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Business Scenarios for the Ecosystem Surrounding Licensed Shared Access

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Master of Science in Communication Technology
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Problem description:

Licensed Shared Access (LSA) is a regulatory approach in spectrum sharing aiming to get incumbent spectrum users (license holders and primary users) to share their underutilized spectrum with limited number of LSA licensees (secondary users). The sharing will be under well-defined conditions between the incumbent, LSA licensee and regulator to provide predictable Quality of Service (QoS) for all actors involved. LSA is believed to replace the current exclusive spectrum access rights, as the "spectrum crunch" problem increase for every year as new technologies demanding frequency spectrum escalate. So as to have a successful implementation and deployment of LSA, investigation of business scenarios for the actor ecosystem surrounding LSA is necessary. Following, the objectives include:

- Studying the present-day state of LSA, which technologies that are required for the deployment of LSA and how they fit with the current spectrum allocation framework.
- Examine the ecosystem actors surrounding LSA and business benefits for those actors.
- Provide a sustainable business model for LSA. The business model will provide insights about:
    - Who are going to pay for the technological resources necessary to deploy and implement LSA.
    - What the revenue streams attached to the actors when implementing LSA are.
- Provide a strategic SCOC-Analysis to get insights in strengths, opportunities and challenges that arises when deploying LSA.
- Present potential deployment strategies for different ecosystem actors to facilitate for an efficient and reliable transition between present-day spectrum allocation and LSA.

Supervisor: Wantanee Viriyasitavat, IIK

Abstract

Licensed Shared Access (LSA) is a regulatory approach in spectrum sharing which aims to meet the requirements of the high demand after frequency spectrum. Allowing incumbent spectrum users (license holders of the frequency bands) to share their underutilized spectrum with a limited number of LSA licensees (secondary users), LSA guarantees certain Quality of Service (QoS) under pre-defined sharing conditions between them.

There exists numerous works related to the concept of spectrum sharing and LSA. Considering several studies only look at Mobile Network Operators (MNOs) as service providers wanting to use spectrum shared by license holders, there are limitations needed to be challenged.

To ensure a streamlined migration from the traditional exclusive spectrum access to LSA, several aspects have to be examined. This thesis presents the business scenarios for LSA and its surrounding ecosystem. Possible deployment strategies and a business model for LSA will be presented, along with examination of ecosystem actors and corresponding benefits for those actors. Finally, an SCOC-Analysis will be provided for strategic decisions to understand the different strengths, opportunities and challenges for the deployment of LSA.

A business model for LSA is provided by the Osterwalder business model canvas to answer what the cost structures look like and what the revenue streams devoted to LSA are. Furthermore, an strategic SCOC-analysis for LSA is proposed, and several challenges are addressed, including adoption of new technology and cross-border challenges. Lastly, the current state of the development of LSA and the technologies needed are presented along with possible reactions from key ecosystem actors for deployment strategies towards LSA.

Conclusively, in order to assist for the progress of the adoption of LSA, regulators and standardization organizations have to establish compatibility and omnipresent deployment.

Sammendrag

Licensed Shared Access (LSA) er en regulatorisk tilnærming i frekvensdeling som har som mål å tilfredsstille kravene til den høye etterspørselen etter frekvensspekter. Ved å tillate etablerte frekvensbrukere (lisensinnehavere av frekvensbåndene) å dele sine underbrukte frekvensspekter med et begrenset antall tjenesteleverandører (sekundærbrukere), garanterer LSA en viss tjenestekvalitet gitt forhåndsdefinerte betingelser mellom dem.

Det finnes en rekke arbeid relatert til konseptet om frekvensdeling og LSA. Med tanke på at flere studier bare vurderer mobiloperatører som tjenesteleverandører som ønsker å bruke frekvensspekteret som blir delt av lisensinnehavere, finnes det begrensninger som må utfordres.

For å sikre en strømlinjeformet migrering fra tradisjonelle eksklusive frekvenstilganger til LSA, må flere aspekter undersøkes. Denne oppgaven presenterer forretningsscenariene til LSA og det omkringliggende økosystemet. Mulige distribusjonsstrategier og en forretningsmodell for LSA vil bli presentert, sammen med en presentasjon av aktører i økosystemet og tilsvarende forretningsfordeler for disse aktørene. Til slutt vil en SCOC-analyse bli presentert for strategiske beslutninger for å forstå ulike styrker, muligheter og utfordringer rundt LSA.

En forretningsmodell for LSA presenteres med Osterwalder sin forretningsmodell for å se på hvordan kostnadsstrukturen og inntektstrømmene viet til LSA vil se ut. Videre foreslås en strategisk SCOC-analyse for LSA, og flere utfordringer blir diskutert, blant annet adopsjon av ny teknologi og grensekryssende utfordringer mellom ulike land. Til slutt presenteres den nåværende tilstanden for utviklingen av LSA og den nødvendigee teknologien sammen med reaksjoner fra viktige aktører i ækosystemet til ulike distribusjonsstrategier for LSA.

Til slutt, for å bistå med utviklingen av LSA, må reguleringsmyndigheter og standardiseringsorganisasjoner etablere kompatibilitet og tilrettelegge for allestedsnærværende distribusjon.

Preface

This master's thesis was conducted at the Department of Information Security and Communication Technology (IIK) at the Norwegian University of Science and Technology (NTNU) during the spring 2018. The thesis finalizes my master's degree in Communication Technology with specialization in Digital Economics.

I would like to thank my supervisor Wantanee Viriyasitavat for positive and valuable guidance, good discussions and helpful advise during the master's thesis.

I would also like to thank Cathrine Ludviksen for proofreading my thesis and good suggestions on how to make it better.

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List of Acronyms

ADEL Advanced Dynamic spectrum 5G mobile networks Employing LSA.

AIP Administered Incentive Pricing.

ANFR L'Agence Nationale des Fréquences.

API Application Programming Interface.

ASA Authorized Shared Access.

BWA Broadband Wireless Access.

CAPEX Capital Expenditures.

CBRS Citizens Broadband Radio Service.

CEPT European Conference of Postal and Telecommunications Administrations.

CR Cognitive Radios.

DAS Distributed Antenna Systems.

EC European Commission.

ESC Environmental Sensing Capability.

ETSI European Telecommunications Standards Institute.

EU European Union.

FCC Federal Communications Commission.

FS Fixed Services.

FSS Fixed Satellite Services.

GAA General Authorized Access.

GSMA GSM Association.

IMT International Mobile Telecommunications.

IoT Internet of Thing.

LSA Licensed Shared Access.

LSRAI LSA Spectrum Resource Availability Information.

LTE Long Term Evolution.

M2M Machine to machine.

MNO Mobile Network Operator.

MSP Managed Service Provider.

MVNO Mobile Virtual Network Operator.

NEM Network Equipment Manufacturer.

NKOM Nasjonal Kommunikasjonsmyndighet.

NRA National Regulatory Authority.

OA&M Operation, Administration and Management.

OPEX Operational Expenditures.

PAL Priority Access License.

PMSE Programme Making and Special Events.

QoE Quality of Experience.

QoS Quality of Service.

RRM Radio Resource Management.

RRS Reconfigurable Radio Systems.

RSPG Radio Spectrum Policy Group.

SAS Spectrum Access System.

SCOC Strengths, *internal* Challenges, Opportunities and *external* Challenges.

SDR Software Defined Radios.

SWOT Strengths, Weaknesses, Opportunities and Threats.

TC RRS Technical Committee for Reconfigurable Radio Systems.

TVWS TV White Space.

UAV Unmanned Aerial Vehicle.

UE User Equipment.

Chapter 1
Introduction

1.1 Motivation and Research Question

LSA is a proposed approach which aims to increase the economic scale and reduce the cost of doing service. Applying such service over a large geographical area requires high level of cooperation between the different actors involved. Moreover, LSA aims to answer the society's demand after frequency spectrum, as well as increase competition between actors involved. Subsequently, the end-users can be provided with the best user experience. Simultaneously, availability of additional frequency spectrum brings new business opportunities for actors such as MVNOs, MSPs, Content Providers and BWA Providers. To look into these new business opportunities arising from new shared spectrum, will discover the potential of making extended spectrum available through LSA. Furthermore, most European countries have pointed out that long-term incumbent usage have to be preserved. However, measurements on the occupancy of signals on the 2.3 GHz spectrum band [2] show low levels of occupancy of the frequency spectrum. Therefore, a solution such as LSA that aims to provide protection of incumbent spectrum users, as well as to utilize the full potential of spectrum resources, is central in discussions about new spectrum usage.

Papers [3, 4, 5] assume that the ecosystem for LSA will be equivalent to the existing telecommunication ecosystem; with the same actors containing the same relationships between them and identical business models. Statements like these need to be challenged. First, development of new regulatory frameworks is reasoned to lead to new business opportunities, and hence change or modify the surrounding ecosystem. Second, for regulators and investors it is important to recognize new opportunities, challenges and risks for them to decide strategies related to implementation and investment. Consequently, ensuring market awareness is central in providing value for the ecosystem actors, by faster development of new technological solutions. This thesis aims to discuss and answer these areas by analyzing potential ecosystems surrounding LSA, and how they provide business benefits for these ecosystems.

Key research question: ***"What are the business scenarios for the ecosystem surrounding LSA?"***

This question is comprehensive, and can be divided into five more limited questions:

- Who are the actors in the ecosystem?
- What are the business benefits by applying LSA for ecosystem actors?
- How is LSA providing value for the ecosystem, as well as increasing the economy of scale?
- What are the strengths, opportunities and challenges for the deployment of LSA?
- What will be the different deployment strategies for different actors toward LSA?

These questions will be answered by addressing important actors in the ecosystem, discuss business benefits for those actors, modelling a realistic business model, creating a strategic SCOC-analysis to achieve understanding of the opportunities and challenges surrounding LSA and lastly provide deployment strategies for important ecosystem actors.

1.2 Problem Description

Licensed Shared Access (LSA) is a regulatory approach in spectrum sharing which aims to meet the requirements of the high demand after more spectrum. Allowing incumbent spectrum users (license holders and primary users) of the frequency bands (e.g. Military/Defense operations) to share their underutilized spectrum with LSA licensees (secondary users), LSA guarantees certain Quality of Service (QoS) under pre-defined sharing conditions. To ensure a streamlined migration from the traditional exclusive spectrum access to LSA, several aspects have to be examined. This thesis will mainly focus at the business scenarios for LSA and its surrounding ecosystem, while providing the necessary information about the technological background. The problem description has not been considerably changed after the first submission at the beginning of the thesis. From the first submission, a comparison between the telecommunication ecosystem in Norway and other countries was planned to be provided, but because of limited time this have been taken out of the problem description.

1.3 Methodology

The motivation for this project is to analyze business scenarios for the ecosystem that will surround LSA. The concept of business ecosystem was first introduced by James E. Moore in his book *"The death of competition: leadership and strategy in the age of business ecosystems"* [6] in 1996. Moore described the notion of ecosystem to include different economic actors like producers, suppliers and competitors, which deliver goods and services to customers. Therefore, to analyze the ecosystem, identification of the ecosystem actors, as well as their business benefits is central. Furthermore, a business model, an SCOC-analysis for strategic decisions and possible deployment strategies for some key actors will be provided.

1.3.1 The Actor Ecosystem

The actor ecosystem of LSA will be modelled by means of insights from examining LSA and the organizational structure of related and similar approaches. The ecosystem consists of both traditional telecommunication actors and new actors emerging from the new spectrum market LSA is creating. All these actors are presented in chapter 4.

1.3.2 Business Benefits for LSA

Benefits from the deployment of LSA will be represented by each of the ecosystem actors based on relevant literature. To study the business potential of LSA is important to address the different roles of the ecosystem actors and how the different actors relate to each other. Business benefits are going to be discussed according to benefits and corresponding limitations for the actor ecosystem. Conclusively, how this benefits LSA and the spectrum market as a whole. The business benefits of LSA are presented in chapter 5.

1.3.3 Business Model

A realistic business model for LSA will be modelled and presented. By the Osterwalder Business Model Canvas, the business model for LSA and its ecosystem actors will be provided. The model will explain who the key stakeholders are, and who is going to pay for the technology and implementation of such a system. Subsequently, what are the revenue streams devoted to the implementation of Licensed Shared Access for the key stakeholders? The business model is presented in chapter 6.

1.3.4 SCOC-Analysis

An SCOC-analysis prepares for strategic decisions, based on internal strengths and external opportunities; combined with analyses of the implementation of new processes and structures, as well as challenges that need to be considered. The goal of the SCOC-analysis for LSA is to understand the different strengths, opportunities and challenges for both new and well-known ecosystem actors surrounding LSA. The SCOC-analysis is presented in chapter 7.

1.3.5 Deployment Strategies

An analysis of potential deployment strategies for some key ecosystem actors will be presented. To address possible deployment strategies are important for an efficient changeover from the traditional spectrum solutions to the deployment of LSA. Moreover, the current situation and alternatives for solutions will be compared and discussed, as well as how central actors will react to different market scenarios when discussing deployment strategies towards LSA. The deployment strategies will be presented in chapter 8.

1.4 Limitations

Because of limited time, this thesis will primarily focus on the business scenarios of Licensed Shared Access. Since LSA is an implementation that aims to make more spectrum available for different actors and their users, potential customer segments surrounding LSA might be very large groups of people. Subsequently, customer segments may be different across continents and countries.

Even though Licensed Shared Access (LSA) have had some extensive test trials in countries like Finland (see section 8.1.2.1), Italy [7], Spain [8] and France [9], it has not yet been realized by any country. The LSA concept has existed for some years, but still there are uncertainties among the industry concerning different approaches and deployment scenarios. Therefore, assumptions made in this project are based on the current framework of LSA. Following, there are different implementations of LSA subject to different market and regulatory environments.

To limit the scope of this project, the majority of examples in this project may be more applicable to Norway and Europe than other countries and continents.

1.5 Outline

This thesis is divided into several chapters, and the content of each chapter is shortly summarized below.

Chapter 2 presents background information on current spectrum access models and introduces the concept of spectrum sharing and different regulatory approaches.

Moreover, the concept of LSA is introduced according to technological, regulatory and business perspectives.

Chapter 3 provides an overview of related work on the concept of spectrum sharing and specifically LSA that are relevant for this thesis.

Chapter 4 presents the actor ecosystem surrounding LSA, including possible incumbent spectrum users, LSA licensees, industry stakeholders and also LSA licensee customers. Additionally, an explanation of each actor and the reason for them to approach spectrum sharing with LSA.

Chapter 5 presents insights into business benefits and corresponding limitations of LSA for the ecosystem actors presented in chapter 4.

Chapter 6 provides a realistic business model for LSA for key stakeholders by the Osterwalder business model canvas to get insight in e.g. cost structure and revenue streams for LSA.

Chapter 7 presents an SCOC-analysis for LSA in view of both established and new ecosystem actors in order to get a better understanding of different strengths, opportunities and challenges for the deployment of LSA.

Chapter 8 presents the current development situation of LSA and provides potential deployment strategies for some essential ecosystem actors surrounding LSA.

Chapter 9 concludes the work of this thesis and propose recommendations for further work on LSA.

Chapter 2
Background

2.1 The Need for Additional Spectrum

According to Cisco's forecast [10], mobile data traffic is estimated to increase by 600% from 2016 to 2021. Simultaneously, in 2021 there will be 12 billion global mobile connections with a 3-fold increasing average global mobile network speed. In 2018, the Norwegian Communications Authority in Norway (NKOM) presented mobile data traffic numbers from 2017 in Norway [1]. The study shows 161 million gigabytes transferred in 2017, which is an increase of 61 million gigabytes compared to 2016 (see figure 2.1). Conclusively, spectrum usage for the years to come is not sufficient enough to meet this accelerating demand, and deployment of Long Term Evolution (LTE) and future 5G will only make demand for spectrum even higher. Thus, new approaches to solve this issue is needed.

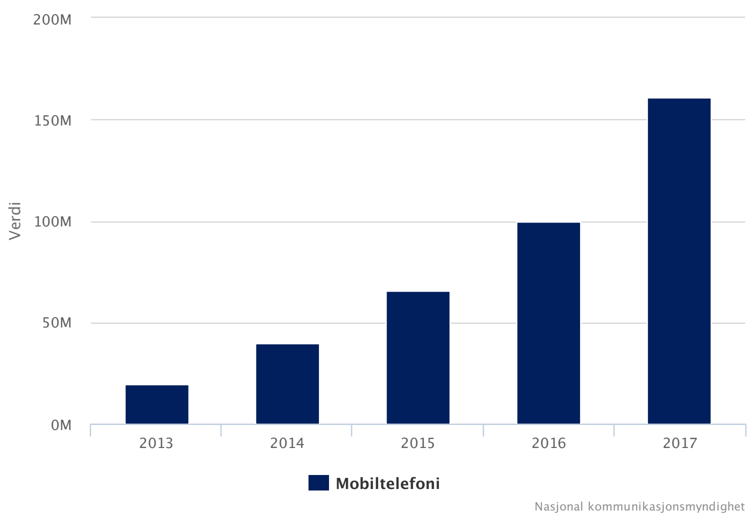

Figure 2.1: *Data traffic numbers in Norway from 2013 to 2017 [1]*

2.2 Traditional Spectrum Access Models

In order to get a better understanding of the development of new spectrum sharing approaches, this section describes traditional spectrum access models and looks at motivation and perspectives for sharing of spectrum.

Traditional spectrum access models are generally based on exclusive spectrum access and license-exempt spectrum access. License-exempt spectrum access is an unregulated model where all actors involved share the use the frequency band without the need of a license. However, there are regulatory constraints such as limitations in power and duty cycles, as well as courtesy rules between the actors for the use of the spectrum [11]. Because of the number of users and devices devoted to the band simultaneously, license-exempt access models cannot guarantee predictable QoS. Exclusive spectrum access with long-term licenses (e.g. 15-20 years) and far-reaching coverage has been the universal spectrum access model for the International Mobile Telecommunications (IMT).

Today, the most used way to make more spectrum available for mobile services are through spectrum auctions. By a market-driven mechanism, huge socioeconomic benefits are created; spectrum auctions have been successful in allocating spectrum since its introduction in 1994. Consequently, assigning spectrum licenses to profit-maximizing companies have led to rapid development of wireless telecommunications. Several advantages lie in exclusive licenses, including providing predictable Quality of Service (QoS) by ensuring that the communication technology will not suffer interference with other bands operated by other technologies and operators. Still, the spectrum licenses are usually allocated to bigger operators with the most money to spend **??**. Thus, it is hard for smaller operators to receive spectrum licenses, and this does not promote for high-degree competition between operators.

However, despite the great success exclusive spectrum access is seeing, the problem of "spectrum crunch" still endures. Subsequently, the industry needs to find inventions in how to access underutilized spectrum. Some only use their spectrum in certain locations, like big cities, while others only use their spectrum at specific times of the year. For example, military services may only use the spectrum in some geographic locations, and the spectrum can be made available to mobile communication services in other parts of the country. Development of new technologies like environmental sensing techniques and interference protection systems, allow multiple services to occupy the same spectrum. However, new regulatory approaches need to be applied to allow more flexible and shared spectrum usage.

2.3 Spectrum Sharing

To meet the requirements of more spectrum, spectrum sharing has the intention to provide spectrum to be used by a secondary user when the primary user is not using or needing it.

Spectrum sharing is defined as:

> *“Spectrum sharing is the simultaneous usage of a specific radio frequency band in a specific geographical area by a number of independent entities, leveraged through mechanisms other than traditional multiple- and random-access techniques.”* [12]

Spectrum sharing approves the use of two or more users to operate and run their services on the same frequency band under well-defined conditions and with sharing rules that will benefit both the primary and secondary user. The concept of spectrum sharing is commonly believed to support the increased demand after mobile data traffic, as well as maintain the users’ requirements after faster data access and higher data speeds. Therein, there have been several regulatory initiatives and technological advancements proposed to support for new spectrum sharing schemes for a more efficient spectrum usage. Improvement in technologies such as Cognitive Radios (CR) and Environmental Sensing Capability (ESC) have been key contributors in the implementation of dynamic access for these spectrum sharing opportunities. However, in order to sufficiently develop a successful dynamic access to shared spectrum, there have to be regulatory conditions to support this new developing technologies. In the last few years, there have been three main regulatory spectrum sharing solutions proposed (see figure 2.2 for high level overview of the three sharing schemes):

- *TV White Space (TVWS)* - A two-tier spectrum sharing scheme that exploits the TV White Space frequency channels. The model consists of primary incumbent users and unlicensed secondary users [13]. Hence, TVWS cannot guarantee for QoS, so this sharing approach is seen as unattractive for operators dependent on high level QoS (e.g. MNOs).

- *Citizens Broadband Radio Service (CBRS)* - A three-tier spectrum sharing scheme proposed in the 3.5 GHz band in the U.S. Also called Spectrum Access System (SAS), CBRS is a complex spectrum sharing scheme that allows for additional spectrum usage on frequency bands that have an existing license holder (incumbent) with both license-based Priority Access License (PAL) users and license-exempt-based General Authorized Access (GAA) users [14].

- *Licensed Shared Access (LSA)* - A two-tier spectrum sharing scheme proposed in the 2.3 GHz band in Europe. The secondary user (LSA licensee) is permitted to use the spectrum band when the primary user (incumbent) is not using or needing it (e.g. at specific locations or at specific times) under well-defined conditions. The primary users maintains their spectrum rights and will have priority access to the spectrum according to sharing rules with the secondary users. The secondary users have to make use of management tools that enable for sharing spectrum with other users in order to prevent interference and maintain high QoS.

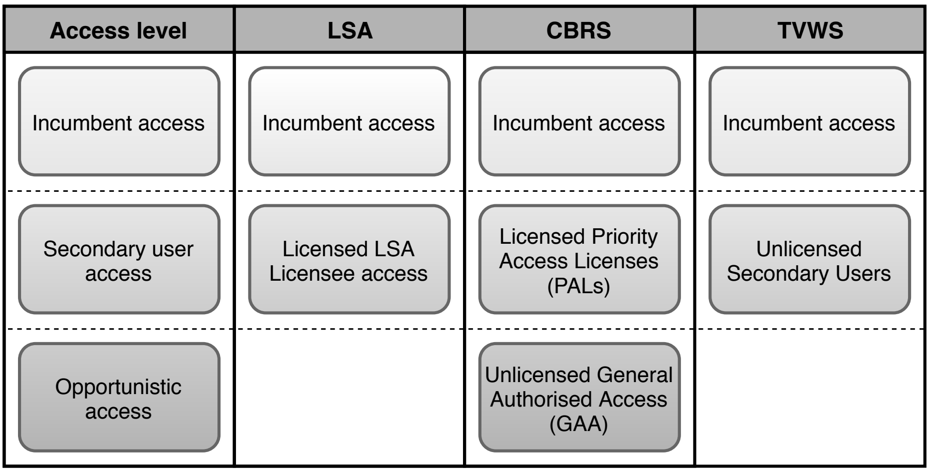

Figure 2.2: *High level overview of LSA, CBRS and TVWS*

As LSA is the most promising spectrum sharing concept in Europe today, LSA will be the focus for this thesis.

The concept of spectrum sharing is not only technical considerations; regulatory and business viewpoints have to be thoroughly considered, as mentioned in [15]. Figure 2.3 highlights the regulatory, business and technological aspects around spectrum sharing. Considering the regulatory aspects, regulators will provide specific criterias for sharing [16]. Moreover, technological features like interference protection in order to protect the incumbent spectrum user have to be satisfied and defined in the sharing framework between the key stakeholders. From the business perspective, it is important to address the business benefits for the key stakeholders. Also, making a realistic business model and discussing opportunities and challenges through an SCOC-analysis are activities crucial for a successful deployment of any spectrum sharing model. Lastly, considering the technological aspects, it is important to develop a beneficial sharing architecture and spectrum management such that the sharing framework can reach economies of scale. Furthermore, to demonstrate spectrum sharing concepts through live trials and testbeds are essential in order to show the regulators the efficiency and usefulness of deployment of spectrum sharing models.

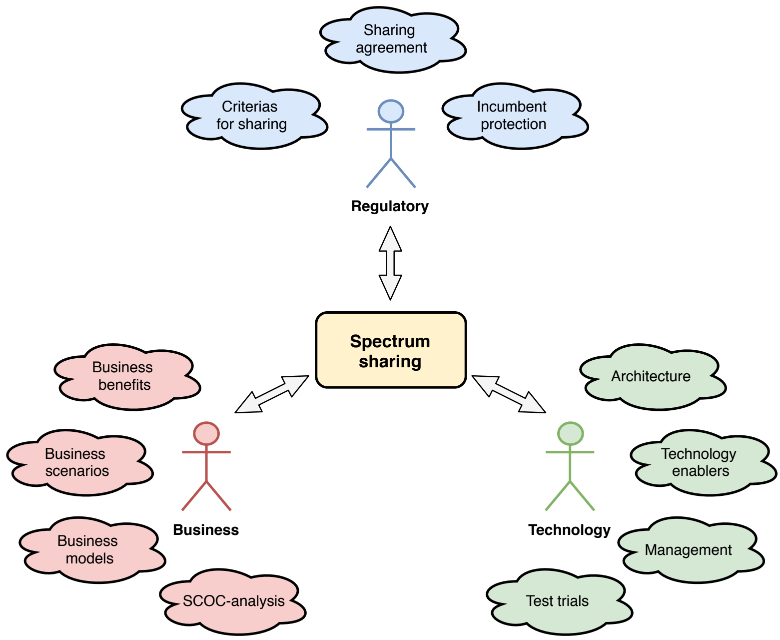

Figure 2.3: *Regulatory, business and technological aspects of spectrum sharing*

2.4 Licensed Shared Access (LSA)

The concept of Licensed Shared Access has been derived from the spectrum sharing initiative Authorized Shared Access (ASA) in order to obtain access to supplementary spectrum for mobile data traffic under a shared access approach. LSA is a regulatory approach in spectrum sharing aiming to provide predictable Quality of Service (QoS) by allowing incumbent spectrum users (primary users and license holders) to share their underutilized spectrum with LSA licensees (secondary users) that can access these spectrum resources under well-defined conditions.

LSA is defined within the framework of the European Union (EU) as:

> *"A regulatory approach aiming to facilitate the introduction of radio communication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users. Under the Licensed Shared Access (LSA) approach, the additional users are authorized to*

> *use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorized users, including incumbents, to provide a certain Quality of Service (QoS)."* [17]

Where actual spectrum is underutilized, LSA provides a new solution for incumbent spectrum users to give spectrum rights to one or more LSA licensees which can use the spectrum under defined conditions. The LSA framework aims at protecting the incumbent users from harmful interference, while at the same time provide predictable QoS for the LSA licensees by exclusive use of the LSA shared spectrum. LSA is based on the incumbent users to freely decide which frequency bands they want to share with LSA licensees (e.g. in specific areas and/or at specific times) [17]. Thus, frequency bands that are frequently used by incumbent users can be left out of the LSA spectrum scheme. Moreover, individual sharing agreements and permissions from national regulatory authorities have to be included in these conditions. The National Regulatory Authority (NRA) will be in charge of the establishment of the sharing agreement between the incumbent user and LSA licensee, as well as being responsible for the distribution of the sharing license to the LSA licensee. Concerning that the number of LSA licensees are limited, benefits relies as specific spectrum bands on a certain location at a specific time, is only authorized to one LSA licensee. Following, the LSA licensee can use the spectrum exclusively with sharing agreements with the incumbent satisfied.

What differentiates LSA from other spectrum sharing schemes is the licensing regime that gives the LSA licensee an individual authorization for access to the spectrum containing their rights and responsibilities towards the incumbent spectrum user. The advantage of this licensing regime is that the sharing rules between the incumbent user and LSA licensee will provide predictable interference protection and QoS for both the incumbent user and LSA licensee. Besides, the incumbent spectrum user will maintain priority access rights to the frequency band, so the incumbent may at all times reclaim the band (or parts of the band) at any time or place [17]. See figure 2.4 for a visual understanding of the sharing framework for LSA.

In the previous section, three different perspectives of spectrum sharing were characterized; regulatory, business and technology perspectives. In the next section, the concept of LSA will be explained and discussed with respect to these three perspectives.

2.4.1 Technological Perspectives

In addition to the existing mobile network architecture, implementation of LSA is expected to be primarily based on two new building blocks; LSA Repository and

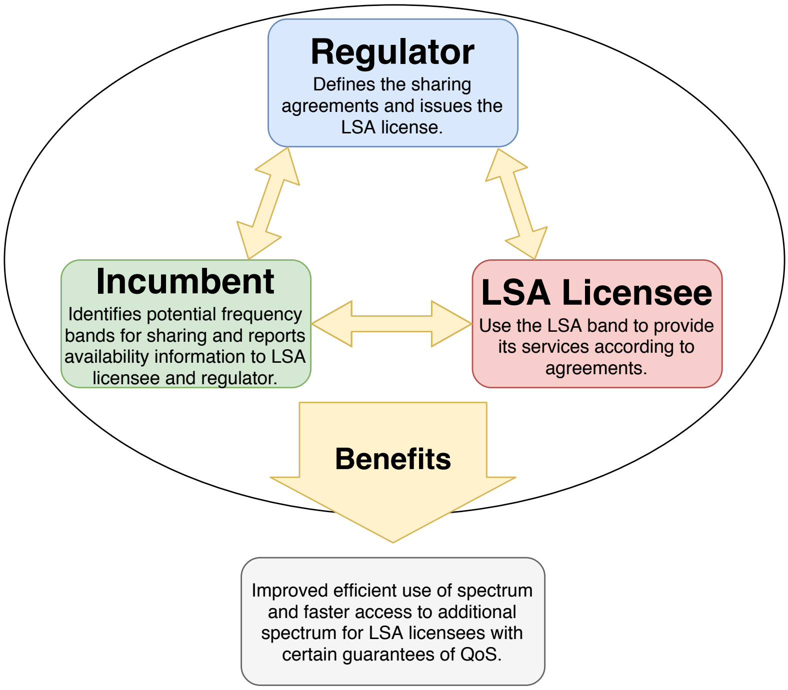

Figure 2.4: *Sharing framework for Licensed Shared Access*

LSA Controller, as explained in [18].

The LSA Repository contains information about the availability and unavailability of LSA spectrum bands. This includes the incumbent user's usage of the frequency band and conditions such as interference protection requirements. Furthermore, the LSA Repository provides the LSA Controller with information about spectrum availability and coordinates this information exchanged between the incumbent and LSA Controller. The LSA Repository may implement different safety features in order to protect or cover the real activity of the incumbent spectrum user [19]. The reason for this is that the incumbent users may not be willing to give up information about their use of the frequency spectrum to the LSA licensees. Especially for activities such as defense operations and emergency services, there are good reasons for the incumbent users' desire to hide such information from others. The LSA Repository can be managed by the regulator, incumbent user or an independent third-party actor, and there can be one or more LSA Repositories in each country.

Next, the LSA Controller takes control of computation of spectrum availability based on the sharing agreement and information received from the LSA Repository. The connection between the LSA Controller and LSA Repository are protected by a secure and reliable interface [19]. The LSA Controller can be managed from either the regulator, incumbent user, LSA licensee or a trusted third-party actor, and there can be one or more LSA Controllers in each country. Furthermore, one LSA Controller can connect to one or more LSA Repositories, as well as one or more LSA spectrum networks.

Along with the LSA Repository and LSA Controller, the LSA licensee side of the network needs network Operation, Administration and Management (OA&M) [19]. For the LSA licensees, the network OA&M carries out the actual management of LSA spectrum bands. Moreover, the OA&M receives information on LSA spectrum availability from the LSA Controller and translates this information into specific commands (e.g. spectrum availability, QoS conditions and data speeds) which are transmitted to the base stations on the LSA licensee side of the network. With this information, the base stations can allow User Equipment (UE) devices to access the LSA spectrum or to smoothly handover the UE devices to other frequency bands based on these commands. An overview of the relationships between the LSA Repository, LSA Controller and network OA&M can be seen in figure 2.5.

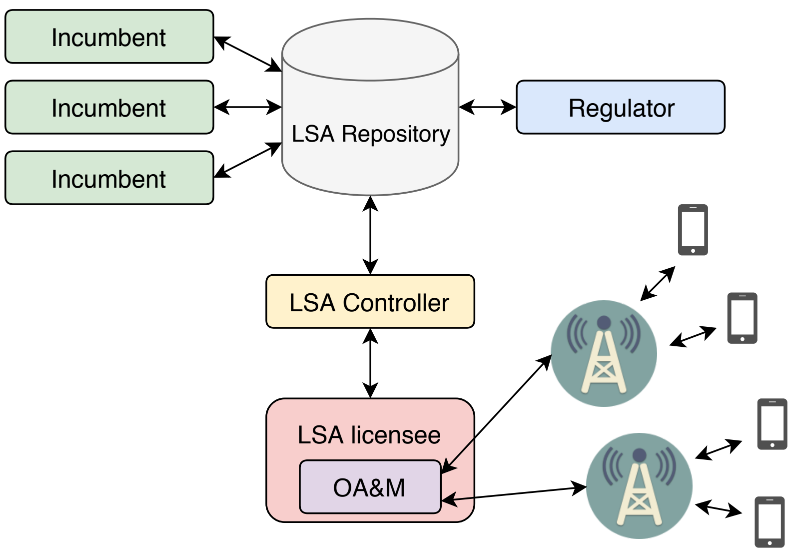

Figure 2.5: *Overview of relationships between LSA Repository, LSA Controller and OA&M*

In addition to the these three components, the ADEL project [20] introduces techniques to support for more dynamic spectrum access such as presentation of Radio Resource Management (RRM) techniques and Environmental Sensing Capability in order to provide increased QoS and improvement in overall spectrum utilization.

These new components will allow for detection of radio environmental changes (e.g. wind, snow, rain, buildings etc.) and make adjustments according to these changes possibly caused by either the incumbent spectrum user or LSA licensee. See [20] for detailed explanations of these functional components proposed by the ADEL project.

Considering the UE devices, no additional modifications other than support for new frequency bands are currently needed.

2.4.2 Regulatory and Standardization Perspectives

When it comes to the regulatory aspects related to LSA, the work done by standardization organizations in Europe have at this point mainly been focused on the 2.3 GHz frequency band for LSA deployment. Traditionally, only MNOs have been considered as LSA licensees for this band, while incumbent users will be different from one country to another. However, the ADEL project [20] foresees other LSA licensees different from MNOs indicated by regulatory activities and LSA opportunities. Reducing entry barriers to new additional LSA band will open up for new actors, such as Mobile Virtual Network Operators (MVNOs), Managed Service Providers (MSPs) and Content Providers to receive spectrum licenses. Moreover, the ADEL project suggests LSA to be implemented in other underutilized frequency bands in addition to the already proposed 2.3 GHz band (e.g. the 3.5 GHz band). These frequency bands should have the potential of spectrum harmonization across Europe to support for higher QoS, as well as supporting new technologies like 5G networks.

The deployment of LSA in a country is up to the National Regulatory Authority (NRA) in each country (e.g. NKOM in Norway). However, in order to get a harmonized approach across countries in Europe, there is need for a harmonized framework between countries. To accomplish harmonized LSA spectrum, different standardization organizations (e.g. ETSI, CEPT and EC) have been working on the LSA concept.

The concept of licensed shared usage of spectrum was first introduced by the Authorized Shared Access (ASA) in the framework of the European Conference of Postal and Telecommunications Administrations (CEPT) in 2012 [21]. Following after, the European Commission's (EC) Radio Spectrum Policy Group (RSPG) introduced the concept of LSA, as well as developed the generalized definition of LSA [17]. Subsequently, the EC delivered a standardization mandate to the European Telecommunications Standards Institute (ETSI) [22] in order for them to develop technical requirements on Reconfigurable Radio Systems (RRS) for operation in LSA bands. RRS technologies such as SDR and Cognitive Radios (CR) have been examined in areas such as military, public safety and commercial areas. This standardization mandate issued by the EC recognizes opportunities and challenges where a standardized approach should allow for RRS operations in Europe. Moreover, ETSI has developed the system architecture for LSA relative to telecommunication services in the 2.3 GHz band as documented in [23]. Furthermore, in document [24], ETSI aimed at allowing mobile access in CEPT countries where access to the LSA band, but because of incumbent spectrum usage, access cannot be provided without some constraints. [23] was developed based on [25], which addressed different system requirements for LSA. Based on both system architecture as defined in [23] and system requirements as defined in [25], [26] defines the protocol interface between the LSA Controller and LSA Repository and the consecutive LSA Spectrum Resource Availability Information (LSRAI). This document was approved by the Reconfigurable Radio Systems (RRS) within ETSI in 2017, and the three-stage document [26], including [23], [25], [24], carries out the first delivery of technical specifications in LSA.

In addition to the delivery of standardization mandate to the ETSI, the EC also delivered a regulation mandate to the CEPT [27]. CEPT responded to this regulation mandate by handing over an overview of the several incumbent services in different countries across Europe [28]. Moreover, CEPT has developed regulatory and technical requirements for the LSA framework between mobile communications and the most frequent incumbent users in the 2.3 GHz band [29]. More recently, the EC issued another regulation mandate to the CEPT [30] that delivered harmonized technical requirements and sharing terms and conditions applicable for the next generation 5G networks. CEPT has delivery date in June 2018 to respond to this mandate from the EC.

Finally, based on research done by CEPT and ETSI, the EC will present harmonized conditions for spectrum usage in the 2.3 GHz frequency band. The framework for LSA in Europe is ready for deployment in the 2.3 GHz band, yet no countries have deployed LSA. Nevertheless, several test trials of LSA in the 2.3 GHz band have been done or is ongoing in order to show the usefulness and efficiency of LSA spectrum access.

2.4.3 Business Perspectives

In order to successfully develop a feasible spectrum sharing model, it is necessary to get a good understanding of the business scenarios surrounding the concept of spectrum sharing. For the incumbent spectrum users, spectrum sharing contributes to possibly improve the incumbent users rights to the frequency band in the long-run. This is because they allow additional secondary users to use their band while the incumbent users at the same time carry on with their existing businesses. Furthermore, the incumbent spectrum users can receive additional income from sharing (by leasing out to secondary users), as well as make use of the secondary users' infrastructure and hence save in infrastructure investments. For the secondary users, spectrum sharing can contribute to lower license costs, introduce new business opportunities that result in extended revenue streams and the possibility to increase their customers' Quality of Experience (QoE) [31].

The business ecosystem surrounding LSA aims attention at three key actors; incumbent spectrum users, LSA licensees and regulators. The incumbent users can either be governmental (e.g. military, defense and emergency services) or non-governmental (e.g. MNOs and PMSE applications). Moreover, LSA licensees are differentiated in two types; MNOs and other LSA licensees such as MVNOs, MSPs and Content Providers. The goal of this thesis is to examine and discuss the business scenarios for these ecosystem actors considering the implementation of LSA. Therefore, the business perspectives for LSA will be presented in following chapters:

- Essential **business benefits** for LSA considering the ecosystem actors are presented in chapter 5.
- A **business model** for LSA is presented in chapter 6.
- An **SCOC-analysis** is presented in chapter 7.
- Different **deployment strategies** towards LSA for some central ecosystem actors are presented in chapter 8.

Chapter 3
Related Work

How to get the spectrum frequency bands more effective and meet the requirements for spectrum demand have been the objective for many research studies the last years. Most of these studies circles around spectrum sharing, as the bottleneck relies in not enough spectrum available for services. Therefore, this chapter will present the related work to this thesis.

To achieve understanding about the necessary concepts, regulatory aspects and market perspectives, background material was discovered through the use of search engines like IEEE Xplore [1] and Google Scholar [2].

Presentation of the sharing approach of Licensed Shared Access (LSA) and its benefits as a complementary approach are presented in [19]. This paper includes LSA stakeholders and responsibilities, market perspectives and legal and regulatory considerations. Moreover, [11] introduces LSA for LTE-advanced networks. This paper presents key elements in the LSA architecture, including the LSA Repository and LSA Controller. The ADEL project [20] introduces new techniques to the LSA architecture, namely Environmental Sensing Capability (ESC) and Radio Resource Management (RRM).

Some business benefits approaching LSA for LTE usage concerning some key stakeholders are presented in [3]. Regulatory solutions for spectrum sharing are also presented in [3], including a regulatory framework for use of the radio spectrum. [5] presents benefits of applying LSA in the 2.3 GHz band for incumbent users, regulators and dominant and challenger MNOs. Moreover, [15] presents opportunities for MNOs for spectrum sharing businesses, and concludes with different opportunities and challenges for dominating and challenger MNOs. Additionally, [31] presents spectrum sharing benefits and opportunities for the CBRS approach in the 3.5 GHz band in the U.S. This paper focuses on business frameworks of CBRS, as well as

[1] ieeexplore.ieee.org
[2] scholar.google.com

recommendations for a successful implementation of CBRS in the U.S. Business scenarios for similar approaches like CBRS are aspects to consider when developing business scenarios for LSA. However, these papers only consider Mobile Network Operators (MNOs) as LSA licensees, which will be expanded to include additional LSA licensee actors that will arise with a new spectrum market in this thesis. Some key challenges for LSA in the future are presented in [32], and concludes that these challenges will not be of major concerns, but rather something to be beware of for future development of LSA. An SWOT-analysis for the TVWS approach is presented in [33]. TVWS has many similar characteristics as LSA, and several aspects of spectrum sharing with TVWS can be applied to LSA.

A proposed business model for MNOs in LSA is presented in [4]. However, business model considerations have to be extended to include other LSA licensees and key stakeholders; business models will look differently depending on the different types of stakeholders. Further, [34] identifies and analyzes potential business models and investment options for both established and new actors in the ecosystem surrounding LSA. According to this paper, situations where new actors need to make huge investments in infrastructure do not look particularly promising. Additionally, [34] provides interviews with industry leaders about LSA deployment scenarios, and what is important for a successful implementation of LSA in Europe. With respect to the incumbent spectrum users, [35] presents different business model scenarios for them towards LSA. The paper derives two strategies for the incumbent users to approach LSA: aggressive or defensive. The evaluation showed that a defensive strategy may be more preferred for incumbent spectrum users. However, in order for them to seek new business opportunities, an aggressive approach may be preferable despite the risks. Regarding similar regulatory spectrum sharing approaches, a business model for TVWS is presented in [36]. The business model is modelled by means of the support of LTE services.

Potential economic benefits of spectrum sharing are presented in [5] and [37]. However, these two reports conclude differently. While [5] concludes with the economic benefits of spectrum sharing to be significantly lower than for exclusive spectrum access, [37] estimates significant net benefits of LSA in the 2.3 GHz band. [5] also includes possible risks and uncertainties related to spectrum sharing with LSA in the 2.3 GHz band in Europe and sharing with CBRS in the 3.5 GHz band in the U.S.

Some potential incumbent users suited to share their spectrum are presented in [17, 29, 38]. Further, characteristics of possible incumbent spectrum users are specified in [5].

Chapter 4
The Actor Ecosystem

This chapter will present an overview of the actor ecosystem that will surround LSA. Figure 4.1 highlights these actors corresponding to the incumbent spectrum user domain, regulatory and standardization domain and the LSA licensee domain. The ecosystem actors presented in this chapter will be used as the foundation for the following chapters. The different actors participating in the LSA sharing concept have been classified into five different categories:

- Incumbent spectrum users
- LSA licensees
- Regulators
- Industry stakeholders
- LSA licensee customers

The different actors will be described according to their businesses and the reason why they will be involved in a new spectrum market with LSA.

4.1 Incumbent Spectrum Users

From the definition of LSA, the incumbent spectrum users refer to the current holder of spectrum usage rights [17]. The incumbent users can be divided into two types: governmental and non-governmental entities [39]. Firstly, governmental incumbent users have the access rights to spectrum bands and can operate with their own businesses. However, they do not have exclusive individual spectrum usage rights as their access usually is on a shared basis which are generally inspected by the regulator. Examples of governmental users are military/defense operations,

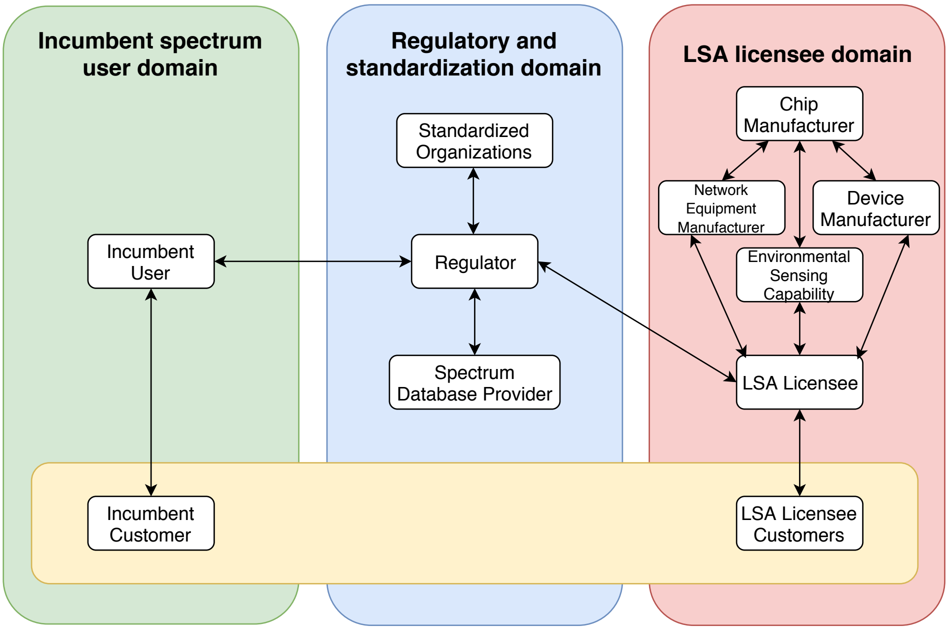

Figure 4.1: *The actor ecosystem surrounding LSA*

aeronautical telemetry and Fixed Satellite Services (FSS). On the other hand, non-governmental incumbent users refer to private entities that have acquired individual spectrum usage rights by exclusive licenses received from the regulator. Examples of non-governmental incumbent users are Mobile Network Operators (MNOs) and PMSE applications. With the introduction of LSA, the main difference between governmental and non-governmental incumbent users is that it will be less complicated to introduce new additional LSA licensees to share with governmental incumbent users. The reason for this is, as mentioned above, that governmental incumbent users do not have individual spectrum usage rights and may be familiarized with access to the frequency bands on a shared basis. The exclusive licenses possessed by the non-governmental incumbent users allow them to keep exclusive access until their spectrum licenses terminate. As a consequence, to get a governmental incumbent user to share their spectrum with LSA licensees may be the best way to make available additional spectrum with the LSA approach. Furthermore, [17] states that the LSA approach may be more suitable when the incumbent spectrum user and LSA licensee are of different types.

In the next subsections, some potential incumbent spectrum users (both governmental and non-governmental) will be presented.

4.1.1 Mobile Network Operators (MNOs)

Assuming that the MNO has underutilized frequency spectrum, then the MNO can share this band with other actors. They can either share horizontally with other MNOs/MVNOs or share vertically with other actors and industries (e.g. MSPs and Content Providers). Opportunities in the scenario with horizontal sharing in the event of increasing mobile broadband consists of already established market mechanisms in which they can sell and buy spectrum capacity. A sharing approach like this have turned out to be successful and has been quite efficient compared to the complexity and cost of designing, building and running side-by-side mobile networks.

Moreover, opportunities in vertical sharing where the MNO share their frequency spectrum with non-MNOs are contrary to the improvement of the availability of spectrum for the shortage of spectrum capacity. This is because the amount of spectrum in the MNOs possession will be reduced. However, MNOs are reasoned to be generally more efficient in the usage of spectrum relative to other spectrum users (e.g. governmental users) [5]. Therefore, they may assume the role to provide frequency spectrum to others through sharing as a less tempting solution.

4.1.2 Programme Making and Special Events (PMSE)

Programme Making and Special Events (PMSE) includes the production of programs to be broadcasted, production of movies, presentations, advertising or audio/video recordings [40]. It also includes production of e.g. sporting events that are available to the public. PMSE is also termed as Service Ancillary to Programme-Making (SAP) and Service Ancillary to Broadcasting (SAB). PMSE services are events that are limited in time, usually during time-periods between one day and several weeks, and takes place at specific geographical locations. Examples include cultural, sporting and entertainment events and also music festivals. In Norway, several frequencies are set for this type of PMSE applications, including wireless cameras (e.g. 2327 MHz and 2390 MHz).

PMSE applications in the 2.3 GHz band in Europe are mostly related to video links and wireless cameras [41]. PMSE applications can act as incumbent spectrum users by coexisting with LSA licensees with exclusion and protection zones where and when their current PMSE applications are active. In Finland, an extensive trial of LSA has taken place with PMSE applications as the incumbent spectrum user (see section 8.1.2.1).

4.1.3 Aeronautical Telemetry

Aeronautical telemetry activities are mainly used for testing of both manned and unmanned flying vehicles appearing in aeronautics and astronautics. The aeronautical telemetry system consists of ground stations and airborne stations (flying vehicles, e.g. airplanes and UAVs). Telecommunication signals are transmitted from the ground stations to the airborne stations in specific frequency bands as described in [42] (2.3 GHz band). As these activities contribute to security tests, aeronautical telemetry operations are making the safety of flying vehicles relying upon the accuracy of real-time information acknowledged. Dependent on national conditions, it is estimated that this transmitted information will require high integrity protection (e.g. 95%). As described in [28], several different criterias have to be recognized in order to support for aeronautical telemetry as incumbent spectrum users in LSA:

- Geographical locations of the aeronautical telemetry activities. The telemetry ground stations are generally located in fixed locations.
- The path of the airborne stations. These areas of usage are usually acknowledged beforehand.
- Frequency bands that need protection against interference for the LSA licensees. This can be solved by the definition of exclusion and/or protection zones.
- At which specific times or periods the LSA licensees are not permitted to use parts or all of the frequency bands.

With these criterias satisfied, there are opportunities for aeronautical telemetry to act as an incumbent spectrum user and share their spectrum bands with LSA licensees.

4.1.4 Fixed Services (FS) / Fixed Satellite Services (FSS)

Fixed Services (FS) is a fixed radiocommunication link between particularized stations in a telecommunication network [43]. Considering the nature of FS applications, protection of the short length and directivity of the radiocommunication links is reasonably straightforward. Still, the precise geographical location of FS applications may be held private. Fixed Satellite Services (FSS) have characteristics that can be suitable for an LSA incumbent spectrum user. FSS is defined as radio communication services between different ground earth stations usually fixed to specific geographical locations.

Because of the secrecy of geographical locations of FS applications, these locations cannot be stored prior to usage in the spectrum database [43]. Hence, with an FS incumbent spectrum user, protection from harmful interference will need to be solved by environmental sensing techniques. As FS/FSS applications are allocated frequencies (e.g. 3.4 GHz to 3.6 GHz in Norway [1]) which are suitable for 5G

[1] frekvens.nkom.no

communications, FS/FSS applications can be important incumbent spectrum users for LSA deployment especially for 5G services.

4.2 LSA Licensees

LSA licensees are new users in the LSA spectrum scheme that will share spectrum with incumbent spectrum users under well-defined conditions. By utilizing LSA spectrum, LSA licensees can use the spectrum resources at specific times or at specific locations where the incumbent users are not using or needing the frequency bands. For an LSA licensee to move from existing licenses to shared licenses will require cautious considerations. Moreover, the LSA licensees will have a central role in identifying and recognizing sharing possibilities, as well as to make and receive suggestions and negotiate terms and conditions about the sharing agreement with the regulator and/or incumbent user. Eventually, they will make a bid for a LSA license to the regulator based on the sharing agreement negotiated with the regulator and incumbent spectrum user.

4.2.1 Mobile Network Operators (MNOs)

In a world where limited spectrum is a problem, MNOs have to deal with the dilemma of unlimited consumer demand after mobile data. The more bandwidth the MNOs provide, the more data the consumers consume. Together with high competition among MNOs and MVNOs, this is a complex problem to solve for the MNOs. When spectrum becomes available in traditional spectrum auctions, they come with a high price. For the MNOs, gaining access to these shared bands can result in economy of scales with minimal changes to the existing infrastructure [5]. LSA will provide a shared spectrum to reduce license fees, as well as adding more spectrum capacity whenever and wherever it is needed.

Vertical sharing where an non-MNO share their spectrum band with a MNO represent the largest opportunity to increase the mobile spectrum capacity. Regulators draw attention to these non-MNOs to conclude the shortage after mobile spectrum. For non-MNOs with underutilized spectrum bands, sharing of these bands can create possibilities to take the edge of spectrum shortfall. Hence, the spectrum efficiency becomes better and will produce a better economic and social benefit served by the incumbent spectrum users [5].

4.2.2 Mobile Virtual Network Operators (MVNOs)

Traditionally, Mobile Virtual Network Operators (MVNOs) provide their mobile services to their end-users by buying spectrum capacity from MNOs. With the introduction of LSA, the MVNOs can buy capacity from other LSA licensees. This will reduce their costs related to the renting of frequency spectrum as a result of more competition and more spectrum available. Moreover, LSA opens for new business opportunities for the MVNOs.

4.2.3 Content Providers

Content and service providers like Google and Microsoft are looking for ways to make use of frequency spectrum to support their services (e.g. Internet of Thing). Microsoft has tested free Wi-Fi for people in Glasgow with the TVWS approach [44]. Moreover, they are checking out the opportunity to use TVWS for the use of sensors that collects environmental data (e.g. weather data), such that this information can be shown real-time on a map publicly available. Google have demonstrated a concept in London Zoo, where they put out cameras and radios in the enclosures of tortoises, otters and meerkats [45]. The content from these cameras and radios were transmitted to YouTube via Google's spectrum database to prevent interference. Not only for the public to enjoy wildlife in real-time, but it is also an important tool for zoologists to observe and understand the different species' behaviour. These approaches can be the first steps towards the development of smart cities, and the potential to give huge socioeconomic benefits. This is a market where LSA have to promote itself, such that providers like Google and Microsoft can use shared LSA bands to provide their services.

4.2.4 Managed Service Providers (MSPs)

Managed Service Providers (MSPs) usually develop themselves in vertical markets with Premise Owners such as hospitals, university campuses and sporting venues. These Premise Owners usually have a business open for the public that needs to be operator neutral. Solutions based on Distributed Antenna Systems (DAS) have been successful in providing network for Premise Owners. However, deployment of DAS solutions are quite expensive, particularly for smaller premise customers. The deployment of LSA can put on the market new openings for the MSPs to deliver high-speed operator-neutral mobile broadband solutions for premise owners both indoor and outdoor. Both at the same ease and cost as deploying their own Wi-Fi network.

4.2.5 Cable Operators

Cable Operators are searching for new opportunities to reach their customers when they are not present at their home or office. Cable Operators have been focusing on their investment in Wi-Fi together with partnership with a MVNO to complement with cellular services. However, Wi-Fi uses unlicensed spectrum bands, where data capacity and speed is threatened as more access points are set out. Moreover, their relationship with MVNOs have turned out to be challenging since they are dependent on a network they do not have the control over.

4.2.6 Broadband Wireless Access (BWA) Providers

In areas where fiber and cable network solutions are costly and not cost-efficient, Broadband Wireless Access (BWA) Providers provide fixed wireless solutions. In underserved communities and areas, they look for new opportunities to serve these markets. With the LSA approach, the BWA Providers can make investments in the network to get a more reliable and inexpensive broadband service for these rural and suburban markets.

4.3 Regulators

The national regulatory authorities in each country have an important role in the establishment of LSA. The regulator will perform several tasks, including promoting discussions about the possibilities of LSA, defining the sharing framework for LSA, provide a fair licensing process and perform issuing of licenses [17]. In Norway, the regulator that will perform these tasks is Nasjonal Kommunikasjonsmyndighet (NKOM) [2].

- *Promote discussions about LSA possibilities* - One important task the NRA will have to do is to promote discussions about the possibilities of LSA. These discussions can be based on input, suggestions and technical studies from incumbents and LSA licensees.
- *Define the sharing framework for LSA* - Definition of the spectrum parameters related to the LSA framework is a central task for the NRA in order to get an efficient use of the new shared band. The framework also has to protect the incumbent users by contribute with positive assurance for their service. Moreover, for the LSA licensees, it is important to offer the needed possibilities for them to join a shared band. Hence, the NRA should set parameters for the sharing framework such that the LSA licensees get the appropriate level of Quality of Service (QoS) to their end-users. Through mutual discussions, incumbent users and LSA licensees can together with the NRA develop a sharing framework.
- *Provide a fair and cost-effective licensing process* - The regulator will make sure that LSA spectrum will be allocated in a fair and transparent conduct in consonance with the sharing framework defined in advance. The regulator

[2] nkom.no

will also have to consider the national situation and the market demand when allocating LSA frequency spectrum.

- *Issuing of LSA licenses* - Finally, after providing a fair licensing process for LSA spectrum, the regulator has to issue the LSA licenses.

4.4 Industry Stakeholders

To involve industry stakeholders in the LSA development, is necessary for a successful implementation of LSA; both in terms of standardization and technology. Several actors belong to this category, including Network Equipment Manufacturers (NEMs), Device Manufacturers, Chip Manufacturers, Standardization Organizations, Spectrum Database Providers and Environmental Sensing Capability (ESC) Operators.

4.4.1 Network Equipment Manufacturers (NEMs)

Network Equipment Manufacturers (NEMs) are companies that sell network equipment and network management to service providers such as MNOs and Premise Owners. The NEMs will be responsible for distribution of the required equipment necessary to run LSA operation, and can distribute the equipment to Device Manufacturers or to LSA licensees.

NEMs experience new competition (e.g. MSPs) because of the growing demand after mobile network [46]. For example, when it comes to management and hosted services, NEMs get competition from new entrants such as content providers like Google. Moreover, because of increased standardization of network equipment, there are more competition in providing network equipment. Additionally, service providers like MNOs are perceiving to lower their OPEX and CAPEX costs due to profitability concerns, which will challenge the NEMs margins. With the introduction of spectrum sharing with LSA, this opens for new business opportunities for NEMs in order to increase their margins and profitability [3].

The NEMs will have an important role considering a successful deployment of LSA. Firstly, the NEMs will have the power to determine the network equipment costs. Secondly, NEMs will gain the opportunity to provide more network equipment to new LSA licensee users, as well as competing with other actors in providing network management. Furthermore, NEMs can also try to utilize additional spectrum made available with LSA, and buy LSA licenses to provide their services in a frequency band which they have access to. However, this depends on standardization standings and the adoption of LSA in the spectrum market.

4.4.2 Device Manufacturers

The Device Manufacturers are responsible for the development of devices which will use LSA spectrum frequencies to provide communication services to the end-users. With reference to the NEMs, the Device Manufacturers will also have an important role when it comes to a successful deployment of LSA; the Device Manufacturers can choose whether or not they want to participate in the different development stages of LSA. Examples are promoting standardization activities, being an early adopter of LSA and support research done on the concept of LSA. Finally, the Device Manufacturers will eventually provide the best product at the lowest possible cost.

4.4.3 Chip Manufacturers

The Chip Manufacturers will provide both the Device Manufacturers and NEMs with chips. With standardized technology in place and a sufficient market demand, the Chip Manufacturers will benefit from selling additional chips to other stakeholders. In the U.S., big Chip Manufacturers (Qualcomm and Intel) together with Original Equipment Manufacturers (e.g. Ericsson and Nokia) have implied support for spectrum sharing with CBRS in the 3.5 GHz frequency band [31].

4.4.4 Standardized Organizations

The standardized organizations have an important role in the identification of frequency bands suitable for LSA, as well as recognizing areas where there exists opportunities for additional spectrum usage (e.g. densely populated areas). Moreover, it is important for them to study the potential and possibilities around the implementation of LSA and determine the harmonized circumstances for sharing. The various standardized organizations will have different responsibilities when it comes to the implementation of LSA [17]:

- *CEPT* - European Conference of Postal and Telecommunications Administrations builds the technological foundation for sharing between the incumbent users and LSA licensees. This includes identification of suitable LSA bands and spectrum plans for these LSA bands together with guidelines for interference protection for actors running their services in the same band.
- *ETSI* - European Telecommunications Standards Institute aims attention at the standardization activities in order to make sure that harmonized principles meet the regulatory conditions agreed upon. ETSI is currently developing the 2.3 GHz band for LSA use in Europe.
- *EC* - The role of the European Commission includes to define a regulatory framework for LSA that contains harmonization of the technological circumstances. For the administration of additional technological and regulatory

aspects concerning interference protection for the incumbent, this is handed over by the EC to other administration entities.

4.4.5 Spectrum Database Providers

The spectrum database providers take care of frequency spectrum access management with centralized spectrum databases. They provide solutions that support spectrum sharing by following and tracking the incumbent user's movements both geographically and time-based. Correspondingly, the database can authorize or deauthorize spectrum access for the LSA licensee devices. Before they need spectrum access, the LSA licensees' devices will have to ask the spectrum database in order to receive spectrum access rights. In the U.S., the FCC has developed a spectrum database in the TV White Space spectrum where unlicensed users can get access when the frequency spectrum is not used by the licensed TV broadcasters [47]. Moreover, Google is currently working together with industry leaders and regulators on a spectrum database in order to make more spectrum available [48]. The Google spectrum database [3] has been approved by the FCC and is operational for devices in the TV White Space frequency bands. Furthermore, Device Manufacturers can use the API provided to recognize and use available TV White Space spectrum. Google has currently deployed the spectrum database in the U.S., but is planning to expand to additional countries in the years to come.

4.4.6 Environmental Sensing Capability (ESC) Operators

The Environmental Sensing Capability (ESC) operators will provide networks consisting of sensors that detect the occupancy of signals from the different services existing in the same LSA band. This sensing capability is important to protect the incumbent users from interference, as well as LSA licensees from other licensees offering other services in the same band. The ESC operators have also the capability to protect the incumbent users in protection and exclusion zones (e.g. areas they need their spectrum at all times without any interference) [31]. Operators capable of offering environmental sensing capabilities are e.g. companies like Google and Nokia [31].

4.5 LSA Licensee Customers

The LSA licensee customers are the customer segments which the LSA licensees want to reach and serve. In this section, two LSA licensee customer groups will be presented; the mobile industry customers and premise owners.

[3] google.com/get/spectrumdatabase/

4.5.1 Mobile Industry Customers

While the mobile industry customers are not directly participating in the sharing agreements between the regulator, incumbents and LSA licensees, they have a central role in the contribution of a successful spectrum sharing scheme. By being an experienced customer, they reward the LSA licensees that provides the best service and punish those that does not satisfy their requirements.

4.5.2 Premise Owners

Premise Owners are new LSA licensee customers that can be interested in working together with other actors (e.g. MSPs) providing an extensive solution in order to provide connectivity to their end-users. Premise Owners can be either public or private entities, including hospitals, hotels, university campuses and sporting venues to mention a few. For the Premise Owners to provide their services by this the LSA approach will allow them to have direct attention to their core businesses. Additionally, the Premise Owners will benefit from economic profit by buying and using LSA bands instead of costly exclusive access bands. As an example, a test trial of spectrum sharing with CBRS on a race track in Las Vegas has been demonstrated (see section 8.1.2.2).

Chapter 5
Business Benefits of LSA

The previous chapter introduced important ecosystem actors participating in the LSA sharing concept. This chapter will provide insights and perceptions of the business benefits of implementation of LSA for each ecosystem actor. A report done by Plum Consulting for Ericsson, NSN and Qualcomm [37], presents significant net benefits for LSA with harmonized spectrum in the 2.3 GHz frequency band for mobile communication networks. The report concludes that the costs of making additional spectrum available through LSA are reasonably low, and the estimated financial worth of cost savings remain between €6.5-€22 billion. Following, in order to make LSA a successful approach in providing frequency access, the sharing framework between different stakeholders should benefit all involved ecosystem actors. For that reason, this chapter evaluates the business benefits for the different ecosystem actors as presented in chapter 4.

5.1 Incumbent Spectrum Users

Figure 5.1 presents the key business benefits and corresponding limitations for the incumbent spectrum users with the implementation of LSA. First, the LSA concept offers the incumbent spectrum users the opportunity to maximize the value of their own frequency spectrum. However, they oblige to spectrum terms and conditions established by the regulator; the incumbent user's spectrum arrangement will be dependant on the regulator. The business benefits for the incumbent users can vary based on the type of the incumbent spectrum users (e.g. governmental or non-governmental) and specific national circumstances. Moreover, by discovering underutilized frequency bands and be willing to share them with other parties, the incumbent users can get additional income by license fees from the LSA licensees. Other incentives can also be provided to the incumbent spectrum users, for example access to the LSA licensees' services and infrastructure (see section 8.2 about incentives for sharing). In order to protect the incumbent users from harmful interference, rules and conditions for sharing with the LSA licensees and regulators are essential.

For the incumbent spectrum users, it is important to get a good position in the negotiation of these sharing rules and conditions in order to protect their services and businesses. Additionally, the incumbent users want the ability to claim their frequency bands back (if this is agreed upon in the sharing agreement). What is more, this is a business scenario they will have to consider concerning whether they want to share their spectrum bands and get compensation from doing this or if they are better off by utilizing their spectrum bands themselves. Lastly, for the incumbent users to be willing to share their frequency bands with others, spectrum refarming negotiations may be postponed or put aside by the regulator. Hence, the LSA concept will in this scenario benefit the incumbent spectrum users, such that they won't risk the chance of losing their spectrum bands to spectrum refarming [3].

Benefit	Limitation
Additional income/value by discovering underutilized spectrum bands and share them with others → Maximizes the value of spectrum resources.	Costs of developing new technology and sharing conditions, dependency on the regulator and have to establish and maintain relationships with the sharing parties.
Allowing their spectrum to be shared with others → Improve their position in spectrum re-farming negotiations.	Risk of losing the spectrum to mobile telecommunication services in spectrum re-farming negotiations.
Maintain full access to their services without constraints from sharing with LSA licensees → Maintain QoS and customer satisfaction by sharing rules and conditions with the LSA licensees.	If the sharing rules and conditions are not followed by the involved parties, this can damage the incumbent's own businesses.
Possibility to maintain control over their spectrum bands → Protect their own businesses by sharing rules and conditions and the opportunity to request the shared band back.	Possibility that the sharing rules and conditions are more advantageous for the LSA licensee than for the incumbent itself.
Respond to the society's need after more frequency spectrum → Improve the efficiency usage of spectrum.	Concerns around limitations in spectrum availability for their own frequency band.

Figure 5.1: *Business benefits and limitations for incumbent spectrum users*

5.2 LSA Licensees (MNOs)

Figure 5.2 presents the key business benefits and corresponding limitations for the Mobile Network Operators (MNOs) with the implementation of LSA.

Benefit	Limitation
Access to extra spectrum both faster and cheaper to complement their exclusive licenses by sharing spectrum → Respond to the society's growing demand after spectrum by accessing low-cost LSA spectrum.	Costs of developing new technology and regulatory uncertainties.
Competitive advantage by cooperation with incumbent users and hinder the competition from accessing additional spectrum → Build up their dominant position in a new market scenario.	Possibility of raised competition because of lowered entry barriers.
Follow the regulatory requirements to protect the rights of the incumbent users → Keep up good relations with incumbent users and regulators by sharing rules and conditions between them.	Negotiation of sharing rules and conditions and dependency on the incumbent users.
Balance capacity supply and demand → Maintain predictable QoS and customer satisfaction with low-cost LSA spectrum by utilizing LSA bands in high market demand areas.	Investments in infrastructure in high market demand areas and risks to suffer from losing highly sensitive network data.
Invest in base stations in current locations instead of densifying in existing network → Cost savings in network expenditure.	Risk of short-term licenses; will the shared usage in LSA bands justify investments costs on a short-term basis.
Extended income by new additional LSA spectrum → Maximize income/value from new spectrum resources.	Competitive surroundings.
NEMs and device manufacturers develop new solutions incorporating LSA → Improve customer experience and hence MNOs relationship to their customers.	NEMs and device manufacturers will only start developing new solutions when they are certain of the adaption of LSA.

Figure 5.2: *Business benefits and limitations for MNOs*

An essential benefit for the MNOs is that LSA will bring faster access to new shared spectrum without having to wait for drawn-out and costly refarming arrangements. This will also contribute to less conflicts between stakeholders. Moreover, accessing new LSA spectrum can contribute to cost savings in network expenditure by setting up base stations at current locations rather than densifying in their existing network which demands huge investments in infrastructure [37]. Despite the fact that the LSA concept provides several business benefits for MNOs, the level of which MNOs will adapt LSA may be lower than for other LSA licensees like Mobile Virtual Network Operators (MVNOs) because they already have exclusive spectrum access. Simultaneously, the dependency on LSA frequency bands for MNOs is not as significant as for other ecosystem actors, which consequently lowers the risk. Because of lowered entry barriers to the spectrum market, both smaller emerging actors and bigger international players can access this new spectrum market by sharing with others. These actors represent a significant threat for the MNOs in providing telecommunication services. Accordingly, for the MNOs to share spectrum with others in the LSA situation, can be a way for them to build up their dominant position in the spectrum market. Moreover, they provide this shared spectrum capacity they have acquired to actors like MVNOs for additional income. With the utilization of LSA spectrum bands, the MNOs can weight the demand and supply after spectrum capacity more efficiently than before by for instance providing LSA spectrum in densely populated areas. One of the biggest concern for the MNOs is the risk of losing highly sensitive network data to outside individuals, as well as new competitive surroundings arising from LSA [3].

5.3 LSA Licensees (MVNOs, MSPs, BWAs, Content Providers, ...)

Figure 5.3 presents the key business benefits and corresponding limitations for LSA licensees with the implementation of LSA. The previous section presented benefits for MNOs as LSA licensees, while this section presents benefits for other LSA licensees such as MVNOs, MSPs, Content Providers and BWA providers. First, with the opportunity to get access to new low-cost LSA spectrum, the LSA licensees can diversify into new businesses, as well as challenge the MNOs in providing mobile telecommunication services. Moreover, the current situation involves LSA licensees to purchase licenses from spectrum auctions, which are tough especially for the smaller LSA licensees as the license costs often exceed their limits [49]. Furthermore, in spectrum demand areas where the MNOs are not particularly interested in providing spectrum access, the other LSA licensees can provide access with lower competition from MNOs. Next, the LSA licensees have to keep up good relations with the incumbent spectrum users in order for them to acquire a strong market position among the other LSA licensees. Still, this relies upon the length of LSA licenses as long-term licenses are less beneficial for smaller emerging actors. Lastly, if LSA licensees decide to provide spectrum access and services in high-demand areas where MNOs have dominant positions, they have to keep an eye out for customer satisfaction and Quality of Experience (QoE) for customers in these areas.

Benefit	Constraint
With new business opportunities, they can diversify into new businesses and offer new services to customers by acquire access to new shared spectrum → Increased income with minimal investments.	Costs of developing new technology and dependency on the behavior of the incumbent user.
Access to new low-cost spectrum by acquiring LSA licenses instead of costly exclusive licenses from auctions.	Risk of long-term licenses and no guarantees of service continuity if the licenses expire.
Obtain market positions in new businesses to challenge MNOs by acquiring access to shared spectrum and provide services to particular market demands (e.g. rural areas).	Additional infrastructure investments may be necessary, more competition by lowered entry barriers, can threaten their relationship with MNOs and costs related to the new business opportunities.
LSA will lower entry barriers for taking part in the spectrum market.	Risk of long-term licenses of LSA spectrum.
Take part in new businesses while protecting the incumbent's rights → Keep up good relations with incumbent users and regulators by sharing rules and conditions between them.	No guarantees of service continuity if the LSA licenses expire.

Figure 5.3: *Business benefits and limitations for LSA licensees*

5.4 Regulators

Figure 5.4 presents the key business benefits and corresponding limitations for the regulators with the implementation of LSA. The regulators are the facilitators of spectrum sharing businesses, and hence essential for every ecosystem actor. By creating rules and conditions for sharing, the regulators establish relationships between incumbent spectrum users and LSA licensees. The main goal for the regulators is to maximize the utility of spectrum resources, as well as balancing the demand after spectrum for different industries and type of services. Moreover, by opening new LSA spectrum bands for sharing that are currently occupied by an incumbent user, additional income for the regulators through compensation from LSA license fees can be collected.

Benefit	Limitation
Provide fair access to the frequency spectrum for all actors and promote innovation $\rightarrow$ Maximize utility and value of spectrum resources.	Unclear business models, cost of new technology and harmonization concerns.
Regulators get compensation from LSA licenses from LSA Licensees $\rightarrow$ Additional income for the government by the utilization of radio resources.	Ensure the incumbent user's spectrum rights.
Maintain reasonable price level in the consumer market by offering more spectrum for both new and existing players $\rightarrow$ Increased market competition and avoidance of monopolies.	Prevention of competition in the market; spectrum hoarding concerns.
Answer to the increasing demand after more spectrum from industry actors by spectrum sharing between different stakeholders $\rightarrow$ Increase spectum efficiency.	Development of a new sharing framework.
Efficient licensing process and equivalent treatment for every actor by creating an LSA framework that considers each actor's requirements $\rightarrow$ Efficient and fair spectrum management.	New sharing framework concerns.
Contribute with different rules and conditions for sharing $\rightarrow$ Ensure full certainty for incumbents in their own band without limitations from sharing with others.	Interference and QoS concerns.

Figure 5.4: *Business benefits and limitations for regulators*

Additionally, the deployment of LSA will bring increased competition in providing mobile communication services between the different ecosystem actors involved. This is accomplished by the reducement of entry barriers to the spectrum market by opening shared frequency LSA bands. However, the development of sharing rules and conditions and creation of the sharing framework between the incumbent and LSA licensee, can bring several concerns for the regulator. Still, this have to be seen in correspondence with the current usage of the frequency band; there may be more burdens coming from throwing out current incumbent owners of spectrum bands, and then reallocate these frequency bands to mobile telecommunication services. Next, assurance of the incumbent user's spectrum rights and protection against interference are necessary for the regulator to develop a successful LSA concept [17]. Accordingly, the regulator can ensure the incumbent spectrum user's rights, as well as introducing additional spectrum for stakeholders demanding more spectrum. Furthermore, the regulator intends to improve the efficiency on the usage of spectrum resources, and can give incentives to the incumbent users in order to get them to be willing to share their frequency bands. Lastly, LSA allows the regulator to keep charge of the spectrum resources as they possess and defines the LSA sharing framework.

5.5 Industry Stakeholders

Figure 5.5 presents the key business benefits and corresponding limitations for the industry stakeholders with the implementation of LSA. Considering the Network Equipment Manufacturers (NEMs), they have anticipated the increased demand after additional network equipment solutions. NEMs will have to develop and provide both existing equipment and new range of products supporting LSA spectrum bands in order to get increased income for their businesses. However, this depends on the adoption of LSA and time-to-market together with development costs of new equipment. Next, for the Device Manufacturers, by providing devices that supports for higher capacities, this will improve customer experience (QoE). However, standardized technology is necessary for the device manufacturers to profit from devices supporting LSA. When it comes to the Chip Manufacturers, if the market is large enough, they have the potential of selling increased amount of chips and hence increase their incomes. In view of the standardization organizations, promoting competition and cut-down the LSA time-to-market by cooperation between European countries are key benefits. Still, challenges remain in getting harmonized spectrum between these countries as each country have various use of different frequency bands. Moreover, for the Spectrum Database Providers, benefits build upon the development of new business opportunities for all actors with a standardized spectrum database. On the other hand, limitations are connected to security and time-to-market concerns, as well as they are dependent on standardization and regulators. Lastly, the Environmental Sensing Capability (ESC) operators aim at selling more network solutions by providing protection of harmful interference with network sensors that detects occupancy of telecommunication signals. Limitations relate to costs of developing this technology, uncertainty of the adoption of LSA and time-to-market concerns.

Stakeholder	Benefit	Limitation
Network Equipment Manufacturers (NEMs)	Sell additional network equipment and extend range of products → Increased income by using existing equipment in a larger scale.	Costs of developing new equipment, uncertainty of the adoption of LSA and time-to-market concerns.
Device Manufacturers	Better QoE for users by using devices providing greater capacity while supporting the new LSA bands → Improve customer experience.	Need standardized technology to reach economy of scale and uncertainty of the adoption of LSA.
Chip Manufacturers	Additional income by spectrum market growth because of increased spectrum availability → Sell increased amount of chips with reduced price per chip.	Large market is needed for standardized solutions.
Standardized Organizations	Harmonized spectrum and equivalent business opportunities for all actors involved → Reach economies of scale, promote competition and cut-downed time-to-market by cooperation between different countries.	Cross-border concerns and harmonized conditions.
Spectrum Database Provider	Develop new businesses with a standardized spectrum database → Expand spectrum market and possibility for new actors to enter the market.	Security concerns, sharing of information and dependency on regulators and standardization organizations.
Environmental Sensing Capability (ESC) Operators	Enlarge market by providing protection of spectrum users by network sensors that detect the presence of signals → Sell more network solutions.	Cost of developing new technology, uncertainty of the adoption of LSA and time-to-market concerns.

Figure 5.5: *Business benefits and limitations for industry stakeholders*

5.6 LSA Licensee Customers

Figure 5.6 presents the key business benefits and corresponding limitations for important LSA licensee customers with the implementation of LSA. First, the mobile industry customers will get improved QoE by the access to additional LSA spectrum. Also, they will experience lower prices as a result of increased competition between LSA licensees in providing mobile services. Still, customers may have to buy new devices supporting LSA, and the availability of LSA bands can be limited. Next, LSA provides new business opportunities for premise owners such as hospitals, university campuses and sporting venues. LSA can provide a solution for hospitals to complement their existing Wi-Fi coverage to deliver improved customer experience for the large number of hospital visitors. For university campuses, solutions based on LSA can provide extra capacity for users moving in and out of the different campus buildings where Wi-Fi solutions have experienced some challenges [31]. Concerning sporting venues, LSA can provide a solution for them to serve their customers with premium services such as in-game highlights and statistics. An example is the 360° race car experience demonstrated in Las Vegas with the CBRS shared approach (See section 8.1.2.2). Finally, limitations for these premise owners with the adoption of LSA solutions relate to security concerns, sharing of information and improvement in Wi-Fi technology.

Customer	Benefit	Limitation
Mobile Industry Customers	Enhanced QoE by obtaining access to additional spectrum capacity → Improved service experience and customer satisfaction. Increased competition between operators providing mobile telecommunication services → Lower prices for customers.	May need to buy new devices and restrictions in the availability of the additional LSA spectrum.
Hospitals	Complement the Wi-Fi network with a dedicated service to large number of users and visitors.	Security concerns and sharing of information and Wi-Fi improvements.
University Campuses	Extra capacity needed for multimedia and users that move in and out of buildings on campus (Wi-Fi coverage may here be a challenge).	Security concerns and sharing of information and Wi-Fi improvements.
Sporting Venues	Complement Wi-Fi network by an elastic event-driven network. Provide premium services such as in-game highlights and statistics.	Security concerns and sharing of information and Wi-Fi improvements.

Figure 5.6: *Business benefits and limitations for LSA licensee customers*

Chapter 6
Business Model

It is essential to study the fundamental business ecosystems in the development of new spectrum sharing schemes in order to discover reasonable business models for the key stakeholders. LSA is reasoned to be one of these emerging spectrum sharing schemes that is predicted to change the existing business models and actor ecosystems [50]. This change is believed to add new business opportunities for the actors in the ecosystem, as well as acquiring innovation in business models. Hence, a realistic analysis of a business model for the key stakeholders is crucial for the development of LSA. This chapter will present the business model for LSA. Based on the information discussed in the previous chapters, the business model for LSA will be presented by the Osterwalder business model canvas [51]. The suggested business model for LSA is presented in figure 6.1.

6.1 Key Stakeholders

Key Stakeholders include:

- *Incumbent spectrum users* - Owners of the spectrum band. Examples are governmental (e.g. Military/Defense operations) and non-governmental (e.g. MNOs and PMSE applications).
- *LSA Licensees* - Want to use the spectrum provided by the incumbents. Examples are Mobile Network Operators (MNOs), Mobile Virtual Network Operators (MVNOs), Managed Service Providers (MSPs) and Content Providers (e.g. Google and Microsoft).
- *Regulators* – Define the framework for sharing between the incumbent and LSA licensee and issue LSA licenses. Examples are National Regulatory Authority (NRA); Nasjonal Kommunikasjonsmyndighet (NKOM) in Norway.

6.2 Key Activities

Key Activities represent the most important activates for the key stakeholders, such that they maintain the value propositions.

For the regulator, the key activity includes to make the incumbent users willing to share their spectrum with LSA licensees, as well as getting the LSA licensees to be interested in making investments in infrastructure and network equipment. To accomplish this, the regulator have to encourage and give incentives to the incumbent spectrum users and LSA licensees such that they will consider LSA as an attractive opportunity for their business. Hence, the sharing conditions between the stakeholders have to be adequately fair and predictable (e.g. concerning interference protection and spectrum availability); the regulator will have to define the sharing agreement between the incumbent user and LSA licensee and therefore defines a set of rules for the sharing arrangement. Also, the regulator needs to negotiate the most beneficial pricing model for both incumbent spectrum users and LSA licensees.

Furthermore, the incumbent user and LSA licensee have to estimate their business benefits (see chapter 5) from sharing spectrum with other actors. Additionally, possible network infrastructure and user experience issues have to be identified before joining a shared spectrum approach.

6.3 Value Propositions

Value Propositions represent how value is created by the key activates for the different stakeholders and customer segments.

The additional LSA bands provide new opportunities for LSA licensees by gaining access to licensed bands in areas with high data demand. This is a more cost-efficient solution than densifying existing infrastructure in the traditional exclusive access spectrum bands. Hence, implementation of LSA is a cost-efficient solution to utilize existing spectrum bands. Similarly, with minimum modifications to the existing infrastructure and user equipment, economies of scale can be achieved. Moreover, LSA brings new business opportunities for rural and underserved communities with access to mobile broadband.

Also, the access to new LSA bands opens for smaller emerging actors eager to enter the spectrum market. This will increase the competition in providing mobile services, and these smaller actors gain the opportunity to challenge the bigger MNOs for the mobile industry customers. Particularly, these minor actors can aim at various markets and customer segments (e.g. rural communities, premise owners, M2M applications and IoT applications).

One of the most beneficial value propositions for LSA involves guarantees of Quality of Service (QoS) for both incumbent users and LSA licensees. This is possible by providing sufficient interference protection and considering limited number of actors involved in the sharing agreement. LSA intends to make use of harmonized bands both within each country and cross-border between countries. What is more, deployment of LSA can contribute on the road to global harmonization of frequency spectrum which will reduce interference and contribute to higher QoE for the end-users.

Moreover, LSA will provide flexibility, both in spectrum, time and location, as well as utilizing CR capabilities to provide sharing in circumstances not possible before. Lastly, for the LSA licensees and their customer segments, LSA will provide faster data access and higher data speeds; improving the customers' QoE.

6.4 Key Resources

Key Resources represent the most central assets the key stakeholders need to make for the business model to work.

First, the LSA Repository is central in the implementation of LSA to provide spectrum management. The Repository contains information about the availability and unavailability of spectrum based on information from the incumbent user, and the sharing framework provided by the regulator. The Repository can be managed from either the incumbent user or regulator, but also from an independent third-party actor [19].

Second, the LSA Controller takes control of computation of spectrum availability based on the sharing agreement received from the regulator. The LSA Controller can be managed from either the regulator, incumbent user, LSA licensee or a trusted third-party actor [19].

Third, network Operation, Administration and Management (OA&M) on the LSA licensee side carries out the actual administration and management of the LSA spectrum bands. Moreover, the OA&M receives information on the availability of the LSA spectrum from the LSA Controller and translates this information into commands (e.g. spectrum availability, QoS conditions and data speed) which are transmitted to the LSA licensees' base stations [19].

6.5 Customer Relationships

Customer Relationships represent the relationships the stakeholders want to maintain with their customer segments.

First, relationships with regulators must be established, which will result in a contract (sharing agreement) between the regulator, incumbent spectrum user and LSA licensee. Also, it is important for the LSA licensee to build a good relationship with the incumbent user in order to ensure predictable and reliable spectrum access.

Second, for the LSA licensees, customer acquisition is central for building customer relationship. This includes providing the best service possible for their customers; fast data access, high data speeds, low-priced subscriptions/services and a satisfying customer support.

6.6 Channels

Channels represent how the stakeholders manage to deliver value to their customer segments.

Within the implementation of LSA, the LSA Controller and LSA Repository is central, and this technology have to be distributed to the different customer segments of the LSA licensees.

Furthermore, keeping a good relationship with the regulator is important for the incumbent user and LSA licensee. This relationship can be maintained by a good dialog based on the sharing agreement between the key stakeholders.

Lastly, for the LSA licensees, it is important to reach out to their customer segments. For example, this can be done by different marketing strategies (e.g. social media advertising and television commercials).

6.7 Customer Segments

Customer Segments represent the entities and people which the key stakeholders target to reach and serve.

For the regulator, it is essential to make the LSA spectrum attractive for incumbent spectrum users and LSA licensees. Therefore, it is important for the regulator to reach these actors in order for a successful implementation of LSA. Moreover, for the incumbent user, the LSA licensees are the customer segment they want to reach.

For the LSA licensees, mass market is their main customer segment. Moreover, smartphone users with high data traffic demand, are segments relying on spectrum sharing. Similarly, high-end users demanding the highest service continuity and quality QoS, are essential customer segments for the LSA licensees. Additionally, for LSA licensees like MSPs and Content Providers, other customer segments such as Premise Owners (e.g. hospitals, university campuses and sporting venues) are businesses they want to reach and serve.

6.8 Cost Structure

Cost Structure represents the costs the key stakeholders experience while functioning the business model.

From the LSA licensee side, the main costs come from license fees to the incumbent user, development of infrastructure costs (CAPEX), operational costs (OPEX) and possibly costs related to the LSA Controller and network OA&M.

For the incumbent user and regulator, the foremost costs come from expenses related to the LSA Repository and/or LSA Controller. In addition, the regulator may need to provide incentives to the incumbent user in order for them to be willing to share their frequency spectrum with others.

6.9 Revenue Streams

Revenue Streams represent revenue the key stakeholders earn from their customer segments.

The incumbent spectrum user gets revenue in form of a LSA license fee from the LSA licensee. Similarly, the regulator gets a compensation from the license fee to the incumbent by the LSA licensee. Additionally, the incumbent may receive incentives for sharing from the regulator (e.g. payments to upgrade equipment needed for sharing).

The LSA licensee gets revenue from potential subscription/service fees from their customer segments. With the possibility to provide improved mobile data access, additional customers can be reached.

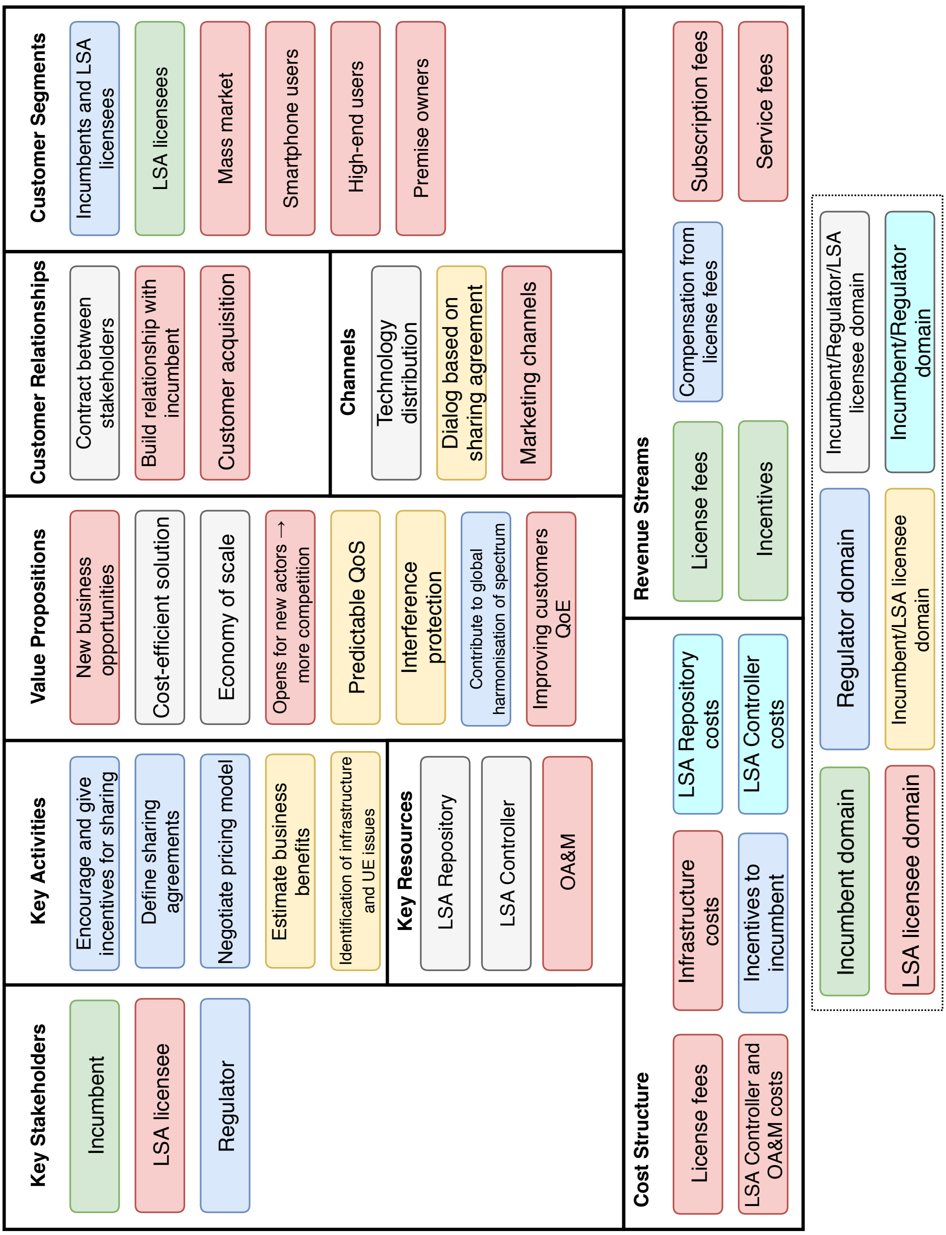

Figure 6.1: *Business Model for LSA*

Chapter 7 SCOC-Analysis

The objective of this chapter is to get a better understanding of the different strengths and internal challenges side by side with the opportunities and external challenges for LSA with a view to both established and emerging actors in the spectrum market. When it comes to the implementation of LSA, the SCOC-analysis prepares for strategic decisions and analyzes the strengths and advantages of the solution (**S**trengths), areas where there exist challenges that will have to be considered in order to stay competitive (internal **C**hallenges), beneficial external circumstances to give competitive advantage (**O**pportunities) and the threats that may harm the business (external **C**hallenges). This chapter will present an SCOC-analysis of LSA based on knowledge gained from the previous chapters about business benefits (chapter 5) and the business model (chapter 6). The SCOC-analysis is provided in figure 7.1.

7.1 Strengths

Strengths take into account the positive internal aspects of the product. These describe the advantages that tells the difference about the product in the market opposed to its competition. The strengths when it comes to a SCOC-analysis can be described as a part of business preparation and decision making, and includes:

- Product potentialities and advantages
- Unique selling proposition
- Innovative aspects
- Financial capital and likelihood of returns
- Distribution to customers
- Price when it comes to quality and other values

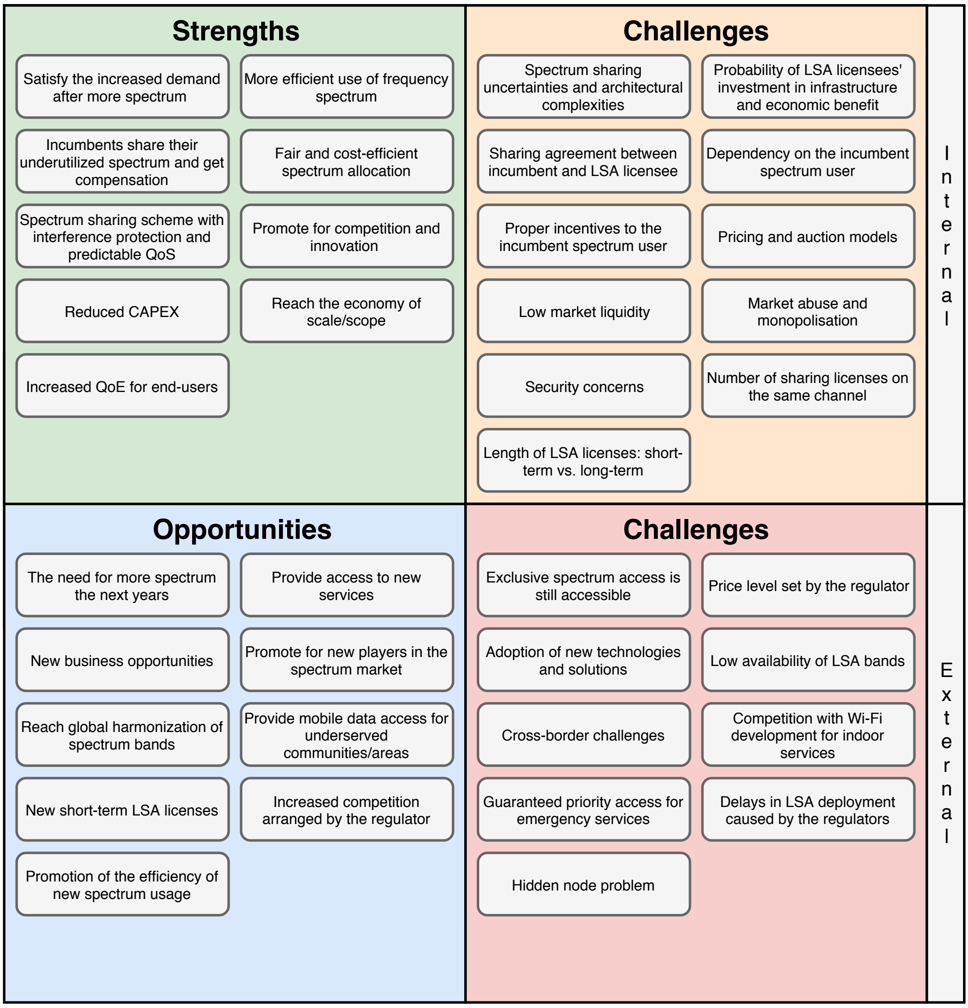

Figure 7.1: *SCOC-Analysis for LSA*

First, as mentioned in previous chapters, the demand after more spectrum has escalated. LSA is a spectrum sharing scheme that makes use of underutilized frequency bands and hence meets the demand after additional spectrum. Subsequently, this leads to a more efficient use of the current frequency bands which yields in greater economic benefits. This again derives in improved usage of spectrum resources. Also, technological improvements allow for numerous radio technologies to coexistence in smaller chunks of the frequency spectrum.

The incumbent spectrum users have the possibility to resell their underutilized or unused frequency bands and share them with LSA licensees. Consequently, the incumbent users get paid from the LSA licensees and generate incomes as well as contributing to the optimization of spectrum efficiency. Additionally, the incumbent users can receive proper incentives for them to be willing to share frequency spectrum (see section 8.2 Simultaneously, the regulators get a compensation from the license fees to the incumbent spectrum users from the LSA licensees.

Protecting the incumbent from interference that can harm their business and to provide strategic use of the spectrum is compulsory to guarantee continuity and safety for the incumbent spectrum user [5]. In the LSA shared spectrum market scenario, protection of the incumbent are performed by Environmental Sensing Capabilities (ESC), spectrum databases together with exclusion and protection zones. An exclusion zone is a geographical area where the LSA licensee are forbidden to use the frequency spectrum, while a protection zone is a geographical area where the incumbent user will not be subject to harmful interference from the LSA licensee [52]. Paper [53] performed interference measurements between an LTE network and wireless cameras in the 2.3 GHz band. The results showed that coexistence between these two services can be doable in the wireless cameras scenarios as considered in [42]. As well as protecting the incumbent spectrum users against interference, LSA provides a certain level of Quality of Service (QoS) for both the incumbent users and LSA licensees. The LSA Repository registers the LSA licensees in the spectrum database, and have charge of who is currently using the spectrum. By this approach, a certain level of QoS is provided to the actors. However, the QoS will be worse than for exclusive spectrum access and there are challenges corresponding to the hidden node problem (see section 7.4).

A secondary spectrum market with temporary and short-term exclusive spectrum access rights avows for small-scale actors to enter the spectrum market [5]. Alongside a LSA spectrum scheme, the market will be more dynamic and efficient with short-term contracts to frequency spectrum. Thus, smaller actors (e.g. Premise Owners) that needs more capacity for a limited period of time can make use of other ecosystem actors (e.g. MSPs or Content Providers) to go up against and compete with the bigger actors (e.g. MNOs) for spectrum access and mobile services.

In traditional businesses, Capital Expenditures (CAPEX) means the investments in an asset that lose value over time, while Operational Expenditures (OPEX) means the costs related to maintenance of the asset. There may be a quite huge advantage to change in-advance investments considering maximum capacity coverage over the entire period of time to a variable pricing model that is based on the current activity that is happening. With the LSA spectrum market, actors are encouraged to ask for LSA bands on a provisional basis. An example can be MNOs that lack mobile spectrum capacity in peak hours and therefore can use LSA to overcome this situation.

However, big upfront investments (CAPEX) can bring huge benefits in providing faster data access and higher data speeds for consumers (e.g. more base stations in urban and densely populated areas).

The necessary technology for the deployment of LSA is already there, so the possibility to reach the economy of scale is highly present. However, standardization of LSA is necessary to bring the economy of scale which subsequently leads to raised investments.

For the end-users, LSA will provide faster data access and higher data speeds; improving their Quality of Experience (QoE).

7.2 Internal Challenges

Internal challenges take into account the negative internal aspects of the product. To address these aspects of the product are important to recognize the potential challenges (e.g. efficiency limitations). The internal challenges when it comes to a SCOC-analysis can be described as:

- Product disadvantages
- Common vulnerabilities and incapabilities
- Shortage in competitive edge
- Financial concerns
- Time-to-market pressure
- Continuity and supply chain stability
- Probable distractions

LSA is after all a spectrum sharing approach. Hence, there exists many uncertainties when it comes to the concept of sharing frequency spectrum with others. Moreover, the complexity of the LSA architecture becomes bigger which could lead to a reduction in the economic benefit since the probability of investment decreases.

To get a successful deployment of LSA, it is crucial for the regulator to get the incumbent users willing to share their spectrum bands. To accomplish this is going to be a huge challenge in the development of LSA. In order to bypass this challenge, the regulator have to provide sufficient incentives to the incumbents (see section 8.2. Payments to upgrade necessary network equipment received from the regulator to the incumbent users may be such an incentive. However, the development of LSA is relying on and will be influenced by the license fees' price level. Moreover, the incumbent user will want to have the ability to renegotiate or even terminate the sharing contract during the contract period. As a result, this may lead to restricted investments in the network by the LSA licensees (e.g. MNOs).

Spectrum sharing with LSA will require the incumbent spectrum user and the LSA licensee to negotiate on essential terms and conditions. For the LSA licensee, it is important to evaluate each term and condition clearly to understand the potential value in joining the sharing arrangement. A small change in one of the terms or conditions can turn the spectrum valuation from high to low. For example, if the sharing agreement states that the LSA licensee will have access to the spectrum 50% of the time, but this is only in off-peak hours, this will have little or none value for the licensee if their target customer segment needs the service at peak hours [5].

The regulator will stay in charge of both the pricing and auction model; pricing model when the supply is higher than the demand, and auction model when the demand is higher than the supply. LSA will be a new concept for the actor ecosystem, so when it comes to the pricing model and what price level the regulator should set for LSA licenses, there are several aspects to consider for the regulator in order to get a sufficient and efficient spectrum allocation. On the other hand, to achieve a successful auction depends on the involved actors to have a clear understanding of their responsibilities and rights appointed to them. If there are any concerns about these points in question, it will prevent competitive bidding [54]. In case of the auction approach, there is also uncertainties around which auction mechanism to use for allocation of the frequency bands.

An important matter according to the deployment of this secondary market with LSA licensees is the low market liquidity. A reason for this can be as result of the limited number of licensees competing for frequency spectrum in a particular area. To get a better understanding around this issue, we consider the mobile telecommunication market in Norway. In Norway there are two dominant MNOs (Telenor [1] and Telia [2]) and on challenger MNO (Ice [3]). If we assume the LSA licenses to be allocated on a long-term basis, the spectrum market may not be very dynamic because of few actors competing for the LSA licenses. However, if the licenses are provided on a short-term basis, the market may be more dynamic because more actors are looking at the opportunity to get an LSA license. Also, we have to consider small actors wanting to enter the market and buying spectrum for provisional use with predictable QoS. This makes the market more dynamic and can raise the market liquidity.

The regulator will have to promote for efficient utilization of spectrum resources,

[1] telenor.no
[2] telia.no
[3] ice.no

while at the same time make room for new actors to enter the spectrum market [55]. Accordingly, to avoid monopolization, spectrum caps should be implemented to reduce the risk for this. Currently, Norway use spectrum caps in exclusive spectrum access, so they only have to continue using spectrum caps in the new secondary spectrum market. The regulator also need to keep an eye on actors (e.g. big companies or MNOs) trying to hoard or using its market power in order to hinder the competition with other actors [56]. However, as stated in the definition of LSA [17], in the implementation of LSA, fair competition and the interest of the consumers should be maintained. Also, the paper mentions that the national authorities have to ensure that the transition from exclusive licenses to LSA licenses will not result in spectrum hoarding.

To secure messages transmitted between the actors and the regulator, the spectrum market needs security mechanisms to prevent harmful intervention. These messages can be control messages that are transmitted to the regulator in order to request a LSA band or to update market information. However, standardized security mechanisms such as asymmetric or public-key cryptography seems to be adequate to prevent intervention in these messages.

For the case with sharing between one incumbent user and more than one LSA licensees, many sharing licenses in the same channel will reduce the block size available for each LSA licensee and hence increase interference with alongside LSA licensees [5]. With uncertainties around the number of sharing licenses, this will reduce the value for the LSA licensees.

When it comes to the length of the LSA licenses, long-term licenses (typically 15-20 years) will normally be favorable for dominant actors like MNOs. The reason for this, is that buying LSA licenses will have to justify the investment costs the MNOs need in order to fully benefit from additional frequency spectrum. At the same time, short-term licenses will reduce the investment scope, and hence shared spectrum may be of little or no value for the MNOs. However, for other LSA licensees (e.g. MVNOs, MSPs and Content Providers), short-term licenses can be beneficial for them to diversify into new business opportunities. Conclusively, the regulators have to thoroughly review short-term vs. long-term licenses in order to successfully utilize the potential of LSA shared spectrum. [5] has examined the impact of license lengths between an incumbent spectrum user and a MNO. The paper concludes with adequate economic benefits (€86 billion) for long-term licenses (15 years or more), while for short-term licenses with only investments from smaller operators, the economic benefits can be reduced to only €9 billion.

7.3 Opportunities

Opportunities take into account the positive external aspects of the product. These describe the objectives or goals for the product to achieve in the future, and can influence to reduce the impact from the external challenges. The opportunities when it comes to a SCOC-analysis, can be described as identification of the market opportunities, and includes:

- Worldwide influence, both in industry and way of life
- Technological progress and innovation
- Market developments with creation of new horizontal and vertical markets
- Reaction to competitive strategies
- Market demands
- Take advantage of competitors vulnerabilities
- How to reach their customers
- Expand into new geographical areas

As mentioned earlier in the thesis, the global mobile data traffic is believed to increase by 600% from 2016 to 2021 [10]. As the deployment of 5G is around the corner, more frequency spectrum is needed to provide the users with high speed mobile data. At the same time, with the increased amount of IoT devices requiring spectrum access, the world need more frequency spectrum to be able to fully satisfy the demand. LSA provides opportunities for shared spectrum to completely exploit the spectrum resources that we have. Simultaneously, additional spectrum may bring new players to the spectrum market, which can lead to new products and services, as well as lowering overall prices.

The possibility of harmonized bands across countries and within the European continent is present. The biggest benefit for harmonized spectrum is to avoid interference from different radio services when crossing borders. However, the frequency band that is proposed as the harmonized band in Europe is the 2.3 GHz band, which differs in use between the different countries [42]. The cross-border challenges are addressed in section 7.4.

LSA provides new opportunities for communities or rural areas that are underserved by telecommunication services today. This is because these communities are not very dense populated areas, so the availability of LSA bands are higher than in densely populated urban areas. Thus, this allows for several new actors and solutions to enter this rural market without interference between the services. Consequently, telecommunication services can be provided in areas not sufficiently served before because of lower costs and more competition between actors. This yields in social benefits and is a great opportunity for LSA to support for new business scenarios.

With new short-term licensing contracts, LSA provides new solutions for emerging actors to improve their market position. Concurrently, the regulators have the opportunity to increase competition by for instance using spectrum caps to prevent monopolization or market abuse by dominant actors. However, short-term licenses will most likely cut-off dominating MNOs in making investment in the infrastructure (see section 7.2 for the challenges around long-term vs. short-term licenses).

To promote for the efficiency of additional frequency spectrum, it is important with examples from other countries that have already implemented a successful secondary spectrum market. Moreover, to show the regulators that more spectrum is beneficial for competition and innovation in the spectrum market. For instance, the Office of Communications (OFCOM) in the UK has released a report [57] where they encourage for spectrum sharing. An example like this will encourage regulators in other countries to look at opportunities around spectrum sharing. Moreover, successful test trials of LSA will help promoting the usefulness of the LSA spectrum sharing approach (see section 8.1.2).

7.4 External Challenges

External challenges take into account the negative external aspects of the product. These aspects can be seen as hindrance for the product development and are considered out of hand for the company. These aspects may bring the product to fail, and includes:

- Environmental and regulative consequences
- Technological progress and innovation
- Competitors' strategies
- Overwhelming vulnerabilities
- Financial challenges
- Market demands

Even though LSA will be implemented and deployed, exclusive spectrum access will still be available. Therefore, it is critical that the regulators in charge of setting the price of license fees take this into consideration. Assuming that the difference in license prices between LSA and exclusive spectrum access is insignificant, then it will not be beneficial to choose LSA over exclusive access for the actors involved. Therefore, the price difference between access to LSA and exclusive spectrum have to be large enough for LSA to be attractive to the ecosystem.

On the surface, it may seem like customers tend to turn down on the adaption of new technology and solutions even though the new technology or solution proves to be better than the prior one. This is a normal and natural behaviour for most people, since people tend to rely on familiar and safer solutions rather than facing the risk of unfamiliar solutions. When thinking of LSA as a concept, incumbents may be anticipated by the possible impact from interference and how this will affect their users. Therefore, it is important that LSA becomes standardized and can prove predictable protection against interference.

Another important challenge to address is the low availability of LSA frequency bands. According to [55] there are four aspects related to the limited availability of spectrum for telecommunication services: monopolization concerns, specifically acquired uses for the spectrum provided by the regulator, restrictions on the technology such that it cannot be used on specific frequencies and because of uneconomical conditions (e.g. MNOs are clearly outbidded by other actors). The availability of LSA bands is a major challenge that have to be carefully considered and treated by the regulators.

For the success of LSA, it is essential to provide the same spectrum frequencies across countries and regions; namely spectrum harmonization [27, 30]. The reason for this is that it is crucial with a successful and cost-effective implementation of LSA to reach the economy of scale, as well as promote for investment. If we consider the case without spectrum harmonization across the countries, the spectrum interference in these countries will be presumably high. Subsequently, Quality of Service (QoS) and Quality of Experience (QoE) for the different actors will be critically restricted. This may result in two scenarios; either prices on devices remain low which result in devices not operating accurately because of high interference or prices on devices become noticeably higher because more complex interference filters are needed. Conclusively, without a harmonized frequency spectrum across countries, the mobile industry and their customers will be harmed as well as reducing the economic benefits those actors are bringing to the society.

LSA development for indoor services are threatened by the advancements of Wi-Fi services. Wi-Fi is by this time hugely available and if new technological features can provide the same advantages as LSA, Wi-Fi development can be a considerable threat for the deployment of LSA for indoor services [31]. Hence, it is more probable that companies favor Wi-Fi over LSA to provide solutions for their indoor services.

An important aspect when it comes to sharing spectrum is to consider the nature of the incumbent spectrum users. Issues arise when considering governmental organizations, and especially safety organizations that rely on priority access for their emergency services [5]. For these actors, shared spectrum may not be very valuable as emergency cases are very critical for all actors involved. Although the incumbent user will have priority access, what will happen in case of the hidden node problem (see section 7.2? This is a notable challenge that have to be clarified in order to invite emergency service actors in a shared spectrum approach.

In the majority of European countries, they are still in the research stage for the use of LSA in the spectrum market. It is important for them to figure out and understand the different business scenarios when it comes to necessities, management and production costs, market size, investment probability and potential economic benefits. To address these business scenarios are essential for the regulators to allow for efficient regulation. There is a common interest in Europe to establish some sort of cooperation between between standardized organizations, bigger companies and regulators in shared spectrum markets [58]. Most importantly, regulators have to guarantee that they provide suitable access conditions which protects the incumbent spectrum users.

Another challenge is the hidden node problem. This problem is situated when transmission signals are not properly detected by the LSA repository, Spectrum Database or Environmental Sensing Capability (ESC) operators because of blockage made by buildings, trees or other obstacles [59]. This may result in the devices to mistakenly detect no transmissions done between the devices and repository. Moreover, this frequency channel will remain positioned as vacant, when it's actually not. This may cause harmful interference for other transmissions done on the same frequency channel, as well as decreasing the QoS. To get around this issue, the appropriate conditions and signal strength thresholds together with information about the users' location have to be accurately implemented.

Chapter 8
Deployment Strategies

This chapter will look at potential deployment strategies towards LSA for some of the most central ecosystem actors. These deployment strategies will be based on the information gained in the previous chapters; the nature of the actors (chapter 4), their business benefits (chapter 5), the business model for LSA (chapter 6) and the SCOC-analysis (chapter 7). This chapter will also present the current development of LSA in Europe, as well as examples from similar regulatory approaches in spectrum sharing.

8.1 Current Development

LSA was developed in order to provide spectrum access to licensed frequency bands that under other conditions would not be possible to access in Europe. Nearly all studies to this day have been focusing on using LSA in the 2.3 GHz frequency band where LSA will provide additional spectrum capacity for mobile communication services. In order to get a successful deployment of LSA across Europe, proper definitions and sharing frameworks have to be agreed upon in LSA specifications. Additionally, extensive test trials to show the potential of LSA have to be arranged. This can include looking at test trials of similar spectrum sharing approaches (e.g. CBRS and TVWS) in other countries and continents.

8.1.1 Recent LSA Specifications

In 2017, the ETSI TC RRS released the finalization of the specification that supports for LSA shared spectrum [26]. This document provides a way to allow spectrum sharing coordination between current users of the spectrum and LSA licensees, such that they receive predictable Quality of Service (QoS). [26] contains information about essential features and technical protocols for the implementation of LSA in the 2.3 GHz frequency band. This includes the definition of a new application protocol (LSA1 protocol) that belong between the LSA Repository and LSA Controller and the information transported by this protocol. Following this new LSA specification, ETSI TC RRS has concluded a set of specifications ([23], [25], [24]) that support for the exchange and use of information between LSA Repositories and LSA Controllers in the target 2.3 GHz band. However, expansion to other bands are not excluded; the motivation is to consider both future and additional regulatory requirements in the announcement of LSA specifications.

8.1.2 Test Trials

In the development of the LSA approach, real-time trials are especially important in order to properly demonstrate the usefulness of this spectrum sharing concept. LSA is a concept that has been studied and demonstrated in several European countries, including:

- *Finland* - Demonstrated a live LTE network with LSA spectrum sharing in the 2.3 GHz frequency band. See section 8.1.2.1 for more information about the Finnish LSA trial.
- *France* - In 2016, the ANFR together with the Ministry of Defence demonstrated an LSA trial of an LTE network in the 2.3 GHz band operated by industry stakeholders [France]. The LSA trial was up and running for 6 months and showed promising results without interruptions during the period.
- *Spain* - At the GSMA Mobile World Congress in Barcelona in 2015, a demonstration of LSA spectrum sharing between mobile services and PMSE video links was carried out in the 2.3 GHz frequency band [8].
- *Italy* - The Ministry of Economic Development has demonstrated an live LSA trial in the 2.3 GHz band where an LTE network was deployed and run [7]. The trial took place in Rome and was up and running for 6 months and measurement results showed the usefulness of LSA to provide mobile communication services without drawbacks for the incumbent spectrum users (e.g. Fixed Services).

Moreover, specialized business opportunities that arises from new additional LSA spectrum have to be demonstrated. No such demonstrations with LSA have taken place in Europe so far, but in the U.S., the CBRS approach have successfully showed the feasibility of additional spectrum made available by spectrum sharing in such new businesses. See section 8.1.2.2 for an example of using CBRS at the Las Vegas Motor Speedway.

8.1.2.1 LSA Trial in Finland

Finland launched the world's first trial on spectrum sharing with LSA in 2013 [60]. This trial was demonstrated in the 2.3 GHz band between an incumbent user (PMSE application) and LTE secondary users, and showed promising results. In 2014, an improved trial of the LSA approach as specified in [60] was presented [61]. This paper introduces two new building blocks, LSA Repository and LSA Controller, to the LSA concept as described in [60] to demonstrate more lifelike activity in the 2.3 GHz frequency band. The trial showed that a LTE network (MNO) can successfully make use of the 2.3 GHz band and vacate the band when the incumbent user wants it back, and then move their end-users to other networks to keep connection to LTE services. Moreover, the trial showed that spectrum availability in LSA bands can easily be resolved with current network equipment together with the LSA Repository and LSA Controller. Next, the Finnish trial developed in 2015 and demonstrated a more improved incumbent protection that considers combined interference from a LTE network [62]. This trial introduced a more advanced algorithm for interference protection in protection zones in order to enlarge the LSA licensees' spectrum resource availability. Also, the ability to track the incumbent users' movements are demonstrated to an enhanced interference protection. Furthermore, an estimation algorithm that dealt with combined interference protection was demonstrated in [63]. This trial took place in 2016 and demonstrated improved power control for interference protection between an incumbent spectrum user and an LSA licensee running a LTE network. Figure 8.1 illustrates the LSA trial development in Finland from 2013 through 2016.

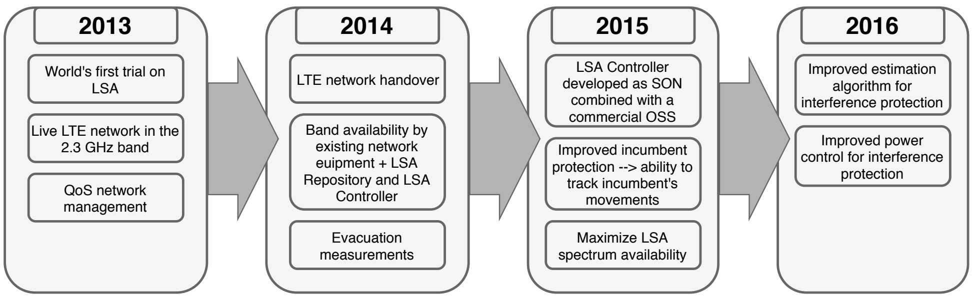

Figure 8.1: *Development of LSA trials in Finland*

8.1.2.2 360° Race Car Experience

In 2017, Nokia, Alphabeth's Access Group and Qualcomm Technologies demonstrated the first live trial of a private LTE network over Citizens Broadband Radio Service (CBRS) in Las Vegas [64]. This shared spectrum demonstration at the Las Vegas Motor Speedway showed an "in car" real-time experience with a 360° video streaming inside a race car. The demonstration showed how shared CBRS spectrum together with innovative technologies can provide new experiences for the audiences, as well as how shared spectrum can provide premise owners like sporting venues with their own private LTE network to support for their services.

Development of such private LTE network solutions have become a reality as a result of CBRS spectrum availability and development of technologies to support for new shared spectrum approaches. The live trial of the 360° race car experience showed efficiency benefits of using CBRS shared spectrum over LTE, including:

- Steady data speeds when streaming the 360° video to the audiences.
- Exceptional mobility at high-speed race cars (180 mph).
- First-rate outdoor network coverage.
- Capacity to meet future demands.

CBRS is the new shared spectrum scheme that is used in the demonstration at the Las Vegas Motor Speedway. CBRS is released in the U.S. by the Federal Communications Commission (FCC), and supports for new innovative business models. The three companies in charge of the race car test trial, Nokia, Alphabeth's Access Group and Qualcomm Technologies, are all members of the CBRS Alliance which are promoting network solutions based on LTE in CBRS spectrum bands.

Successful test trials like this CBRS trial in the U.S. are valuable for LSA development in Europe; LSA can perform similar network demonstrations in Europe.

8.2 Incentives for Sharing

The regulators and public authorities have huge influence and power when it comes to the implementation of new technologies that impact large parts of society. They have the ability to provide sufficient incentives in order for the users to adapt new technologies before demand-side economies of scale has reached its critical mass.

The first stage for a successful implementation and deployment of LSA involves the incumbent user to identify possible underutilized frequency bands the incumbent user can share with others. The incumbent user will have to identify the business potential of sharing with others. However, in order for the incumbent spectrum user to be willing to share spectrum, appropriate incentives for sharing has to be provided. The RSPG within the EC said the following about incentives for LSA:

> *"Balancing the impact on the incumbent and the usage constraints on any additional user is a challenge. Administrations, when examining*

socio-economic benefits would inter alia need to take into account (i) the conditions under which existing assignments were made, including costs incurred, and (ii) the legitimate expectations of the incumbent as well as LSA users." [17]

For the incumbent users to be willing to share their spectrum, they have to see benefits coming from the LSA arrangement (see chapter 5). These incentives can include:

- License fees from the LSA licensees.
- Incentives from the regulator (e.g. payments to upgrade equipment needed for sharing).
- Lowered fees paid to the regulator for spectrum licenses.
- Get access to the services provided by the LSA licensees.

In the U.S., the President's Council of Advisors on Science and Technology (PCAST) have proposed an incentive solution where they reward incumbent spectrum users that early adapt and promote for new shared spectrum with "Spectrum Currency" [65]. Correspondingly, in Europe, arrangements done by regulators with Administered Incentive Pricing (AIP) model propose solutions that reward incumbent spectrum users that support for more efficient use of spectrum resources by sharing underutilized frequency bands with other actors [66].

If the incumbent user manages to identify business benefits and receive sufficient incentives, the incumbent notifies the regulator about potential parts of the LSA band they are willing to share. Moreover, the incumbent spectrum user reports sharing conditions (e.g. geographical area, time period) and possible conditions related to incentives for sharing.

It is not sufficient to only provide incentives for the incumbent users; the LSA licensees also need benefits (see chapter 5 about business benefits) or incentives to join a shared spectrum approach. These benefits can include:

- Certainty of access to the frequency spectrum so that they can provide their services to their customer segments.
- Predictable Quality of Service (QoS).
- Improved Quality of Experience (QoE) for their customer segments.

The LSA licensees are eventually the ecosystem actors that will actively use the LSA spectrum shared with incumbent users. Dependent upon the actions taken by the regulator, incumbent and other ecosystem actors, LSA licensees have to make a decision whether or not they are going to adopt and use LSA spectrum resources. If the regulators determine to not provide incentives for the incumbent users, the LSA licensees will be compelled to pay more for the LSA license, which subsequently will increase subscription fees towards their customers. Eventually, every LSA licensee has different preferences and demands which needs to be satisfied for them to enter this new spectrum market.

For LSA, the willingness of regulators to provide incentives for sharing will be critical. As LSA provide a solution that will improve the utilization of frequency spectrum, support for new technologies (e.g. 5G) and create new opportunities for other players to join the spectrum market, we can expect Nasjonal Kommunikasjonsmyndighet (NKOM) in Norway to have the capability to provide proper incentives for the LSA approach. The business benefits of LSA are presented in chapter 5; together with the incentives listed above, we can expect these conditions to increase the adoption rate of LSA.

8.3 Actors' Strategies

This section describes potential deployment strategies towards LSA for MNOs, MVNOs, Premise Owners, MSPs and NEMs together with the relationships between them. Additionally, for each of these ecosystem actors, a discussion of the most likely strategy for the situation in Norway will be reviewed.

8.3.1 Mobile Network Operators (MNOs)

MNOs typically buys exclusive licenses and equipment and sometimes Operation, Administration and Management (OA&M) from Network Equipment Manufacturers (NEMs). Businesses belonging to MNOs are protected by high entry barriers (e.g. licence fees and costs related to deployment and infrastructure). The introduction of LSA threatens these entry barriers. With the increasing demand after mobile data, it is very likely that MNOs will have to take advantage of this new capacity LSA is creating. There are several strategies MNOs can deploy; buy an LSA license and make investments in infrastructure, only buy an LSA license and not make investments in infrastructure, buy capacity from a new LSA licensee owning an LSA license or have a follower role and not promote for sharing. Figure 8.2 presents the different strategies the MNOs can take with each strategy's risk level and effect.

Strategy	Risk Level	Effect
Buy an LSA license and make investments in infrastructure	Low risk: adapt their typical businesses from traditional exclusive spectrum licenses, so the ecosystem is already there.	Responding to the increased demand after more spectrum and cost-savings in network expenditure → Profit from economy of scope.
Only buy an LSA license and not make investments in infrastructure	Medium risk: the network is deployed and managed by a third-party actor.	Reduced costs related to investments in infrastructure and OA&M.
Buy capacity from an LSA licensee	Medium risk: the network is deployed and managed by a third-party actor.	Reduce investments related to CAPEX, which will be valuable when considering the large investments they will have to make in their own bands to meet the high demand for mobile data.
Have a follower role and not promote for sharing	Medium risk: can lose important bands → will have to make large investments and densifying in their own bands.	Possible to maintain their dominant position; MNOs are not as dependent on the LSA bands as other actors like MVNOs, which are more reliable on the availability of the LSA band and the relationship with incumbents.

Figure 8.2: *MNOs' deployment strategies*

With the potential deployment of LSA in Norway, the most likely strategy for the MNOs in Norway will be to buy an LSA license and make investments in the network. The reason for this is that this strategy is the most typical way of doing business for the MNOs in Norway today and is also pretty low-risk. Still, this rely upon long-term licenses such that the MNOs investments can be justified (see section 7.2. What is more, in Denmark, the two largest MNOs, Telenor and Telia, have granted Nokia to take care of the management of their collective communication network [67]. About Nokia, the network director at Telenor Denmark, Peter Nødbak, said: *"They have the necessary expertise, capacity, and know-how in the area that will ensure the most optimal operation and making our network ready for the future."* [67]. To get companies like Nokia to manage the communication network in a LSA shared approach, can be possibilities for the MNOs to save costs in spectrum management. On the other hand, the largest MNO in Norway, Telenor, have been negative to the deployment of LSA [68]. Therefore, it may be a chance that they instead will have a follower role and not promote for sharing even though they risk to lose important frequency bands suitable for mobile communication services.

8.3.2 Mobile Virtual Network Operators (MVNOs)

MVNOs typically buys capacity from MNOs and retails the capacity to their end users. The LSA solution offers new opportunities for the MVNOs; they can either reduce their costs or make new businesses rising from the new approach. We consider three strategies for the MVNOs; extend their contracts with the MNOs, buy capacity from other actors or become an LSA licensee. Figure 8.3 presents the different strategies the MVNOs can take with each strategy's risk level and effect.

Strategy	Risk Level	Effect
Extend existing contracts with MNOs	Low risk: similar to their existing businesses, but rely on the behavior of the MNOs	The MVNOs wait for the MNOs to make investments in the LSA network, and then extend their existing contracts upon this network.
Buy capacity from other LSA licensees	Medium risk: pretty similar to their existing businesses, but rely on the behaviour of the LSA licensees and can threaten their relationship with MNOs.	New business opportunities, reduce their license costs (more competition) and MVNOs can make use of different actors providing spectrum to differentiate between different services.
Become an LSA licensee	High risk: can threaten the relationship with MNOs, have to acquire the necessary capabilities to deploy a network or utilize a trusted third party for this task.	For a MVNO that wants to become a MNO or just wants to be more independent, this strategy may be the first step on the road to accomplish this.

Figure 8.3: *MVNOs' deployment strategies*

There are almost no independent MVNOs in Norway today. Simultaneously, the same situation is seen in several European countries; almost every MVNOs have eventually been purchased by dominant MNOs or even disappeared [69]. Based on numbers from 2016, in Spain there were 24 well-known MVNOs, but together they only managed to capture about 16% of all consumers in the market [70]. Further, in France, there were no more than 40 MVNOs with the combined market share of 10.5% (2015), down from 13% the year before (2014) [71]. Based on this, the most likely strategy for MVNOs in Norway will be to just extend their existing contracts with the MNOs, as there may be huge risks for them to terminate these contracts. However, if new LSA licensees are able to provide network capacity with low-cost and short-term licenses, MVNOs can make use of these actors to differentiate between new business opportunities. Still, this may threaten their relationship with the MNO, so there are risks to consider. Moreover, for new independent MVNOs, buying a LSA license from other LSA licensees different from MNOs can be a solution for them to provide their services without dependency on the dominant MNOs.

8.3.3 Premise Owners

Premise owners can either be public or private, and includes hospitals, hotels, university campuses, sporting venues and offices to mention a few. Premise owners value the fact that only one actor deploy and run their network, so their strategies includes; provide their own solution, cooperate with a MNO or cooperate with another LSA licensee. Figure 8.4 presents the different strategies the premise owners can take with each strategy's risk level and effect.

Strategy	Risk Level	Effect
Continue with Wi-Fi solutions	Low risk: established practice; almost everyone use Wi-Fi	Familiar and less expensive solution. Wi-Fi is an unlicensed system; coverage and interference concerns. Wi-Fi is not always the most secure solution.
Cooperate with a MNO	Low risk if cooperating with only one MNO. Higher risk if cooperating with multiple MNOs (manage several networks and more relationships).	A simple and effective way for premise owners to provide new business opportunities, lowering their costs of deploying such a system.
Cooperate with an LSA licensee (e.g. MSP or Content provider)	Low risk: cooperate with third parties which will be in charge of providing connectivity for their end-users.	A simple and effective way for premise owners to provide new business opportunities, lowering their costs of deploying such a system.
Develop and provide their own solution	High risk: will be very costly since they have to make investments in a whole new infrastructure as well as buying LSA licenses.	This strategy can provide the premise owners with a more valuable network for their business where they are in charge of the network.

Figure 8.4: *Premise Owners' deployment strategies*

For premise owners in Norway, the most likely strategy will be to either cooperate with a MNO or with network providers such as MSPs or content providers. By utilizing such service providers will provide a simple and effective solution for the premise owners to provide connectivity to their customers. However, for premise owners to have a private LTE network rather than getting their network data going through the MNO, can be valuable if they need sensitive data to remain in-house. For example, keeping security cameras connected to their private LTE network, may benefit the premise owners. Compared to Wi-Fi, a LTE network will give new opportunities for premise owners using Internet of Things (IoT) devices, as well as providing a more secure network. For example, Einar Flobak examined LTE solutions in high capacity locations in his master thesis [72]. Specifically, Flobak studied a LTE solution provided by Telenor at Lerkendal Stadium in Trondheim, Norway, and the performance measurements showed promising results. Also, the private LTE solution over CBRS at the Las Vegas Motor Speedway provided by Nokia, Alphabeth's Access Group and Qualcomm Technologies (see section 8.1.2.2) is a promising alternative for the premise owners when it comes to deployment strategies.

8.3.4 Managed Service Providers (MSPs)

MSPs task is to deploy a network to accommodate for MNOs or other actors needing to make use of a network to their end-users. With the deployment of LSA, strategies for MSPs include to continue to do their existing business or become an LSA licensee and provide capacity to other actors. Figure 8.5 presents the different strategies the MSPs can take with each strategy's risk level and effect.

Strategy	Risk Level	Effect
Continue with existing business	Low risk: similar to MSPs existing way of doing business; wait for actors to buy LSA licenses and then propose to provide their network to those actors.	A simple and effective way for MSPs to provide their businesses to potentially new customers that have bought a LSA license → Potential of more customers.
Become an LSA licensee and provide capacity to other actors	High risk: large investments are required, and can threaten their relationship with MNOs (MNOs may look at the MSPs as competitors).	MSPs will get better control of the value chain, and hence increase their margins. Also, for premise owners, this approach can be seen as a simple solution that may accelerate their indoor and outdoor coverage.

Figure 8.5: *MSPs' deployment strategies*

For the deployment of LSA in Norway, the most likely strategy for the MSPs will be to just continue with their existing businesses. The reason for this is that this strategy is similar to the MSPs existing way of doing business and hence presents low risks for them. For example, Nokia can provide management of MNO networks, like they did with the Telenor and Telia collective network in Denmark [67]. With the introduction of new additional LSA spectrum, the MSPs can provide network solutions for new customers in the new spectrum market. Moreover, the MSPs can include new business opportunities to their portfolio by bringing high-speed operator-neutral LTE access for e.g. premise owners. Hospitals, hotels and sporting venues can benefit from such service by keeping their customers connected at all times and all over the property. For the MSPs to become an LSA licensee and offer both capacity and mobile services to others, will most likely be too risky [34].

8.3.5 Network Equipment Manufacturers (NEMs)

NEMs sell network equipment primary to MNOs and MSPs. Moreover, NEMs can provide these players with Operation, Administration and Management (OA&M) of the network. Three strategies for NEMs will be addressed; sell network equipment, sell network equipment and provide OA&M or deploy its own network without selling network equipment and providing OA&M. Figure 8.6 presents the different strategies the NEMs can take with each strategy's risk level and effect.

Considering the NEMs in Norway, the likely strategies for them with the deployment of LSA will be to sell network equipment and also network OA&M if that is something that they already provide and have expertise on. The reason for the NEMs to most probably deploy one of these strategies, is that these strategies are similar to their existing businesses and with the potential of additional customers (LSA licensees), they can increase their revenues.

Strategy	Risk Level	Effect
Sell network equipment	Low risk: the development costs of network equipment can be lower than the revenues generated from the market demand.	Similar to their existing businesses, but with the potential for new customers and new technology → More customers and possibly more income
Sell network equipment and OA&M	Low risk: related to developing costs, and if these costs will be lower than the revenue raised from the market demand.	Same as above. Moreover, with revenue streams from both network equipment and OA&M, the NEMs will more likely be able to bypass the investment costs.
Become an LSA licensee and sell capacity to other actors needing spectrum access	High risk: large investments, have to deploy and run its own network and sell capacity, as well as establishment of new relationships.	For the NEMs: potential of more income, make use of their expertise. For the buying actors: reduce CAPEX costs.

Figure 8.6: *NEMs' deployment strategies*

Chapter 9
Conclusion & Further Work

9.1 Conclusion

This thesis has described and discussed the concept of LSA and how it will be used to satisfy the demand after frequency spectrum and more specifically the enormously increased demand after mobile data. First, the actors in the ecosystem surrounding LSA were presented, and showed both established telecommunication actors (e.g. MNOs, MVNOs, MSPs and NEMs) and emerging actors wanting to take part in the spectrum market (e.g. Content Providers and Premise Owners). The ecosystem actors were deliberated and presented with each actors' benefits and corresponding limitations towards the implementation of LSA.

Next, a realistic business model for LSA has been provided by the Osterwalder business model canvas. The business model showed that the cost structure for LSA licensees will be mostly based on license fees to the incumbent spectrum user and costs related to investments in infrastructure and possibly OA&M. When it comes to revenue streams from new LSA spectrum, the LSA licensees have the opportunity to receive increased income from additional customers by providing improved mobile services.

Furthermore, an extensive SCOC-analysis for LSA was thoroughly presented according to strengths, opportunities and challenges for the implementation of LSA. Key challenges that became visible from the SCOC-analysis were the adoption of new technology, long-term vs. short-term LSA licenses, cross-border challenges and how to provide guaranteed priority access for emergency services.

Then, information about the current development of LSA and necessary technology have been possessed and further explained. Additionally, potential deployment strategies for some key ecosystem actors were proposed and discussed in chapter 8. Key findings for a successful deployment of LSA, include the regulator to give proper incentives for sharing to the incumbent spectrum users.

Finally, LSA is a regulatory approach in spectrum sharing with much potential of satisfying the increased demand after frequency spectrum. In order to assist for the progress of the adoption of LSA, regulators and standardization organizations have to establish compatibility and omnipresent deployment.

9.2 Further Work

Even though LSA have been focus for studies about spectrum sharing for several years, it has not yet been deployed by any country. Therefore, LSA is still in a quite early stage when it comes to deployment, although multiple test trials have taken place across Europe. Through the work of this thesis, some areas of further work on LSA have been identified.

The challenges addressed in the SCOC-analysis in this thesis, are areas where further research and studies have to be performed. Both when it comes to cross-border challenges without harmonization of spectrum and the lengths of LSA licenses.

Currently, the LSA concept is being developed by CEPT, ETSI and EC with the goal to implement LSA for LTE specific services in the 2.3 GHz band in Europe. However, the LSA concept is a general approach in spectrum sharing and not restricted to any specific frequency band. Therefore, it is expected that LSA will be used for other frequency bands as well. Implementation of LSA in other frequency bands have to be tested further, especially in spectrum bands feasible for 5G communications.

Since several actors (especially MNOs) do not look at LSA as an attractive option for additional spectrum, the regulators in each country have to promote LSA considering national circumstances in order to contribute to efficient use of spectrum resources. They have to come up with proper incentives, as well as demonstrate new business opportunities that are created by additional shared spectrum.

Finally, LSA has still some challenges to solve, but with further development and further work on the concept of spectrum sharing with LSA, neither of these challenges seem impossible to overcome.

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