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STUDY OF LSA IN WISE2 PROJECT

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BACHELOR'S THESIS | ABSTRACT

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This thesis is set to examine the basics of licensed shared access (LSA) spectrum sharing method and how it is developed in Finland project and internationally. Focus of study is at Turku University of Applied Sciences WISE2 project and LSA tools developed there. The thesis also studies the background of LSA development and examines how LSA is constructed and its basic operating principles. This thesis focuses on administrative aspects of LSA and how the system operates rather than on specific equipment and operational effort needed for fully operating LSA. Thesis is done using qualitative method.

The thesis will cover the history of LSA and the reasons why it was developed for. It will present the basic definition of LSA and define what it currently means. The thesis will also study LSA as a potential mean for spectrum sharing by examining the current use of the spectrum and the development needs that it has both nationally and internationally.

Thesis has an interview of Arto Kivinen from WISE2 about the current state of LSA development in Finland and in WISE2. The interview focuses on the WISE2 projects and its affiliates work and reached goals on LSA development and also on the future development of LSA nationally and on European level.

Thesis presents results that show that LSA is a possible way to share spectrum in the future. LSA has still some issues to overcome, but with future development none of those seem impossible to deal with.

KEYWORDS:

spectrum sharing, LSA, mobile networks

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LSA-TUTKIMUS WISE2-PROJEKTISSA

Tutkimuksessa perehdytään licenced shared access (LSA) spektrinjakotavan toimintaan ja sen kehitystyöhön sekä Suomessa että kansainvälisesti. Tutkimus keskittyy erityisesti Turun Ammattikorkeakoulun WISE2 projektiin ja siinä kehitettyihin työkaluihin. Tutkimus avaa LSA-järjestelmän taustaa sekä esittelee sen rakenteen ja perusperiaatteet. Tutkimuksessa keskitytään LSA-järjestelmän yleiseen toiminnallisuuteen sekä sen hallinnolliseen puoleen, eikä siinä perehdytä järjestelmän vaatimiin laitteisiin tai itse järjestelmän operoinnin vaatimaan toimintaan. Tutkimus on tehty käyttäen kvalitatiivista tutkimusmenetelmää.

Tutkimuksessa käydään läpi LSA-järjestelmän taustaa ja sen tarpeen aiheuttaneet syyt sekä LSA-järjestelmän tarkempi määritelmä. Tutkimus avaa LSA-järjestelmän potentiaalisena taajuudenjakojärjestelmänä selventämällä taajuuksien nykyistä käyttöä sekä kansallisella että kansainvälisellä tasolla.

Tutkimus sisältää WISE2 projektin projektisuunnittelijan Arto Kivisen haastattelusta tehdyn yhteenvedon, jossa käsitellään Suomen LSA-tutkimuksen ja kehityksen tilannetta WISE2-projektin kautta. Haastattelussa keskitytään projektin ja sen yhteistyökumppaneiden saavuttamiin tuloksiin sekä LSA-järjestelmän jatkokehitykseen ja tulevaisuuden näkymiin Suomessa ja Euroopassa.

Tutkimuksesta käy ilmi, että LSA on potentiaalinen tapa jakaa spektriä tulevaisuudessa. LSA-järjestelmällä on vielä joitain haasteita ylitettävänä, mutta jatkuvalla järjestelmän kehityksellä ne eivät vaikuta ylitsepääsemättömiltä.

ASIASANAT:

taajuusjako, LSA, mobiiliverkot

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LIST OF ABBREVIATIONS

3GPP	The 3rd Generation Partnership Project
ASA	Authorized Shared Access
CEPT	European Conference of Postal and Telecommunications Administrations
GSMA	The GSM Association
ISP	Internet Service Provider
LSA	Licensed Shared Access
MO/MNO	Mobile Operator/Mobile Network Operator
NRA	National Regulatory Administration
PMSE	Programme Making and Special Events
QoS	Quality of Service
RSPG	Radio Spectrum Policy Group
TUAS	Turku University of Applied Sciences
U.S.	United States
WRC-07	World Radiocommunication Conference 2007

1 INTRODUCTION

Today's world is a world of fast communications systems. Several billion people around the world send and receive information almost in real time even to the most remote locations on the planet. Information transfer speeds and technology that were science fiction not too long ago are becoming the norm for data transfer rates all over the world. This has caused us to view the concepts of communications and information in a profoundly different light. Today's information is instant and everywhere.

The internet has been arguably the most important social and economic invention of the last century. It has enabled a whole new level of information exchange for both the public and the business world and has drastically reshaped many of the traditional medias to match the modern criteria for publishing information. Many industries have had a total makeover to ensure their products still match the needs of their customers and look very different nowadays than few years ago. Also, the general population has changed many of their old habits for new more contemporary ways, shopping for specialty goods and ordering items over the internet is a good example. Internet has profoundly changed the way we view the world and how we see ourselves and others in it.

We are living in a very exciting time of constant progress and ongoing development of the internet itself and phenomenon’s related to it. One phenomenon that is currently very popular is the mobile use of the internet. Major part of the information technology industry has gradually been moving towards mobile information transfer. Devices that were unheard of or not taken too seriously few years ago, like tablets and smartphones, are starting to seize the business of information transfer. Convenience is taking over.

Quickly developing and even more popular mobile information transfer means a need for a fast mobile connection to the internet, a mobile broadband. Many internet service providers (ISP) and mobile operators (MO) have seen the business opportunity and transformed their business to include mobile solutions. Many MO’s tend to invest heavily on mobile broadband solutions as more and more possibilities become available for mobile internet users. This trend has led modern mobile broadband technology to develop very fast and at this rate it will very soon match other current wireless and physical networks in speed and availability.

The fast development of mobile broadband has caused a massive demand for bandwidth. Also, the increased availability of mobile computer programs or “apps” and availability of networks worldwide have made sure that mobile bandwidth is constantly demanded in increased numbers. Latest generation mobile devices can perform the same duties as the traditional computers at home or office and require more efficient ways to broadcast and receive data from around the world. MO’s constantly offer faster mobile connections to customers and develop new networks to ensure that supply to responds for the demand. This development, even as it’s needed and healthy technological progress, cannot continue forever. This is because radio spectrum, on which mobile broadbands along many other things work, is limited.

There are three ways of how we can expand our current mobile information transfer. First is to build more mobile base stations and redefine their cell radius to be smaller so that they accommodate less users per cell. This will ease the load of a single base station and allow more users to access the mobile network on the area. This solution adds capacity to the network but might be cumbersome as it is just a local solution and will require a significant amount of work and investment to implement

Second way to expand mobile networks capacity is to develop new technology. Development of new technology in the field of mobile networks is self-evident. Our current 4G mobile network technology will be replaced by next generation of technology and it in turn will be replaced by the following generation. Every generation find a way to improve the last and define our needs anew for the next one. While development of new technology is vital for our mobile networks to function in the future, it does not remove the issue of other technology being developed and improved as well. In future while we might be able to transfer multiple times more information in same time that we currently do, that information tends to grow and evolve in unison with our capacity to store and transfer it. Biggest current gamechanger has been internet of things, that has vastly expanded the number of appliances connected to mobile networks.

Third way is to optimize the use of bands by sharing the spectrum. As no solution that we currently know removes the fact that there is a limited amount of spectrum, optimizing what we have seems like a good idea. Spectrum is also mostly divided for different factions depending on the band called incumbent users that have the legal right for the use of certain band. This means that if we wish to redistribute spectrum even temporarily, we must go through the incumbents first and find a solution that is also acceptable and beneficial for them. There are few suggested ideas to counter the problem of limited

spectrum, one of them is Licensed Shared Access (LSA), or as it is sometimes erroneously called by its previous term Authorized Shared Access (ASA). LSA is a complementary solution for mobile network operators to access spectrum when critical incumbent uses cannot be vacated from a frequency band. LSA has been identified by the Radio Spectrum Policy Group (RSPG) and the European Conference of Postal and Telecommunications Administrations (CEPT) as one of the key tools to overcome the European spectrum challenge. (Lavender et al 2013)

LSA is meant to be mutually beneficial agreement for the MO's and licensed incumbent spectrum users. It is important that we understand the hopes and demands of both parties and ensure that neither one is left out from the discussion. There is fear in some incumbent users that the system would complicate their operations or even limit their access to their licensed spectrum. This should not be the case and to ensure that incumbents and instances developing LSA need to keep up an open and objective dialogue.

1.1 Research question

In my thesis, I will study the LSA, utilization on LSA and the tools developed at WISE2 for LSA on 2.3GHz. Is LSA a viable answer for the problem of limited spectrum and what kind of tools we should develop to make LSA a possible option for spectrum sharing? The goal of my thesis is to participate in and to help the future development of spectrum sharing by demonstrating and analyzing the tools developed for LSA in WISE2 project. I will also address the structure of LSA, current global and Finnish national state of LSA and the future plans for development.

1.1.1 Background of thesis

I worked for WISE2 project as a project assistant from early 2013 to late 2014 and had an opportunity to participate in the LSA development at WISE2 project. My main focus was at testing and helping in development of Programme Making and Special Events (PMSE) tools developed at WISE2, but I participated also in WISE2 LSA study and development by attending several WISE2 and Fairspectrums SCRUM meetings considering development of LSA tools. I also participated in International LSA workshop

3.9.2013 at Helsinki as an assistant for WISE2 project, where WISE2 presented a demonstration of protection database in simulated environment.

1.2 Background

Currently, commercial access and use of the spectrum globally and at European level is generally authorized in two ways: either through an individual license or in an accordance with license - exempt (unlicensed or ‘commons’) rules (GSMA 2013). There is a much greater demand for frequencies allocated to mobile communications than the current supply. This problem occurs also with television and radio broadcasting.

Recently there has been great interest globally in the LSA principle. Bands that are most interesting are 3.5GHz in US and 2.3GHz in Europe. Currently these bands are partially used by incumbents that have different business cases and services from mobile broadband. (GSMA 2013)

Because of this the current situation is complex in Europe. The 2.3GHz band has been globally identified for mobile broadband at international level at World Radiocommunication Conference 2007 (WRC-07) and it has been standardized at the The 3rd Generation Partnership Project (3GPP), but still in most cases non-mobile incumbents remain the main users of this spectrum (GSMA 2013). There are various national and private incumbents Europe wide that use the band in manners that differ from its identified use and intend to do so in future.

1.3 What is LSA?

In Radio Spectrum Policy Group Draft report “RSPG13-529 rev1” LSA is defined in the following way:

“A regulatory approach aiming to facilitate the introduction of radiocommunication 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)". (RSPG 2013)

In short LSA is a spectrum sharing framework that enables licensee to temporarily get granted spectrum from its incumbent user in a way dictated by the agreement between licensee and the incumbent. Spectrum that is granted in this manner is still licensed for the incumbent by the regulator as it was before and does not undermine incumbents right to it in any way. This means that LSA should not be considered as a new licensing regime but a regulatory framework which aims for more optimized use of the spectrum.

LSA is not just a one-sided solution for some parties to get greater access for the spectrum. LSA is also not spectrum trading and it has nothing to do with unlicensed use of the spectrum. Following key features defined by ECC in their draft report RSPG13-529 rev1 explain the concept more completely.

- Mutually beneficial: There has to be a mutual gain from the use of LSA for it to work as intended. This means that both parties need to have an incentive to engage in a sharing arrangement and that neither of them is the sole net beneficier.

- Voluntary: All access to the incumbent's spectrum by the new user need to be fully agreed and negotiated between the incumbent, new user and national regulator. All arrangements must be completely voluntary.

- Harmonized bands: To create and take advantage of scale economies, the bands in question are likely to be harmonized for uses requiring significant additional spectrum access, in particular for mobile broadband services.

- Legal certainty and quality of service: In a shared band the new license holder has an exclusively defined access to incumbent's spectrum specified case by case in every agreement between incumbent and the new user. Both users will be equally protected from interference; In this matter, the new user will be of equal stand to the incumbent.

- Compatible with European regulation: As with all matters of the spectrum usage, presence of regulator is mandatory as the individual agreements between

incumbent and new user can not be in contradiction with the existing regulations and laws.

Following figures will demonstrate different sides of LSA. The administrative implementation of LSA in the 2.3GHz band is show in the Figure 1and the functional implementation of LSA is shown in Figure 2.

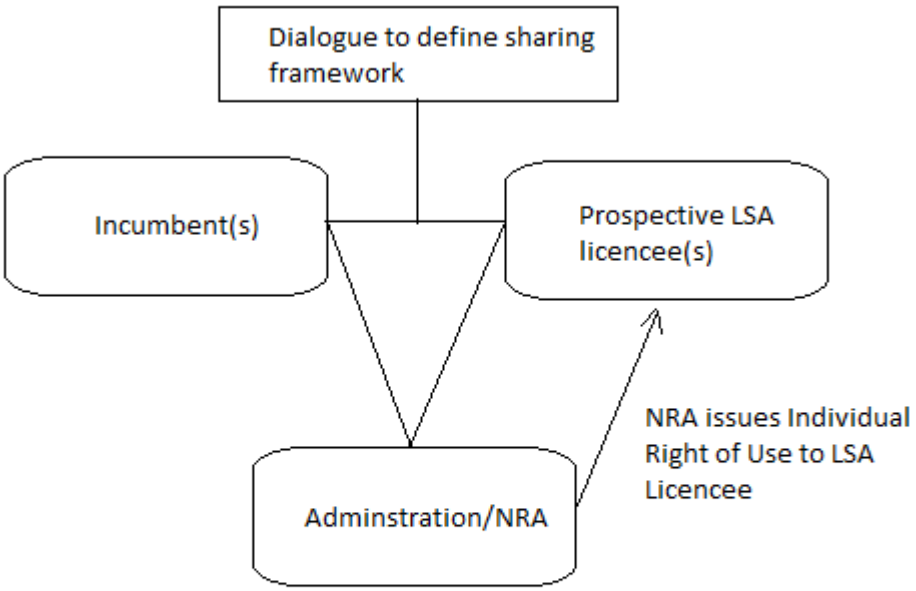


Figure 1 The administrative implementation of LSA (ECC 2012).

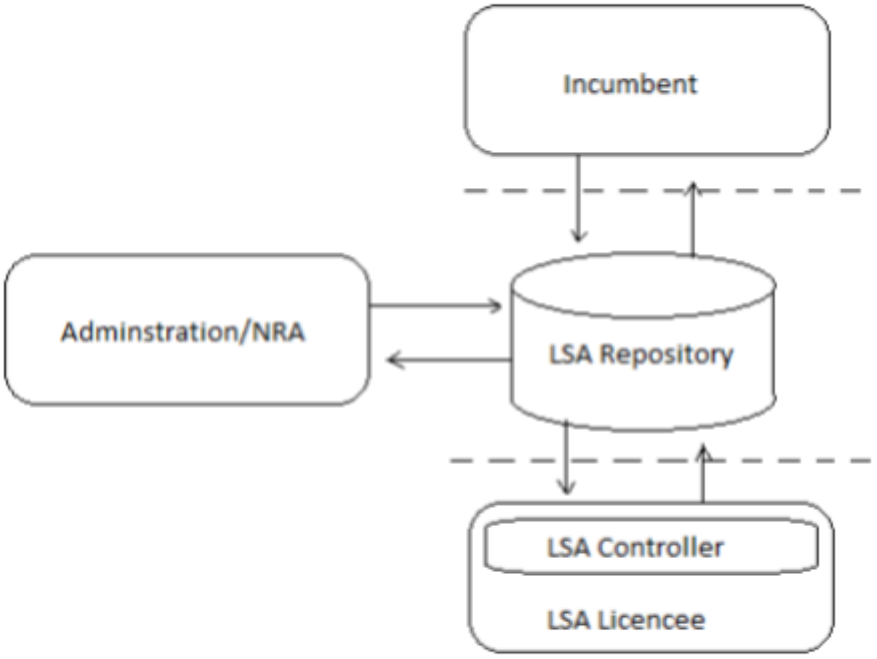


Figure 2 The functional implementation of LSA (ECC 2012).

2 SHARED SPECTRUM

This chapter will discuss the use of the 2.3GHz band at Finnish national level. It will also address the extent of sharing possibilities at 2.3GHz band and go through some predictions of the future development of spectrum use and sharing.

2.1 Use of the 2.3GHz band in Finland

In Finland, the 2.3GHz band is strictly regulated. A radio license for using such frequencies requires a separate broadcasting license and use of the frequencies are determined in a government degree. (FICORA 2013)

The 2.3GHz band as whole has currently been reserved for wireless cameras with following specifications as shown in the following table.

Finland also faces the same mobile broadband difficulties with the rest of the Europe. The demand for mobile broadband is greater than supply, even more so in the case of Finland. In January 2013, Finland had the highest take-up rate of mobile broadband in the EU. While rest of the EU had an average of 54.5% subscriptions as a percentage per population, Finland had a take-up rate of 107.1% (Digital Agenda Scoreboard 2013). This speaks for a high demand of spectrum and that the situation is moving forward to a point where MO’s cannot respond for the markets demand for mobile data transfer solutions unless some way of increasing the amount of spectrum allowed for the mobile use is found.

Frequency band Services in Finland	**Sub-band (its width) and usage**	**Mode of traffic Class of station and direction, Radiated power / Transmitter power (max.) Channel spacing / Bandwidth Duplex separation and duplex band Class of emission Standard type**	**Terms and comments as to radio interface**
FIXED	2300 - 2400 MHz (100 MHz) Wireless cameras	-	Wireless cameras and ENG-links 2290 - 2400 MHz. Channel spacing max. 20 MHz. In the frequency band 2290 - 2315 MHz the channels are assigned on a case-by-case basis. The frequency band 2315 - 2400 MHz is in common use for cordless cameras and ENG links subject to licence. The future use of the frequency band is being studied at European level. Standard EN 300 638. Standard EN 300 744. ERC Recommendation ERC/REC 25-10

Table 1 Frequency Allocation Table (FICORA 2013).

2.2 Possibilities of LSA at 2.3GHz

Plum Consulting has made an analysis of spectrum sharing possibilities in Europe. The analysis is based on interviews with European stakeholders and it studies the extent of current use of the band by frequency, location and time. Countries that were studied were Finland, Germany, Ireland, Italy, Sweden and the UK. In the case of Germany, there were growing use of the band by the incumbent users and no specific activity to address sharing through LSA at the time (Lavender et al 2013). The anticipated role of LSA in countries studied (not including Germany) is as shown in the following table:

Country	Nature of sharing envisaged	Role of LSA	Availability for mobile services
Finland	Sharing by frequency, location and time	To protect incumbent PMSE use	85 MHz available for 90% of the time; 15 MHz on a geographically limited basis
France	Sharing by frequency and location	To protect incumbent defence use	80% band in areas covering 80% population
Ireland	None – incumbent uses not expected to remain	None	100MHz for all population
Italy	Sharing by frequency	To protect incumbent defence and fixed use	85MHz on a national basis and 15Mhz on a geographically shared basis
Sweden	Sharing by frequency and location	To protect incumbent defence use	100MHz in all inhabited areas – exclusion in uninhabited area
UK	None	None expected before 2022	40 MHz exclusive, sharing for 20MHz only considered in the longer term

Table 2 The anticipated role of LSA (Lavender et al 2013).

2.3 Need of future development

There has been a survey made by CEPT in 2012 where they studied the current and future expected use of the 2.3GHz band in 40 countries. Results of the survey showed that the band that was initially harmonized for mobile broadband is in fact used in various ways. Use of this band varied from country to country and included for example governmental use (military, aeronautical telemetry, emergency services, wireless video link), PMSE applications (video links, electronic news gathering) and secondary amateur services. (ECC 2012)

The survey showed that of the 40 countries studied 43% had plans to use the band for broadband wireless access (BWA) or mobile services. 30% of the countries surveyed

had no plans to change the use of the band. Rest 27% were uncertain about their future use of the band. (ECC 2012)

These numbers show us that in many cases there will be increased demand for the 2.3GHz band. As there is a limit for how much spectrum use can increase, future development of LSA framework will be even more crucial in becoming days.

3 INTERVIEW

I interviewed Arto Kivinen from WISE2 project about research and development of LSA at TUAS, in Finland and globally. Arto worked as Lead software developer on LSA related software developed by WISE2 and also as project engineer at WISE2.

3.1 Structure of the interview

The interview has a following structure:

1) What is WISE2 project?
    a) general description of WISE2
    b) Why there was a need for WISE2
    c) Different departments of the project
    d) Goals
    e) Department related goals
    f) Affiliates and partners
    g) Operational environment

2) What has been studied at WISE2 regarding LSA?
    a) Research subjects
    b) Research methods

3) Results
    a) Fulfilled goals
    b) Developed software

4) Future plans
    a) Goals
    b) Affiliates and partners

The interview was held at Turku University of Applied Sciences at Lemminkäisenkatu 30 Turku 6.3.2015. Participants were Arto Kivinen as interviewed and Ville Mattila as interviewer.

3.2 Results of the interview

3.2.1 What is WISE2 project?

WISE2 is a TEKES funded project that was setup to study how to utilize unused wireless frequencies. Projects predecessor WISE was setup to study TV white space protection techniques, where WISE2 has focused more on methods how to protect incumbent users at 2,3GHz (WISE 2011). According to Arto, short answer for biggest difference between WISE1 and WISE2 development wise was the scale of things and number of incumbents that needed protection. Also, a big difference was that LSA at 2,3GHz brought in the mobile networks and their challenges to the study of spectrum sharing. The key need that WISE2 project answers to is study of how to protect the incumbent users and what kind of a tools are needed to ensure that protection at 2,3GHz.

WISE2 was implemented in two departments at TUAS, radio laboratory and business information systems. Radio laboratory has mainly focused on TV white space and LSA measurements and testing, while system development has developed many different tools for LSA system to operate with. Goal of the systems development was to develop tools usable in working, real LSA system, that would suit for the LSA Controller as well as for the LSA Incumbent. In turn radio laboratory's goal was to measure and prove in practice that computer calculated algorithms and their results were true and real results on the field. In general, both departments work towards the same goal which is to ensure and implement a real LSA system development.

Arto mentioned some of the stakeholders that WISE2 has mostly worked with, those are VTT Technical Research Centre of Finland Ltd (VTT), Nokia Networks, Centria University of Applied Sciences and Fairspectrum Ltd. VTT is the leading research and technology company in the Nordic countries and has developed an LSA controller in its projects. Nokia Networks is a multinational data networking and telecommunications equipment company and on LSA associated projects has focused on control systems of base stations. Centria University of Applied Sciences has focused on upkeep, support and administration of LSA test network at Ylivieska. Fairspectrum is a start-up company that works in the field of spectrum sharing and has been responsible the LSA Repository in studies associated with WISE2 project. Centria, Nokia Networks and VTT are also a part of projects called Core+ and Core++ which are an abbreviations of Cognitive Radio Trial Environment+/++.

The whole development environment where WISE2 operates has been made possible by FICORA, that enabled the use of 2,3GHz in Finland for LSA studies. This was a huge thing as nowhere else in Europe had the national regulatory authority enabled this kind of possibility before. At that point this also gave Finnish LSA research a temporarary edge over other countries and has made Finland the leading country in LSA development in Europe.

3.2.2 What has been studied at WISE2 regarding LSA?

Main focus at WISE2 has been on LSA repository which handles the distribution of frequencies on LSA system. Main aspects have been how the LSA repository and the LSA controller communicate with each other, what kind of an information repository should have, what information controller should have and what information can be transmitted between these two entities.

There has also been a lot of communication and exchange of ideas between WISE2 and MNOs about what information MNO can process and share outwards, what can incumbent give to LSA system and what needs to be done to that information before it can be given to MNO to use in LSA. Key issue here has also been the architecture of the repository database itself and how it must be designed to serve multiple MNOs at the same time.

Naturally there has also been discussion with the regulator about the needs of a regulator in LSA system. WISE2 has produced a concept level rapport about what information could be given to the regulator.

One thing that has also been studied is what kind of protection methods there are for protecting incumbent users. These currently include three different protection types. First there is location based protection where protected user is given a radius area around the use location. Polygon based protection is a protection where the area can be defined to be non-circular and cover more ground than location based protection. Lastly there is the masked protection, where the exact location of incumbent cannot be determined from the protection itself. Masked protection has been developed mainly for Military incumbents use.

The study and development at WISE2 has mainly been conducted by trial and error-method as there is currently no standard in place for LSA. This means that the process

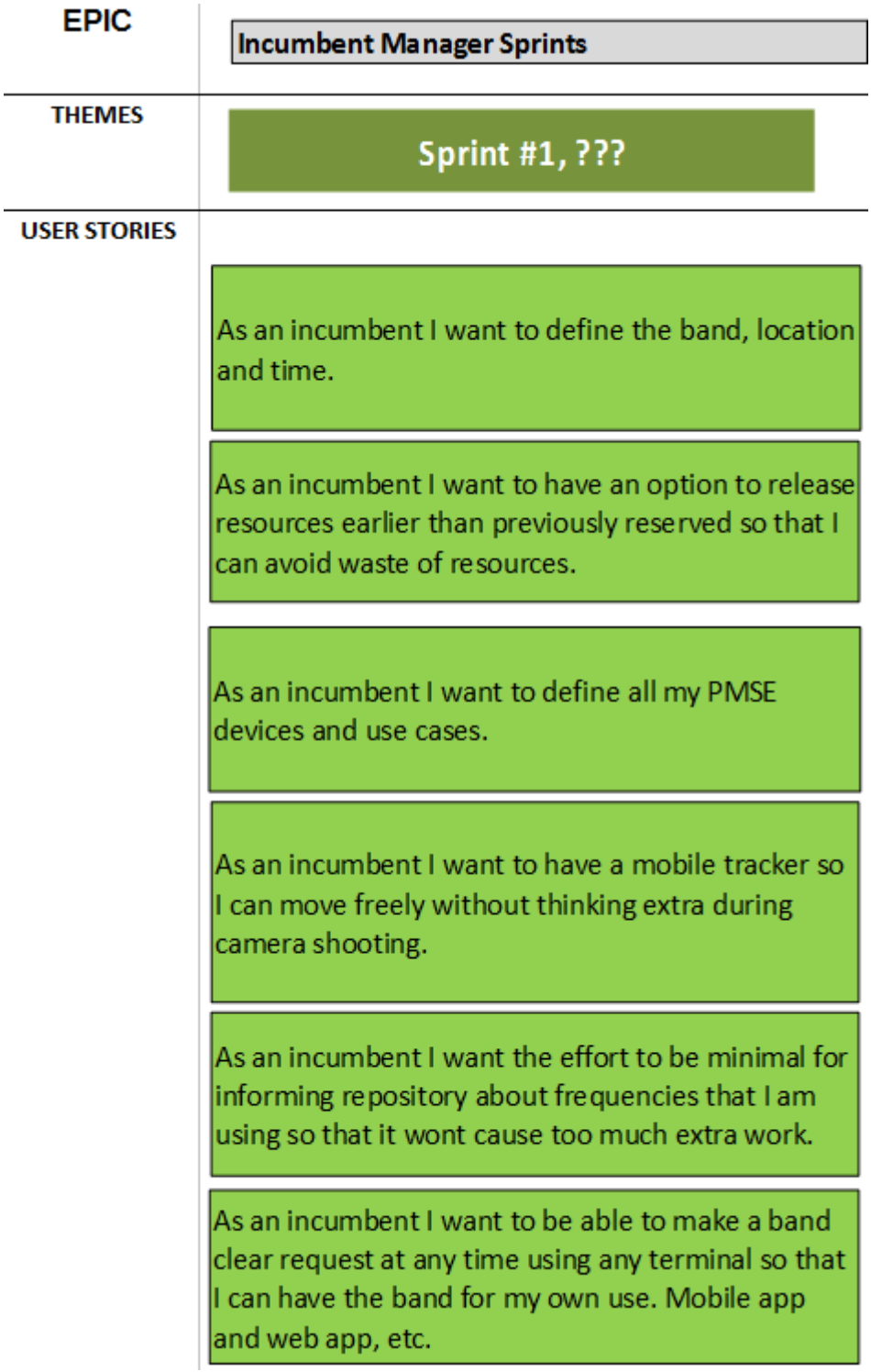
has been first creating a concept and then working on it by trying various approaches and then selecting the one that is best suited for the purpose.

The underlying structure of requirements analysis illustrated in Picture 1 has been mostly based on SCRUM-method user stories that biggest stakeholders in Finland have been working on together. These stories are thought from points of view of all users and thus include both MNOs requirements for LSA and Incumbents requirements for LSA. These stories have eventually been made in sprints, where they have been given a deadline of when the issues related to the story must be solved.

3.2.3 Results of WISE2

WISE2 had a good success rate with set goals, as most of its goals, especially all the goals regarding software development for LSA, that were set were also met. Most noteworthy results were gained from tests at Ylivieska, where WISE2 systems development in cooperation with other stakeholders was able to develop a working test site LSA system. Test were conducted so that LSA Repository could communicate with controller and incumbent could make protections with the tools that WISE2 developed. It was also proven that the tools enabled the evacuation of MNO from the protected area in acceptable time, which could eventually be done in 3 minutes from the protection request. Radio laboratory also had great success at field measurements, that eventually enabled the use of developed measurement protection algorithms for the LSA controller.

WISE2 has also had many changes to present the results of its work and thus has gained a high publicity value for its research. Reports that have been produced with the other stakeholders, mainly with CORE+ members, have received a high amount of interest and attention of world's leading LSA developers. WISE2 has also had a several demo events demonstrating its developed software at several high-end LSA related events. These demos have demonstrated a whole working true LSA system that successfully protects the requested band at requested time. WISE2 has made a profound impression on LSA research and development field and is the leading party on LSA repository development.



Picture 1 examples of CORE+ ASA stories

The following software was developed at WISE2 for the purposes of LSA study and development:

LSA Repository

LSA repository is a cloud database service, where multiple incumbent's information is stored and used to create a protection at certain requested location on certain requested band and time. LSA repository saves protection data anonymously, so that the data saved at LSA repository does not impose an information security risk for the incumbent user. Protection information can either be a single protected spot or an area of protection.

LSA repository can communicate with LSA controller with either HTTP post or websocket methods. When HTTP post protection request is made, LSA repository sends the LSA controller an exception notification that LSA controller processes. When the LSA controller has done all the necessary actions to cut off broadcast on the requested band at the requested location, LSA incumbent receives a protection complete notification. The key difference in use with these methods is that websocket can send these exception notices more efficiently and securely.

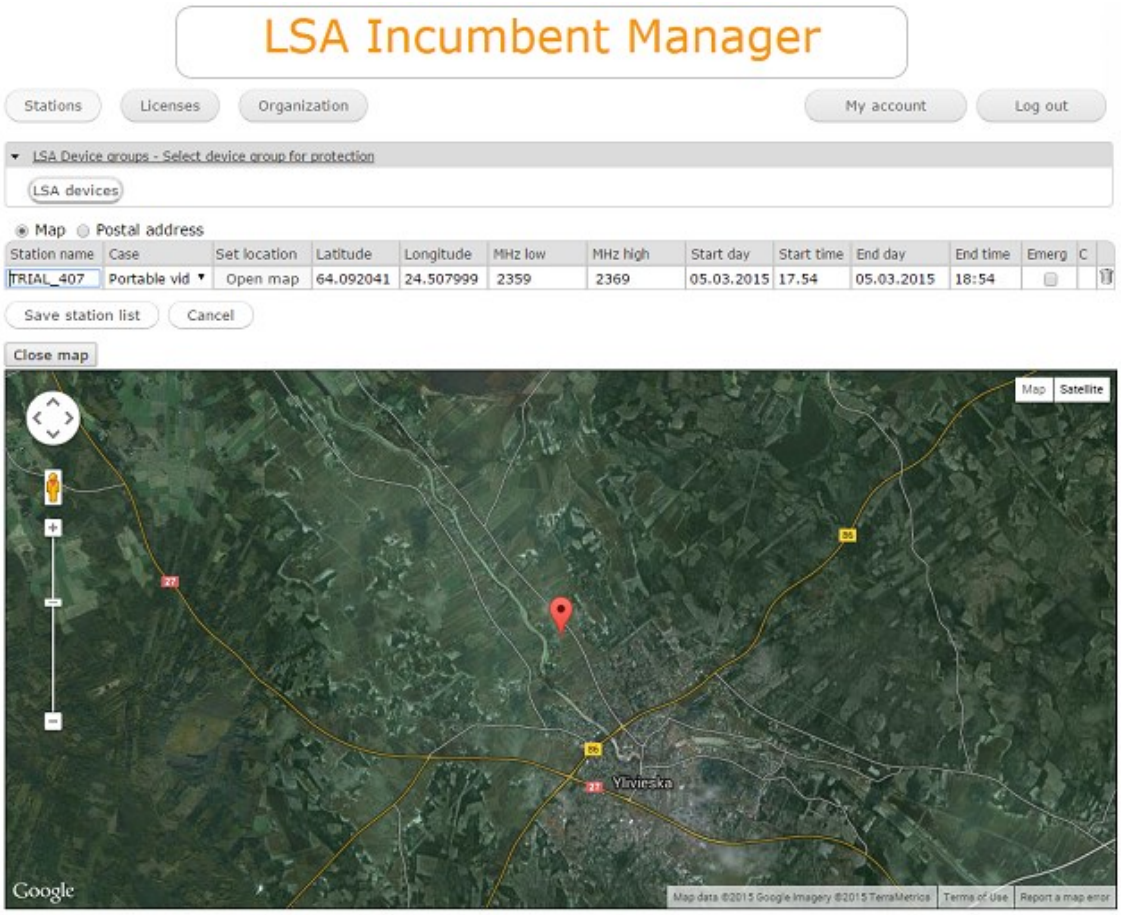
In short, the LSA repository is a protection database where the LSA incumbent's information is stored and what sends said information to LSA controller for further processing.

LSA Incumbent Manager

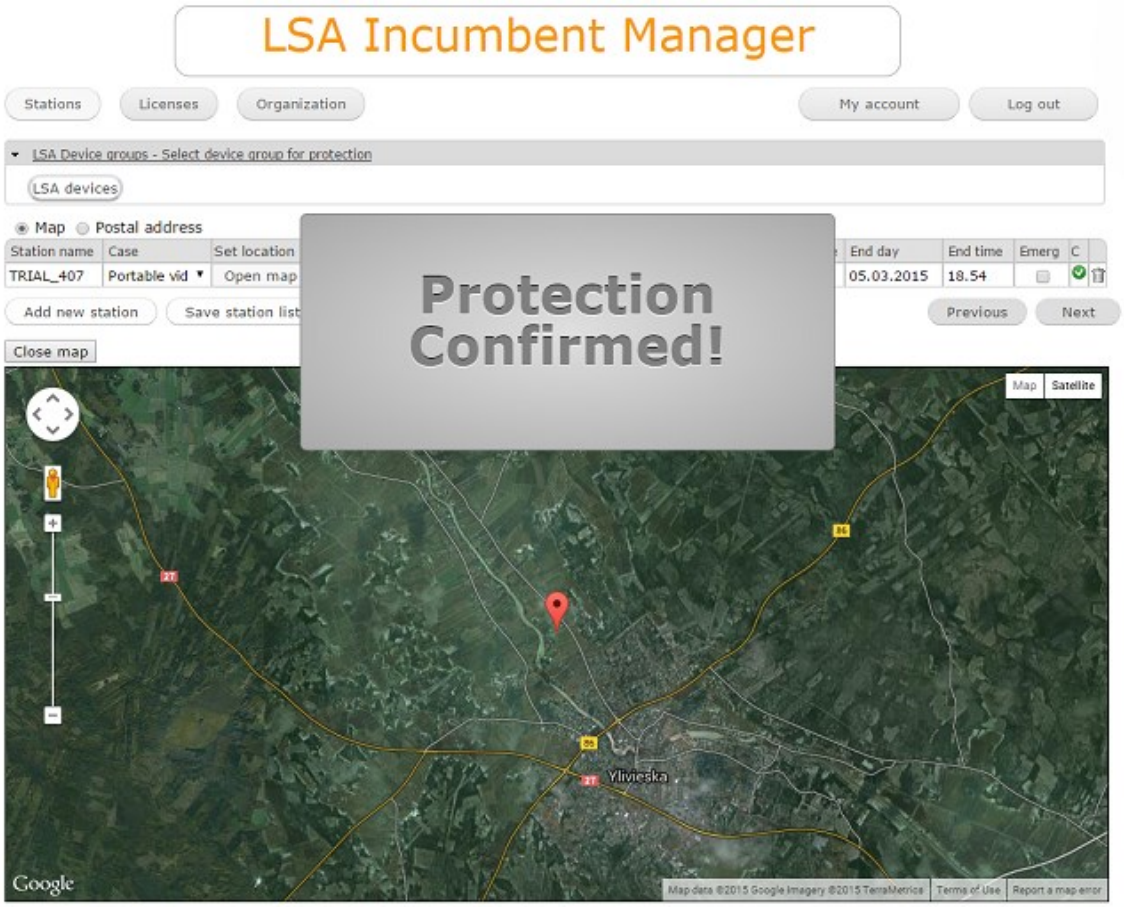
LSA Incumbent Manager illustrated in Picture 2 and Picture 3 is a map based tool for the incumbent for making protection requests at desired location on desired band and time. LSA Incumbent inputs the location, requested date and time, use case of the band and the band of the requested protection to the LSA Incumbent Manager and sends the request to LSA Repository. When the LSA Repository has made an exception notification to the LSA Controller and the LSA Controller has processed the request and made the actions needed to ensure the protection, LSA Incumbent receives a protection confirmed notification and the protection has been made.

LSA Incumbent Manager can and should be used also to update the protection information when needed. If the need for protection has changed or will change, LSA

Incumbent Manager can make an update on the protection request without having to fill all the protection information on a separate protection request.



Picture 2 LSA incumbent manager 2014

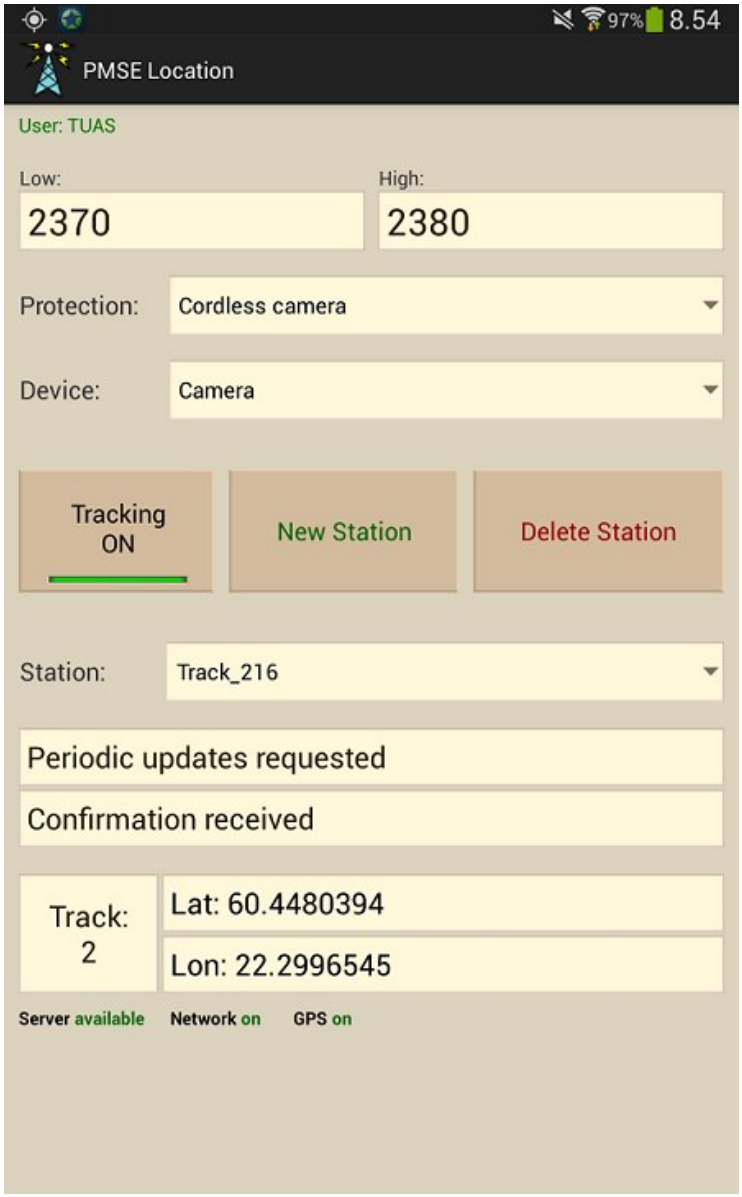


Picture 3 LSA incumbent manager 2014

Android software

Android software works in tandem with LSA incumbent manager for making protection requests for the incumbent. Android software's main function is to provide automated mobile solution for making protection requests. LSA incumbent manager and Android software use the same credentials to log in.

With Android software, you do not have to make a new protection but you can rather pick a premade protection and update it on the field. You can set parameters about where your base of operations is or where you do not need the protection and the automation will take these into account. Basically, the software functions as a mobile version of LSA Incumbent Manager.



Picture 4 Android software 2014

LSA notification protocol

LSA Notification protocol is a communication protocol between LSA Repository and LSA Controller. LSA notification protocol defines what kind of a messages are sent between LSA repository and LSA controller regardless of the technology used to send those messages. LSA notification protocol is used to communicate exceptions in LSA system, meaning LSA Incumbent entering an area where LSA system is deployed.

Main reason why LSA notification protocol was developed is that without it, LSA Repository would need to make calculations that would require LSA Controller to share MNO's sensitive information. With LSA Notification protocol, LSA Repository can calculate a protection zone that forms a polygon which LSA Controller can then compare to its sensitive information. This makes it possible for MNO to evacuate the protected band at the requested time and optimize its network.

3.2.4 Future development

After WISE2 TUAS has plans to keep developing LSA system even further. In future TUAS will be working in even tighter cooperation with other major stakeholders in Finland, as TUAS has joined CORE++ project that will continue CORE+ projects LSA development. Arto said that main focus at TUAS will be at bringing out LSA Repository even more than before, fine tuning and developing existing LSA Repository software, studying possible protection calculations at LSA Repository and bringing in more complex database based on geography and geography related data.

TUAS will also keep developing other existing software. One of the goals will also be to clearly demonstrate LSA Incumbent how the protection is actually made. Most of the development will be fine tuning the existing tools. Final major goal of future LSA development at TUAS will be gathering new information of LSA system and keeping in touch with global stakeholders and LSA related instances. Future development of LSA at TUAS will also include study of SAS system that is used in U.S., so international cooperation with LSA stakeholders at U.S. will be needed.

4 FINAL WORDS AND CONCLUSION

4.1 Conclusion and self-analysis

I set out to study the possibilities and viability of LSA as a spectrum sharing method that could be widely implemented and used in our everyday communications. I concluded that LSA is a very serious possibility for answering the issue of limited spectrum. LSA has few issues to overcome like benefits for the incumbent and all parties to understand that it is not aimed to be a new regulatory regime but a mutually beneficial voluntary system, but with continuing development and open dialogue it has the potential to be the system we could use to share spectrum.

Tools developed at WISE2 have been deemed to be useful and well suiting to the needs of LSA. Goals regarding software development at the project were met and the software has been used in future development of LSA and even in commercial manner by Fairspectrurm, that is pioneering in finnish LSA development in many areas (Kokkinen, H. 2012). Even if all the goals regarding other areas of study and development were not completely met, WISE2 should be considered a success by the tools it delivered for the LSA alone.

My study had its ups and downs, but in the end, I feel that it answers the question it was set to answer. Making of the thesis had an interruption from 2015 to 2017 due personal reasons and I sadly feel that it shows in the end result. I feel that most of my goals were met, but there is clearly room for more study and participation in the development of LSA. The nature and science behind the radio spectrum was also completely new to me at the beginning of my work at WISE2 but after the study and been working at WISE I feel that I have an actual understanding of basics of the spectrum and how we use it to communicate in our everyday life. As an experience, even considering all the ups and downs, this has been a very pleasant one and I feel I have been privileged to participate in something that is profoundly important to our modern society.

4.2 Final words

As the trend of mobile use of internet and online services is ever increasing, framework and system for sharing limited spectrum will be essential in the future. If we wish to keep our fast and comprehensive mobile service and do not want to sacrifice on other services we need a system like LSA for optimizing the use of the spectrum.

WISE2 at TUAS has comprehensively studied and participated in LSA system development in Finland. Tools that WISE2 has developed are held in high value amongst the Finnish and international stakeholders alike. Value and potential of those tools is great and they could easily be counted as the major accomplishment of WISE2.

WISE2 has also had a major part of LSA development environment in Finland and has been actively participating in policy making and academic study of LSA. Reports and demo events held by WISE2 have received much of attention from major stakeholders around the world.

WISE2 has been a successful project, as all its goals regarding software development were met and there will be future development and study of its results. Project demonstrates the potential of University projects and why there is a high potential of actual relevant gain in projects at TUAS. WISE2 has had a profound impact on LSA development field and there are high expectations in future development of LSA system at TUAS.

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