nokia is one of the manufacturing members of ETSI.

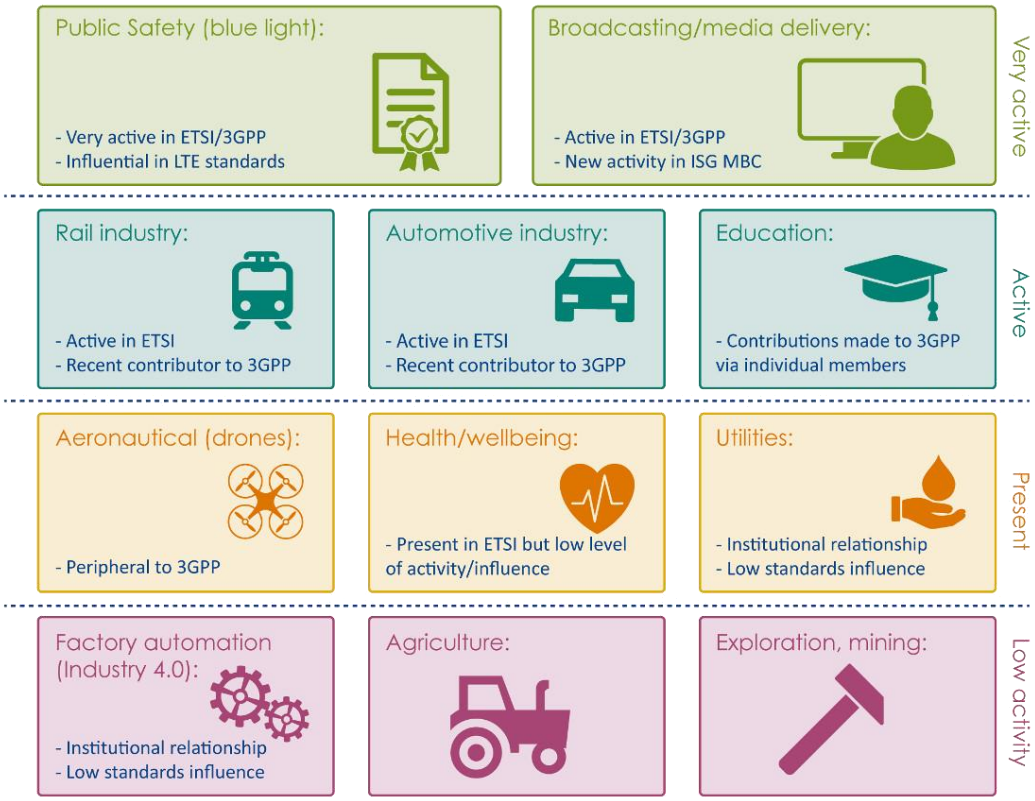

FIGURE 4. Ongoing ETSI activities. (ETSI 2019b, cited 15.7.2019).

4.3 System development and Reliability engineering

"System development is the art and science of creating man-made systems to satisfy predetermined needs" (Grady 2007, 14). In a way, it is problem solving and creating solutions for the problem. When enterprises solve these problems, there must be a solid knowledge base and enough specialists working on the problem, a functional management to deploy resources and cooperation between development teams, to achieve the common goal. The specialist that participate in the development, are usually specialized in mechanics, electricity, chemicals and computer software. (Grady 2007,14.)

The problem solving is usually divided into three steps. They are defining the problem through requirements described in specifications, turning the requirements into design solutions and proving with testing that the design meets the requirements, and thus solving the problem. (Grady 2007,14.) System development is also known as exercising of system engineering.

Reliability engineering is a sub-discipline of systems engineering and its purpose is to highlight dependability in the lifecycle of a product. Reliability is a description of the function of a product in a certain environment or conditions. The definition of reliability is the probability of success or the frequency in which faults occur. High reliability is often achieved with excellent engineering and attention to detail. Ensuring product reliability has an input in the costs of failure and spares, repair equipment, personnel and warranty claims. (Wikipedia 2019i, cited 19.7.2019.) Companies often have their own goals set for reliability. Those goals are often expressed in either the acceptable number of faults in for example 1,000 units, or the acceptable number of returned products.

Software reliability is one of the aspects of reliability engineering. Where the system reliability includes the entire system (hardware, software, supporting structures), software reliability focuses on finding unanticipated results of software operations, using software reliability models. Software reliability relies on requirements, design and implementation. Software development plan contains the design, coding standards, peer reviews, unit tests, configuration management, software metrics and models. Software reliability is displayed in number of software faults per thousand lines of code. After multiple levels of testing, the software is integrated into the hardware. (Wikipedia 2019i, cited 19.7.2019.)

4.4 System verification and validation

Validation and verification are two independent processes. Verification is used to check if the product and the service system requirements, specification and purpose are met. A three-step process of verifying requirements has evolved during a course of time. The first step is that items which have never been used in a certain application must be qualified. This phase is called item acceptance. Second, all the items manufactured must be formally accepted and tested against defined criteria. And third, all end products must be tested at the system level. (Grady 2007, 19.)

Verification testing and formal audits of it, testing results combined, indicate if the system meets the set specifications or requirements. This data is then collected to a formal report, showing the results of verification tasks conducted according to a program verification plan. The process of verification includes a huge amount of documentary, such as verifications requirements, plans,

procedures, reports and results. Thorough documentation is as important as the work itself. Verification is an internal process with multiple testing phases. (Grady 2007,19.)

Validation is used to ensure that the product meets the user's operational needs. The validation process includes making simulations and predictions of faults. This might cause verification or development to be unsuccessful. Validation is said to be the process of proving that the right product is being built. Validation is often an external process. (Grady 2007, 20.)

4.4.1 Design review

A design review is carried out by document review and predictive calculations to ensure the design verification against requirements. There are several ways to conduct the review, such as "The functional specification against the requirements specification, circuit or mechanical assembly performance against the functional specification, predicted reliability/availability against targets in the requirements specification, some software source code against the software specification" (Smith 2005, 158).

Requirement specification reviews are usually hardest to do because that is the point where there are no higher specifications to compare to. In designs feature review, features such as completeness, unambiguity and consistency, are to be considered. Functional specifications are reviewed against the requirement specifications. Detailed design contains reliability predictions, risk assessments and test results. A software review is carried out through code inspection or code walk through. Test specifications and test results also need to be reviewed against design and specifications. A checklist is often used to record the results. The results of all the different reviews must be carefully documented and recorded. (Smith 2005, 158.)

4.4.2 Testing

Testing is carried out through the whole product lifecycle. It is often categorized in four areas. The first one is design testing in which several tests are done in a laboratory and with prototypes to prove the design. Pre-production models will be then tested under environmental and reliability

testing. (Smith 2005, 158.) The second one is qualification testing, using production models which undergo series of “extensive marginal tests, climatic and shock tests, reliability and maintainability tests and the accumulation of some field data.” (Smith 2005, 159). The third area is production testing and commissioning, which is verification of conformance. The fourth area is demonstration testing, which includes environmental testing. (Smith 2005, 159.)

Environmental testing is carried out to ensure that the product works as specified and does not get damaged by the defined conditions. The environmental tests are chosen from various options, including electric fields, radiation, temperature cycling, humidity extremes, temperature cycling at high humidity, rapid change of temperature, wind, direct sunlight, atmospheric pressure extremes, mechanical vibration at given frequency, vibration at simultaneous random frequencies, mechanical shock, acceleration, acids, alkalis, salt, greases, ferrous, carbon, silicate, general dust, defined growth or insect infestation, reactive gases and flammable atmospheres. (Smith 2005, 159.)

Usability testing is used to find out practical information on how the system is used by the user group. Usability testing often uncovers system defects and so it is valuable to the developers. It is usually done in the design phase by a cross-functional team, which adds experience to the testing. The testing itself consists of three phases; preparation, running the test and analysing the results. Usability is often tested by observing the usage of the device. The findings are recorded during the observing, then analysed. Finally, feedback is given about the findings and changes are planned to increase usability. (Engel 2010, cited 18.7.2019.)

Reliability testing is carried out to measure the quality of the product and to verify that the reliability requirements are met. It is also used to ensure that the system does not harm its users or the environment. To ensure reliable test results, the reliability testing is performed using an operational unit in an operational environment. The results (failure analytics) are gathered and the systems reliability can be predicted based on those results. Possible corrections can be carried out for the product after the analysis is ready. Reliable systems are important to a company and they ensure business success. (Engel 2010, cited 18.7.2019.)

Software testing is a very important tool, ensuring the systems functionality. Testing provides knowledge of the software quality and of the functionality. The intention is to find errors or disfunctions by running the code. It is important to configure that the program runs as it should, at

the acceptable speed, is usable and steady, meets the design requirements and can be used in planned environments. The chosen approach determines how and in what state the program is tested. On Agile approach, all the stages of development, requirements, programming and testing are done simultaneously. (Wikipedia 2019l, cited 22.7.2019.) The Agile framework is presented with more detail in chapter 5.

4.4.3 Type approval

To receive a type approval, also known as a certificate of conformity, the product must meet certain regulatory, technical and safety requirements. The requirements vary depending on the country for which the product is manufactured to. The reached compliance to requirements is usually denoted to the project by marking or with a certificate. There are companies like TÜV (Technischer Überwachungsverein) which provide services to inspect and certify products. (Wikipedia 2019m. cited 19.9.2019.)

A type approval process usually consists of documentation review, design verification, execution of test cases, reporting detected faults, supporting fault correction deliveries and assessment of manufacturing procedures.

4.4.4 Failure analysis

The function of failure analysis is to determine what has caused the occurred failure and to prevent it from happening again. In other cases, it is used to improve the performance of the device. (Wikipedia 2019d, cited 18.7.2019) A failure analysis is a significant part of processing test data. The data for the analysis is collected from prototypes, production models and from the field, the last one being the most valuable because it contains failures that have happened under real conditions. (Smith 2005, 167.) The analysis itself is made with using a vast range of equipment, such as microscopes, sample preparation equipment, spectroscopic analysis equipment, device modification, surface analysis, electron microscopy, laser signal injection microscopy, semiconductor probing and software-based fault location techniques. (Wikipedia 2019d, cited 18.7.2019.)

A formal failure reporting document needs to be used when conducting a failure analysis. The report should be a detailed description of the fault, containing at least the type of fault, repair activity, nature of fault, fault conditions and location, environmental factors, actions taken to repair, person involved and unit running time. (Smith 2005, 168.)

5 THE WORKING METHODS AND PROCESSES AT NOKIA

A crucial part of defining the Way of Working model was to understand the organization work principles, workflow and framework. Frameworks, such as Agile Software development, Lean and SAFe, which are used in Nokia, are explained in this chapter.

5.1 Agile Software Development

The Agile approach includes a vast range of tools and frameworks. It is a collaboration of a self-driven, self-organized, cross-functional teams and customers. Key elements of Agile are adaptive planning, evolutionary development, delivering early, continuously improving and responding rapidly to changes. The Manifesto for Agile Software Development proclaims twelve principles to describe Agile:

1. Customer satisfaction by early and continuous delivery of valuable software.
2. Welcome changing requirements, even in late development.
3. Deliver working software frequently (weeks rather than months).
4. Close, daily cooperation between business people and developers.
5. Projects are built around motivated individuals, who should be trusted.
6. Face-to-face conversation is the best form of communication (co-location).
7. Working software is the primary measure of progress.
8. Sustainable development, able to maintain a constant pace.
9. Continuous attention to technical excellence and good design.
10. Simplicity—the art of maximizing the amount of work not done—is essential.
11. Best architectures, requirements, and designs emerge from self-organizing teams.
12. Regularly, the team reflects on how to become more effective, and adjusts accordingly (Wikipedia 2019b, cited 25.7.2019).

Breaking a development process into smaller segments is typical for Agile methods. This reduces up-front planning and design. Development is done in sprints or iterations, lasting from one to four weeks. Every segment has all the functions; planning, analysis, design, coding, unit testing and acceptance of testing. A product of each iteration is presented to the stakeholders. The goal is to be able to release the product after iteration. Development team members should be located close to each other because it makes working together more efficient. An updated status of the project should be visible for the whole team to see. Each team should have a member in Scrum to represent the stakeholders in the development process. Scrum is the framework used to conduct

Agile development. A daily Scrum is held to share work related actions from previous day and to go through the tasks for the current day. (Wikipedia 2019b, cited 25.7.2019.)

There are important roles in implementing Agile methods. A Scrum Team is a group of people who work together to meet a certain goal. A Scrum master is one member of the Scrum Team whose role is to ensure all team members follow Scrum principles. A product owner is also a member of the Scrum Team and their responsibility is to ensure that the team is working efficiently by defining the specifications of the product and planning the backlog with the team. (Wikipedia 2019b, cited 25.7.2019.)

JIRA is a project management tool which supports the Agile methodology and supports both Scrum and Kanban. It was originally created as a bug reporting tool but it has developed into a multi-functional manager which can be used through-out the project, from the backlog through the sprint. (Harned 2018, cited 25.7.2019.)

5.2 **Lean**

In 1988 researchers led by doctor James P. Womack examined the efficiency of Toyota Motor Company and discovered some attributes that made the company stand out from traditional mass production companies. The attributes were that Toyota "Needed less effort to design, make, and service their products, required less investment to achieve a given level of production capacity, produced products with fewer defects, used fewer suppliers, performed its key processes — including concept-to-launch, order-to-delivery, and problem-to-repair — in less time and with less effort, needed less inventory at every step and had fewer employee injuries" (Sayer, Williams 2012, cited 24.7.2019).

Lean is hard to describe as one thing because it is a combination of philosophy, behaviour, management strategies, principles, methodologies, techniques and tools. Adding a value means all activity that brings something to complete the tasks at hand. A Non-value-added activity takes resources and brings no value to the customer. A value stream consists of all the activities from customer contract to the product delivery. Flow (Mura) is used to describe a process which works without interruption. On the other hand, wastes (Mudas) are things that slow down the Lean development. Mudas are the following things; to have too much inventory, to have a waiting time

inside the process, defects on products, overproduction, motion which can cause injuries or lengthen the production time, transportation and over-processing. (Carreira 2004, 1-3.)

There are a few key elements that can be used to explain the Lean principles. The concept of pull means that actions are performed when necessary, not beforehand. The continuous elimination of waste (removing time consuming to free up time, devoting to value added activities) means producing more products with less resource, which leads to more satisfied customers, growth in market shares, more profit for the company and value to the employees. Every employee should seek perfection by developing Keizen (means "change for the better"). The key is to get each employee committed and to believe in the common cause through Keizen. (Carreira 2004, 1-3.)

Lean thinking is a business culture, which aims to increase value and benefits to individuals and to the society, while eliminating waste. "To do more with less" is a sentence that describes the essence of Lean. Companies that have a fully adapted Lean "use less human effort to perform their work, less material to create their products and services, less time to develop them, and less energy and space to produce them." (Sayer, Williams 2012, cited 24.7.2019).

5.2.1 Principles of Lean and the TPS

The TPS is often described as the foundation of Lean. It was manufactured by Eiji and Kiichiro Toyoda and Taiichi Ohno. (Sayer, Williams 2012, cited 24.7.2019.) The high-level activities of TPS are visible in figure 5.

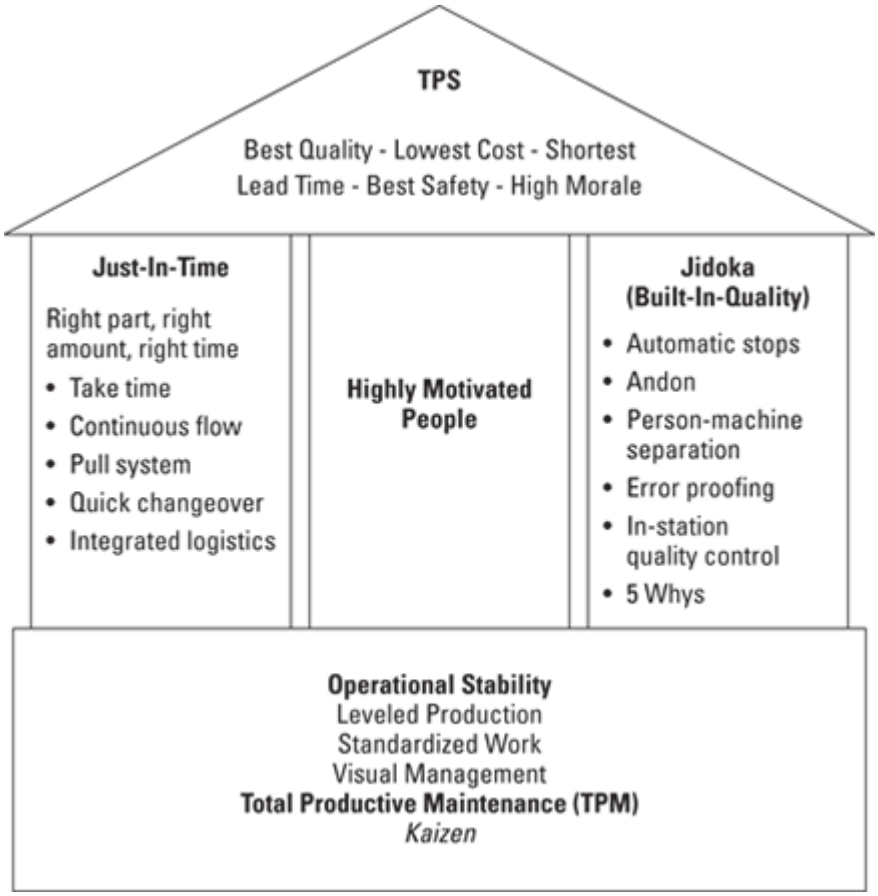

FIGURE 5. High level view of the TPS. (Sayer, Williams 2012, cited 24.7.2019).

Liker summed up the TPS into 14 principles in his book "The Toyota Way". Those are:

> "Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals, create right process to produce results, use pull system to avoid overproduction, balance out the workload (heijunka), build a culture of stopping to fix problems, to get quality right at the first time, standardized tasks are the foundation for continuous improvements and employee empowerment, use Visual Control, so no problems are hidden, use only reliable, thoroughly tested technology that serves your people and process, grow leaders who thoroughly understand the work, live philosophy and teach it to others, develop exceptional people and teams who follow your company's philosophy, respect your extended network of partners and suppliers by challenging them and helping them improve, go where the problem is and see for yourself to thoroughly understand the situation, make decision slowly by consensus (use cross-functional teams), thoroughly considering all options; implement decisions rapidly, and become a learning organization through relentless reflection (hansei) and continuous improvements (Kaizen)" (Liker 2010, 37-41).

If lasting and sustainable improvements are pursued, all these areas of Lean should be implemented. (Liker 2010, 41.) These changes are introduced to the company gradually, starting

from the top management, engaging employees from the lower level upwards and using middle management to deliver the message. (Liker 2010, 290.)

5.2.2 Activities in Lean

Kaizen, a Japanese term for a continuous improvement, is one of the key activities of Lean practice. Kaizen teaches employees to work efficiently in small groups solving problems, documenting and improving processes, collecting and analysing data and teaching self-driven management. Employees make decisions in unison and with the help of open dialogue. An improvement is made part of the everyday work, using the PDCA plan, which a systematic approach to problem solving. (Liker 2010, 23.) A Keizen workshop is often utilized to recognize the areas of improvement. It begins by the team defining the customer processes and models. Next, the process is walked through (concretely if possible), assessed and analysed. All the visions and ideas of improvement are collected and last, they are made into reality by using smaller working groups working on each segment. (Liker 2010, 278-282.)

Kanban, a Japanese term for card, flag or a sign, is a tool used to implement the movement of material in the Lean Mura. (Liker 2010, 35.) Kanban is a technique, using notes or other tools, to visualize the average activity. These notes will ensure that everyone is working on needed areas and not for example producing s part of the product at the wrong time. When using Kanban, the companies must challenge themselves by following the behaviour of the market and responding to changes with their flexibility. (Wikipedia 2019e, cited 24.7.2019.)

Autonomation is a feature of machine design, used to effect on Jidoka (built-in quality). It is a system that is designed to stop production if a fault should occur. This is more efficient and saves more costs than making corrections after they have occurred. The entire line is not designed to stop if a fault should occur, but only the part where the fault is. (Liker 2010, 130.)

Lean thinking is thinking together, and it means that no one should be left alone with a problem. Andon is a central board in the manufacturing facilities to indicate any faults in manufacturing. There are visible and audible signals in Andon to indicate faults. It shows the exact location of the fault, so the team leaders can react to it, as they are trained to do. After Andon gives an alarm and

Jidoka is used, part of the line stops. After a set amount of time, also the next segment stops and this will continue, until the problem is fixed. (Liker 2010, 130-131.)

SMED is a Lean method developed to reduce waste by making the transition from a finished product to starting a new one as fast and easy as possible. SMED is the tool used to guarantee flexibility to production, which is a key concept of Mura. Shigeo Shingo, who invented SMED, summarized it in eight steps. Those steps include separating internal and external setup operations, standardizing functions, using functional clamps and mechanizing. (Wikipedia 2019e, cited 24.7.2019.)

5.2.3 Six Sigma and Lean Six Sigma

Six Sigma, also known as 6σ, was invented in 1980 by Bill Smith when he was working for Motorola. Six Sigma is a process improvement technique, which aims the production to produce less than 3.4 faults per million items. (Liker 2010, 295.) Six Sigma focuses on the output quality and the goal is to identify and remove all causes of defect and minimize the variation with quality and statistical methods. Separate experts inside the organization are trained to master the methods. ISO released its first standard "ISO 13053:2011" to define the Six Sigma process in 2011. (Wikipedia 2019j, cited 25.7.2019.)

In Six Sigma there are six fundamental methodologies which are implemented through improvement projects. They are accomplished with two sub-methodologies; DMAIC and DMADV. The methodologies focus on the customer and process, have a fact driven and proactive management, make improvements, initiate team work and aim for perfection, while tolerating a failure. The goal is to identify and eliminate costs that create no value for the customer. (Desai 2010, 10-16.)

DMAIC is a process of five stages. In the D (define) stage the project leaders define the project purpose, scope, timeline and costs based on all available data. In the M (measure) stage the current process is made clear with the help of a detailed process map, gathering baseline data and summarizing and analysing the data. This includes the calculation of current process variation or faults. The A (analyse) phase is used to figure out why problems occur based on data of the

previous phases. The I (improvement) phase identifies solutions to problems addressed in the project. And finally, the C (control) phase ensures that the improvements of the previous phase are carried out beyond the current project. (Desai 2010, 45-57.)

DMADV is much the same as DMAIC but it is used when there is a new product in production or when the existing one has been optimized but does not meet the quality requirements. (Desai 2010, 60-61.)

In Six Sigma there are implementation roles which have a different action to attend to. Executive Leaders set up the vision for the implementation and empower the other roles. Champions are responsible for the implementation in the organization and mentor the Black Belts. Master Black Belts are coaches of Six Sigma in the company and use 100 % of their working time to the method. Black Belts work to apply Six Sigma to projects and focus on execution. Green Belts implement Six Sigma along with other work-related tasks and Yellow Belts are trained in the basics of Six Sigma management tools. (Desai 2010, 63-64.)

Lean and Six Sigma are two different concepts which share tools, both designed to achieve a better quality. Lean Six Sigma is a methodology which combines the Lean flow and waste removal with the Six Sigma design and variation diminishing. (Wikipedia 2019i, cited 25.7.2019.) Michael George describes: “The activities that cause the customer's critical-to-quality issues and create the longest time delays in any process offer the greatest opportunity for improvement in cost, quality, capital, and lead time.” (George 2002, cited 25.7.2019). Some experts disagree with the combining of these two methodologies because both have clear steps to follow and are not possible to follow in such vigour as they are intended to when followed simultaneously. (Liker 2010, 296.)

5.2.4 SAFe

SAFe is the leading framework for enterprise agility in the world. Dean Leffingwell first introduced Agile Enterprise Big Picture later known as SAFe in his book Agile Software Requirements. It portrays the appliance of Lean and Agile practices for program, team and portfolio levels using the knowledge of Lean, Kanban, Scrum and Extreme Programming. All these features together formed

a framework which was taken into use in several large companies, such as IBM, John Deere and Nokia. (Scaled Agile Inc. 2019, cited 25.7.2019.)

SAFe was formed in 2011 and today it is used in 70% of Fortune 100 companies with over 450,000 users. There are four different kinds of frameworks to choose from, depending on the size and goals of the company; Essential SAFe, Large Solution SAFe, Portfolio SAFe and Full SAFe. Each framework provides unique solutions for desired outcome. (Scaled Agile Inc. 2019, cited 25.7.2019.) The SAFe house of Lean in figure 6 describes the SAFe principles.

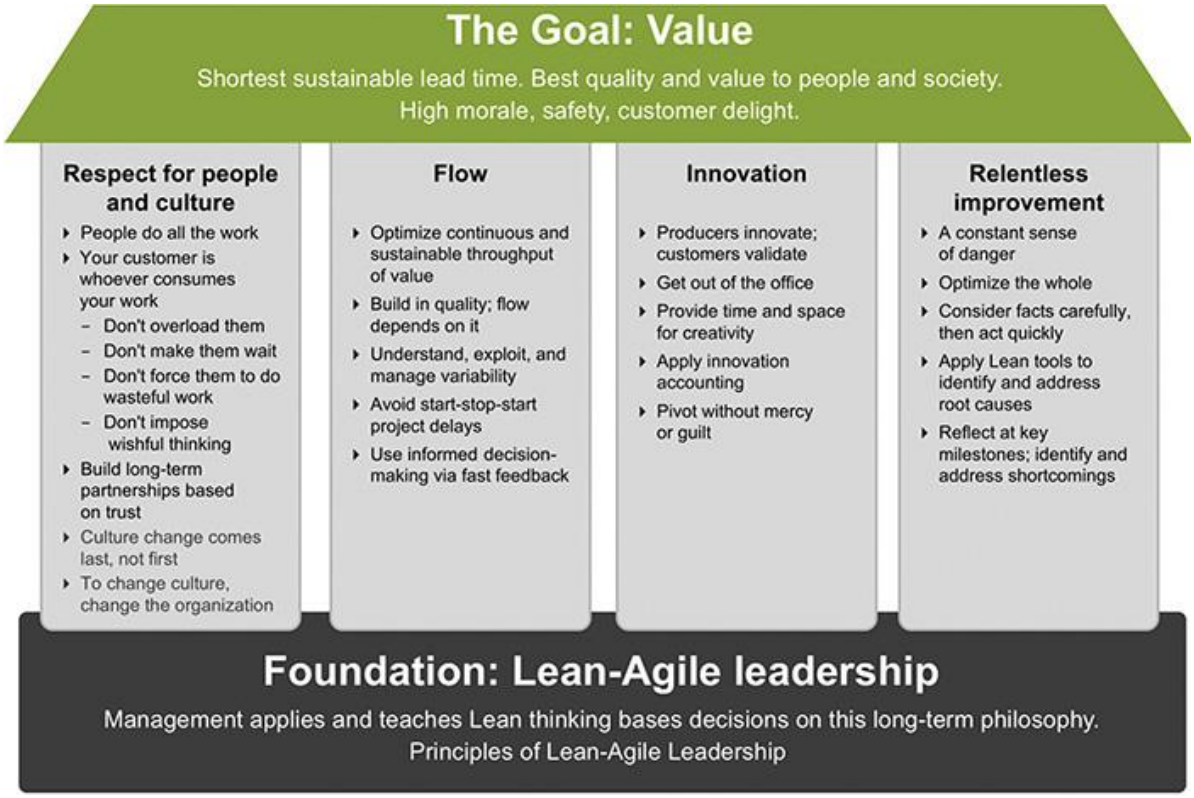

FIGURE 6. SAFe House of Lean. (Leffingwell 2018, cited 25.7.2019.)

The core values of SAFe give employees the ideas and beliefs to implement the framework. The core values are:

- Aligning the management and teams to the common mission of serving the customer. To do so, everyone must understand the strategy and their own role in achieving the goal.
- Built-in quality which increases customer satisfaction, business profitability and faster delivery. In hardware development this means frequent design cycles and integration,

collaborative design practices, MBSE, SBD and investments in development and infrastructure.

- Transparency increases trust and that is necessary for performance, innovation, risk-taking and improvement.
- Program execution in a sense that the whole production must become leaner. The functional silos must be broken to create stable teams to form an Agile Release Train. (Leffingwell 2018, cited 25.7.2019).

5.3 Processes at Nokia Corporation

Successful companies like Nokia, have highly developed and optimized processes to develop, manufacture and support their products. The process from the initial idea to a ready product, contains numerous steps and hundreds of working hours. Therefore, the process needs to be continuously developed, assessed and planned. There are many effective ways to develop processes, of which a few are introduced in the previous chapters. Most of those ideologies are present in Nokia processes, embedded in the working framework.

Product development in Nokia starts with a customer requirement, which is a description of the product that the client is interested in having. It also identifies the business potential and estimates the work effort required. A feature screening (FS) process moves along with FS milestones, which identify business potential and verify the business plan. The negative impact analysis, pricing model, set priority and feature description are also defined in the FS process.

After the feature value has been found high enough to be included, the product is allocated to be released by the project management at the FS3 milestone. At this point the probability that the feature will be implemented is high enough to start sales planning and configurator modelling. In the FS4 milestone, the product is implemented and tested and it is ready for release. After the release, the product goes into a maintenance phase, where it is maintained to operate correctly after the release.

The program P milestones describe the hardware and software development process from the start of the program until the pilot, deliveries and finally the end of the program. The process is

implemented using an Agile software content and delivery management. The SW and HW developments in Nokia combine elements from Create+, LeSS and Agile frameworks. The processes described in this project are in the hardware verification area. The verification processes typically start in the P2 milestone, where investments are approved, and all activities end at the P7 milestone when the pilots are ready.

6 DEFINING THE WAY OF WORKING

A Way of Working is a description of how, by whom and with what tools a certain process is run in an organization. In this case the description of each area was done as accurately as possible, making it in a form of a project, utilizing the teams and professionals conducting the everyday work. Project management activities were an essential role in the WoW project. The activities included setting up the project framework and planning the schedule, defining the new responsibilities, which had changed after the last WoW-material had been published, and streamlining the process material with other similar tribes in Hangzhou and Irving. In this chapter there is information about the methods and the process of the WoW definition in Nokia.

6.1 **Project type of work**

A project can be described as a unity consisting of non-routine tasks, which are operated during a fixed timeline and resources. A project is a coordinated activity of many people working on achieving the same goal. The goal of a project is usually to deliver something, in this case a release containing the collected or produced data. To be a convincing project manager, one must be capable of presenting benefits of the project in such way that it is believable. The role requires determination, a belief in the project, people-skills, excellent time management and organizational skills. Delegation and adequate communication are key tools to a successful project management. (Hobbs 2009, cited 30.7.2019.)

In short, a project is conducted with the following phases. The first phase of the project, the planning phase, includes gathering a project team and sharing responsibilities and tasks related to the project inside the team. Next the scope should be defined by gathering more information about the subject. A business plan is made to assess the costs of the project. Risks included in the project should be considered. A project plan is made with time estimations. A system of communication and regular check-ups should be planned to keep track of the process. These meetings are recorded in a “meeting minutes” type of a way. Review meetings should also be held regularly to assure that there is progress and the quality of the material is sufficient. (Hobbs 2009, cited 30.7.2019.)

At the end of the project, a handover for the product is made. A pre-implementation meeting is held to go over the original scope and the plan used to achieve it, to make an implementation plan and to create a closure checklist to chart the progress. Finally, the project is analysed, and the success is celebrated with the project team. Going through the lessons learnt from the project, gives valuable feedback for coming projects. (Hobbs 2009, cited 30.7.2019.)

6.2 **Interview as a method**

Interviewing is a powerful way to obtain data in a social research. It is a technique used to form comprehension of our social surroundings. It is also one of the most popular ways to collect data for a qualitative research. (Morris 2015, 5.) Opdenakker describes a qualitative research as "an interview, which purpose is to gather descriptions of the life-world of the interviewee with respect to interpretation of the meaning of the described phenomena" (Opdenakker 2006, cited 26.7.2019). There are many interviewing techniques, such as face-to-face interviews, telephone interviews, MSN messenger interviews, and e-mail interviews. Each of these methods have their pros and cons. (Opdenakker 2006, cited 26.7.2019.)

There are numerous types of interview methods to use. Berry lists nine types: "structured interview, survey interview, counselling interview, diary interview, life history interview, ethnographic interview, informal/unstructured interview, and conversations." (Berry 1999, cited 26.7.2019). Unstructured interviewing, also known as in-depth interviewing or qualitative interviewing, is used to gather data from the interviewee with open-ended questions. It aims to get the point of view of the situation in hand. (Berry 1999, cited 26.7.2019.) Planning and executing a good qualitative interview can be harder and more complex task than to use a structured questionnaire with predetermined questions. It can also be a lot more informant, if used correctly. (Mason 2018, 116.)

There are three basic ways to conduct a qualitative interview. The first one is the informal conversational interview where the situation is relaxed, and the questions come up during the conversation. It is used to observe the ongoing fieldwork. Second one is the guided interview in which the interviewer uses a guiding list of topics they want to cover. The third one is the

standardised open-ended interview. In this method the questions are prepared with care to minimize variation. (Berry 1999, cited 26.7.2019.)

There is some debate still about how the in-depth interview is done with quality; how many encounters are needed and how they should be conducted. There are many advantages to the researcher meeting the interviewee several times, such as getting trust built between the researcher and interviewee and being able to clarify the data. This, however, is not always possible, do to scheduling and resources. (Gilbert 2008, 430-431.) The in-depth interview can be used in almost any topic and it can give a large amount of data but the downside is that the interviewees might give an inaccurate description, which can be verified via observation. (Morris 2015, 5-7.)

6.3 The methods and process of this project

The need and initial planning for this project came from the commissioning unit. The method planning and project implementation started in May of 2019. The first thing was to prepare the timeline and identify all competence areas, processes, sub-processes, guidelines, interfaces, interlocks and the people responsible for each one. After identifying these areas, a plan was made to obtain information of each of the processes and to form a high-level picture of the whole area.

6.3.1 The planning and preparation phase

A Face-to-face interview is a synchronous communication in time and place, where voice, intonation and body language can be perceived with the data given by the interviewee. Face-to-face interviews guarantee no-time-delay reactions between the question and answer, thus creating a situation where both the interviewer and interviewee observe reactions and have a spontaneous dialogue. In this method, especially when the interview is designed as unstructured or semi-structured, the interviewer must concentrate on the questions and answers, to be able to collect data. Taking notes or recording is recommended. (Opdenakker 2006, cited 26.7.2019.)

In this study, face-to-face interview was used as a method for obtaining information of all the different competence areas. A face-to-face technique was sensible in this study, because all the

interviewees were in the same location as the interviewer, making the scheduling easy. A few questions were prepared to ensure that the time was used efficiently but mostly the interviewee had a chance to describe their competence area freely. During the interviews, notes were made to gather all the essential information. Interviewing the process owners and participating into daily activities via shadowing were effective ways to collect data and collect information of the possible challenges and needs of improvement for each are. The areas of interest in this study were the process milestones and process description, SIPOC-model, inputs, outputs, organisation framework, interfaces and sub-processes.

6.3.2 The working phase

The Next step was to plan and construct the Sharepoint Online wikipages for the WoW process descriptions. The main page contains links to all the competence area pages and guidance on how to maintain the page collection. The main page also describes the scope of the project. The page was constructed following the Nokia guidelines. A template page was made for each competence area to collect the data in a unified way. The template consisted of a carefully planned table of contents including all the data, such as the SIPOC-model, description of purpose and scope, inputs, outputs, resources and roles.

One of the unifying key elements which was used as a visual description for each process, was the SIPOC-model. A SIPOC is a process improvement tool which is used to describe the suppliers, inputs, process, outputs and customers of one process in a table form. It is a tool that is used in Lean manufacturing and Six Sigma. The SIPOC is often used in the defining phase to give people a high-level overview of the process if they are unfamiliar with it or if the process description has become out-of-date. (Wikipedia 2019k, cited 29.7.2019.) The SIPOC-model template designed for this project is visible in figure 7.

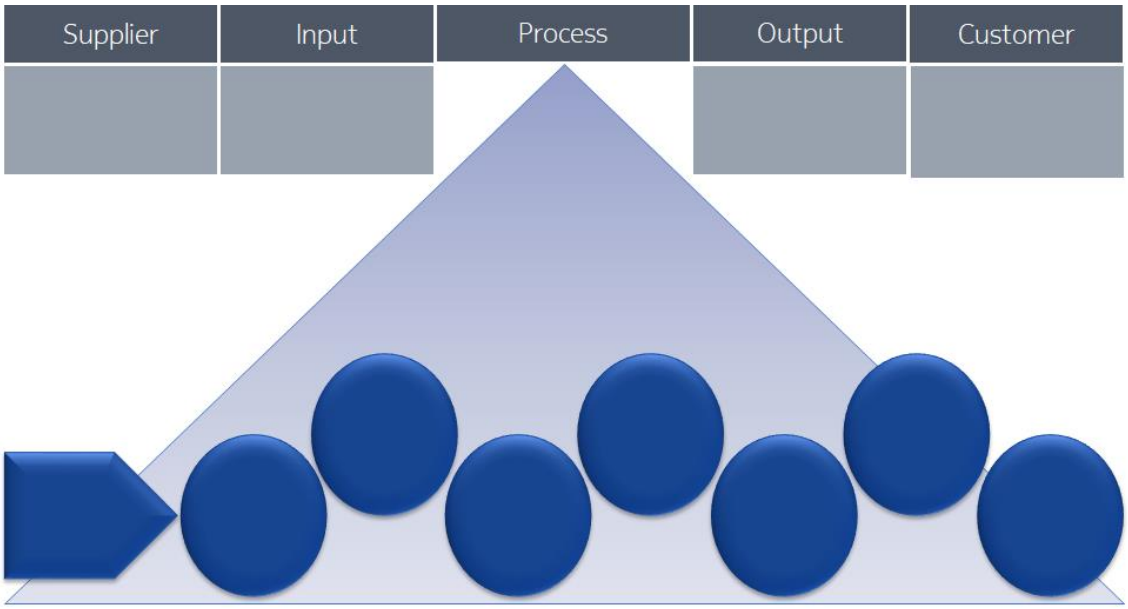

FIGURE 7. SIPOC-model template.

After the process was identified, a kick-off meeting was arranged to present the timeline and expectations for the WoW creation. All the project material and templates were planned, executed and delivered for each process owner and the contributors before they started working on the process descriptions. After the kick off, all the areas started to work independently, producing the process material. Status follow-up meetings were held every two weeks adjusting to three different time zones, to follow-up on the process and offer help, in case there were issues to solve. The review dates and release schedule were agreed separately with each of the process owners.

6.3.3 The implementation phase

The WoW project was defined to proceed by following these six steps:

1. Identifying the process owner for each area.
2. Establishing a working group to collect the material.
3. The first draft of the material is ready.
4. Internal reviews have been planned and held.
5. Official approval has been done and material published.
6. Trainings for the material are arranged.

Each of the six steps had a fixed deadline. An Excel progress chart shown in figure 8 was used to follow up the progress of each area.

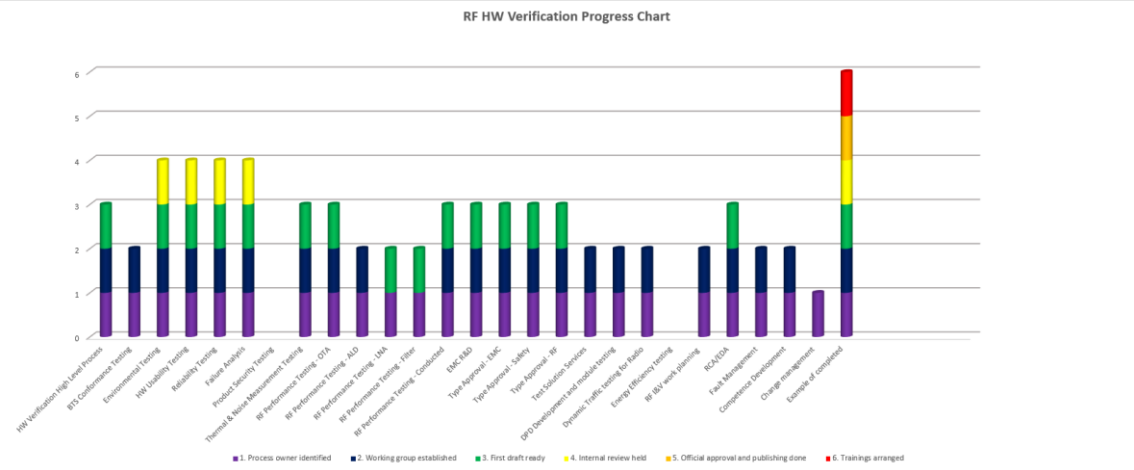

FIGURE 8. Project progress chart.

All members of this project were dedicated to producing their material, although it was extra work on top of their daily tasks. Each finalized page in the Sharepoint page collection included a purpose description, overview and scope, organization framework and interfaces, inputs and outputs, resources, guidelines, tools, templates, roles and responsibilities, execution and process descriptions, process efficiency monitoring and improvements section, references and a table of revision history. The high-level process as it is currently run was described using a process picture with milestones. HTML code was embedded in the process picture to access each process page. The HTML code was designed using an image-map to point the clickable areas. The milestones were also explained in the text to a have a detailed description available.

A maintenance plan, a plan for future updating after the first release, a revisioning plan and release processes and schedules were defined for all the published material. The first review was made within the working group. After that the material was officially reviewed by a nominated steering group. The official release and the presentation of the finished project were held after the official review in October 2019. A recorded training material was published in co-operation with the Competence Development manager after the material was released.

7 CONCLUSIONS

The target of this study was to describe the theoretical framework and process of streamlining and global updating of Way of Working in Hardware Verification at Nokia Corporation. At the beginning of the process, the previously made WoW material was outdated and insufficient due to newly formed processes. Most of the material was available but it was outdated and thus, in some areas, not followed. There was some obscurity concerning the interfaces between teams and this caused confusion inside the organisation. Although everyday work was running smooth, there was a huge need to make the preconditions and deliverables available. This thesis work in Nokia revolved around collecting the Way of Working material from verification, integration and supporting tasks for program management through collaboration with different teams. However, due to time issues, the work was focused on the verification area.

The first part of this thesis work was to form a high-level picture of the area in question, by updating a milestone map and the process pictures. For this the day-to-day activities were defined for each process by using a semi-structured face-to-face interviewing method with some pre-define questions. After the project kick off in June 2019, status update meetings were held every two weeks to ensure that the process was progressing as planned. Defining a template on Sharepoint Online for the WoW material, ensuring that the material was delivered on time, defining a schedule and revisioning plan for future updates and project management activities were important parts of this thesis work.

At the beginning of the process there were some difficulties with the project scheduling and getting everything done on time because summer holidays were approaching. However, the interviews and kick-off arrangements for the project just before the holiday season. The work began as planned and each area started gradually filling out their template. The process owners and contributors were supported and helped by the project manager with any technical difficulties.

This WoW project and its results are an important tool for the commissioning company. The same model and template used in this assignment can be utilized in the future in other areas of the company. Using a unified template of presenting information supports credibility, increases quality and makes the information easier to access, thus making the work more efficient. The challenges, which emerged during the process, can be addressed better when the processes and all the

interfaces are fully visible to all teams. The recorded sessions, where the areas are opened by the process owners, help users grasp the main idea of each process in a more detailed level.

All in all, this project was carried out successfully and the work will continue independently after the first part of the project has ended. All project members involved were dedicated to produce their material, although it was extra work on top of their daily tasks. The material was collected to the templates as planned, using references to ensure quality. The revisioning was done using formal Nokia guidelines.

Now that the processes have been described with detail and gathered in one location, it would be beneficial to observe the processes closer. Many of the processes had deviations between site locations, although the outputs of the processes were the same. Some challenges concerning automatization and testing tools came up during the interviews. Fixing those challenges could improve the efficiency of the process. In a wider scope, encouraging employees to go through trainings on how to use the Sharepoint tools and editing possibilities more efficiently would help finding and presenting information easier. Further development plan for this project could be to implement a same kind of project to all areas of RF development.

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