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## Business models and investment options for use of licensed shared access of spectrum

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## **Business models and Investment options for use of Licensed Shared Access of Spectrum**

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### **Abstract**

A Licensed Shared Access (LSA) “authorization/license” includes an agreement between the secondary sharing user (some type of operator) and the primary license holder (e.g. a government organization) around the conditions of use (where, when, how). Compared to secondary access LSA offers a more attractive case for long term investments.

The contribution in this paper is that we look into how LSA can be used by different types of actors. The outcome depends heavily on what type of actor that makes use of the spectrum using LSA. Based on cost structure analysis (leading to required investments) and analysis of availability of the basic spectrum resource we can identify clear differences of the commercial usability of spectrum awarded using LSA, all depending on what actors that make use of the LSA contract. Cases where new actors need to invest a lot in new infrastructure do not that look that promising.

We cannot identify a separate “LSA business case” that is feasible from a business perspective (where the key resource for the operator is spectrum awarded using LSA). Service availability that cannot be guaranteed due to LSA type of spectrum being the only resource seems risky, especially when combined with high investments. However this applies only for outdoor deployment. For deployment of a new indoor network the situation is different. The cost structure is the same no matter if a new or existing actor deploys the networks. In addition, a multitude of spectrum bands and spectrum access options exist indoor so the service provisioning will be less vulnerable if some part of spectrum is not available some period of time.

### **Key words:**

Actors, Business models, Competition, Cost structure analysis, Licensed/non-licensed spectrum bands, Mobile broadband, Network deployment, Regulation, Secondary/shared spectrum access

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## 1. **Introduction and motivation of work**

Wireless Internet access to an increasing number of new and existing services has become a major trend in just a few years. The rapid success of smartphones, tablets, and mobile broadband dongle in combination with new pricing schemes has resulted in an enormous traffic growth in the mobile networks. Operators are enhancing their networks to meet the demand by adding more sites and capacity, and by introducing new radio access technologies such as HSPA+ and LTE. This creates an increased requirement of spectrum for mobile service. Most of the new requirements are easier to meet with more bandwidth and new spectrum bands. New frequency bands are already allocated for wireless broadband in the 2,6 GHz, 800 MHz and 1800 MHz bands. This will help for some time but quite soon more spectrum has to be made available. Governments and industry organizations have recognized this and have formulated programs targeting 500-1000 MHz of additional spectrum in the relative near term (5 years).

Another possibility is to use unlicensed spectrum band, e.g. bands used for WiFi. Yet another possibility is secondary access to spectrum which has primarily been allocated for other services. Examples of such bands are radar bands and TV white spaces. In all together several hundreds of MHz belongs to those categories. These strategies do not allow dedicated use which results in low level of services guarantees and low incentives for operators to make long term investments. At the same time there exists spectrum which is allocated public services by government organizations that are not used fully. Various forms of shared spectrum access approaches are now therefore considered. In the United States the President's Council of Advisors on Science and Technology (PCAST) recently (July 2012) proposed an accelerated process to study shared spectrum access in public services spectrum.

### ***Problem area and Research Questions***

The licensed shared access has been received with large interest from the telecom industry since it assumes long term contracts and some guarantees for the secondary user. A Licensed Shared Access (LSA) "authorization/license" includes an agreement between the secondary sharing user (some type of operator) and the primary license holder (e.g. a government organization) around the conditions of use (where, when, how). Compared to secondary access LSA offers a more attractive case for long term investments. In this paper we investigate different business scenarios where different actors make use of LSA in order to offer mobile services. We will address two main research questions:

- What business model and investment options can we identify for LSA
- Is there a viable separate "LSA business case" where the key resource for the operator is spectrum awarded using LSA?

### ***Research approach***

Overall we look into a set of *business scenarios* with different types of actors making use of spectrum awarded under a LSA license under the following conditions

- 1) LSA contract to multiple mobile operators that also have licensed spectrum
- 2) LSA contract to a single mobile operators that also has licensed spectrum
- 3) LSA contract to an independent actor that offers capacity on a wholesale basis
  - a. Nationwide network based on macrocell deployment
  - b. Local area networks provided by local operators
- 4) LSA contract to independent actor(s) that will offer end-user services, This could be an Internet player like Google or a M2M service provider

For the analysis of the scenarios we use both quantitative and qualitative analysis. *The quantitative analysis* is based on cost-structure modeling (Johansson, 2007, Markendahl, 2011) and using the same approach used in the QUASAR project for analysis of TV white space using secondary spectrum access (Markendahl et al, 2012).

The quantitative analysis is based on interviews and discussions with the regulator in UK and Sweden and with Ericsson. In addition, we will summarize the main points from a panel discussion on spectrum sharing at the IEEE PIMRC 2103 conference in London, September 2013<sup>2</sup>. The panel members represented a regulator, one fixed line operator, one network vendor and a university researcher. At the panel discussion the use of shared spectrum access was discussed from the perspectives of different actors: a mobile operator (with licensed spectrum), an operator without licensed spectrum, a broadcasting company, a company that wants to offer own services, a manufacturer and the regulator. The quantitative analysis is done at a conceptual system level and focus on pros and cons for different actors and different potential obstacles for these actors. One key question to consider is if the LSA approach is feasible from a long term perspective considering investments and risk.

### ***Outline of the paper***

In the next section related work is reviewed in the areas of mobile broadband technology, techno-economic analysis, relations cost-capacity-spectrum, secondary spectrum access, shared access and spectrum valuation. Then a techno-economic assessment is presented, (i.e. the quantitative analysis) followed by results from interview and discussions from different stakeholders (i.e. the qualitative analysis). In a discussion section these results are reviewed and compared with concepts based on the use of several spectrum access strategies. Finally, the paper ends with conclusions and directions of future work.

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<sup>2</sup> <http://theunwiredpeople.com/a-wide-spectrum-of-opinions-were-shared-at-a-pimrc-panel-session-on-shared-spectrum-access/>

## 2. Related work and contribution

### *Mobile broadband technology*

End user data rates and capacity can be increased by using higher bandwidths, by improving the spectral efficiency of the radio access technology or by adding more base stations. A good example of the Telecom vendor view of how to increase capacity is presented in (Landström et al, 2011) where a combination of three main strategies is described; to improve the performance of the macro layer, to build a denser macro layer and, to add low power base nodes (pico or femtocell base stations). The underlying technology development and standardization has been ongoing for many years in the main standardization body 3GPP. The main type of radio access technology is called 3GPP Long Term Evolution (LTE) and with upcoming releases known as LTE-advanced. Features to improve the spectral efficiency and peak data rates in LTE advanced is e.g. described in (Dahlman et al, 2009). Increase of system bandwidth using band or carrier aggregation is described in (Etemad et al, 2010).

### *Techno-economic analysis, cost-capacity-spectrum*

Cost and cost structure of radio access network have been investigated for more than a decade both by large techno-economic projects like TERA, TONIC and ECOSYS, (Loizillon et al, 2002) (Harno et al, 2006), Olsen, 2009) and by academic researchers (Zander, 1997), (Johansson, 2007), (Markendahl, 2011), and (Colletti, 2012).

For a specified amount of spectrum and for the same type of radio access technology the key relationship is that the deployment of N times more capacity at data rate X will imply N times higher costs (Zander, 1997). A common assumption is that the total cost is dominated by factors proportional to the number of base stations (we simplify by neglecting core network costs). The total cost can in this case (for a highly loaded system), be given by (Zander, Kim 2002)

$$C_{\text{infra}} \approx C_{BS} N_{BS} = C_{BS} c_A \frac{N_{\text{user}} R_{\text{user}} A_{\text{service}}}{\eta W_{\text{sys}}} \quad (1)$$

where  $A_{\text{service}}$  is the size of the service area,  $W_{\text{sys}}$  is the available (spectrum) bandwidth, and  $\eta$  is the effective reuse factor. The number of base stations, and thus the system cost, will almost linearly follow the provided capacity. If we want to increase the capacity  $N_{\text{user}} R_{\text{user}}$  significantly while maintaining the same total cost, we need to either

- i) increase the available spectrum  $W_{\text{sys}}$ ,
- ii) increase the effective reuse of frequencies  $\eta$ ,
- iii) lower the cost per base station  $C_{BS}$  or,
- iv) reduce the coverage area  $A_{\text{service}}$

The above basic ingredients for capacity improvement remain intact also for the coming years. Capacity can be increased by using higher bandwidths, by improving the spectral efficiency of the radio access technology or by adding more base stations. For a specific overall increase of capacity these three factors will contribute. A summary of the view of major vendors of telecom equipment on the relative contributions is presented in (Zander & Mähönen, 2013). There are large differences in the view on what can be achieved and by what means. Assumptions of additional spectrum are in the range 3 to 10 times, the view on improvements of spectrum efficiency range from 3 to 24. (Zander & Mähönen, 2013) argues that a spectral efficiency gain of 10-24 seems quite unrealistic as well as finding 10 times more spectrum for exclusive mobile use. What cannot be achieved in PHY/MAC layer efficiency and additional spectrum, has to be made up by deployment architecture. They argue that a more than 60-fold densification is a more reasonable assumption, both technologically and economically. The only other possibility would be to find more spectrum. That this is a proposition that is not realistic at the required scale is demonstrated by (Zander & Mähönen, 2013).

### ***Spectrum access options, secondary and shared access***

An overview of different spectrum access options and the additional estimated amount of spectrum that can be available is presented in (Zander & Mähönen, 2013). This includes licensed exclusive access, shared spectrum access and secondary spectrum access. Secondary spectrum access has been investigated in a number of EU projects like QUASAR<sup>3</sup> and COGEU (COGnitive radio systems for efficient sharing of TV white spaces in European context)<sup>4</sup>.

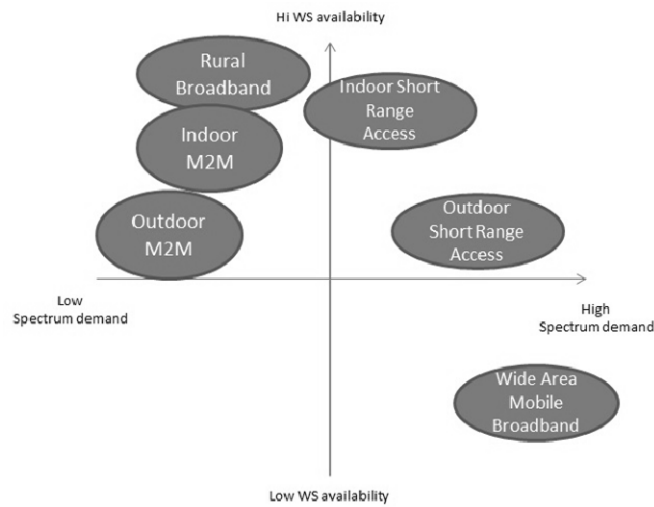
The technical analysis in the QUASAR project shows that the spectrum availability may be somewhat unpredictable in time or space. However, the business feasibility does not only depend on the total amount and size of spectrum opportunities, critical for success is that the spectrum demand of the specific application matches the availability. A key result in the QUASAR project is shown in Figure 1 where the expected spectrum demand of secondary services is mapped against the technical availability of white spaces for a number of the investigated service scenarios.

Rural broadband services and different machine-to-machine (M2M) communication schemes have potentially a lot of secondary spectrum at their disposal, since they either operate in low-population density areas or require only narrowband communication channels. However, the expected demand is relatively low for these applications, even if the customer base should become large. The availability of conventional licensed spectrum for the applications does also look promising for these applications.

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<sup>3</sup> <http://quasarspectrum.eu/>

<sup>4</sup> <http://www.ict-cogeu.eu/index.htm>



**Figure 1 Spectrum demand generated by traffic and business opportunities compared against the availability of white space spectrum (from Zander et al 2013)**

The business case for high-risk investments in “cognitive radio” technology for these applications is therefore limited. The situation is the opposite for the case of wide-area mobile broadband. There is a tremendous demand for mobile data and new frequencies could be used efficiently. The analysis in the QUASAR project shows that there is only limited amount of reliably available white spaces available for this sort of services.

The most obvious “sweet spot” for secondary spectrum use seems to be in the upper right corner of Figure 1: short range indoor systems with medium to large capacity demands, e.g. “WiFi-like” systems providing high-capacity hot-spot and indoor off-loading for mobile cellular data access. The infrastructure cost in these systems is not dominated by the radio specific equipment (which is likely to be low cost) but rather by the fixed backhaul, which will be useful even if the wireless access technology is changed later. For indoor and short-range systems the market entry is easier, and the situation may look more like introducing WiFi-band services.

Another result from the QUASAR project is that the business feasibility of secondary access must be put in an overall techno-economic context. In (Markendahl et al, 2012) the business feasibility of TV white space is analyzed taking into account both networks costs and spectrum auction costs. The analysis shows that market entrants will be in a more difficult position than the established actors. No matter the level of cost-capacity performance of cognitive radio equipment, a new operator at the market needs to invest in a new infrastructure with sites and transmission. If the spectrum costs are “high” (like in India) the use of TW white spaces can be more cost efficient for both existing operators and new operators.

One form of shared spectrum access, Licensed Shared Access (LSA<sup>5</sup>), has received a lot of attention the last years, one reason can be research presenting results like in Figure 1. Using the LSA approach spectrum bands allocated for one specific type of application with low level of use can be “leased” by another actor using agreements that state the conditions of use and how the usage right should be transferred back to the original (primary) license holder. An example is when the LSA licensee (typically a mobile network operator) makes a long term agreement with a government or military agency to use spectrum. The LSA approach has advantages compared to secondary access since the LSA implies exclusive usage for the licensee under the stated conditions. This stimulates long term investments in LSA infrastructure. Many government and industry initiatives have been taken in order to analyze the feasibility of LSA and/or to promote the idea (BEREC/RSPG, 2011), (Parcu et al, 2011), (PCAST, 2012), (Forge, Horvitz, Blackman, 2012). One group within CEPT (ECC FM53) focuses on LSA<sup>6</sup>. The mission of the CEPT group includes making a study on “the level of guarantee in terms of spectrum access under LSA that is required by an operator for network investment”.

### ***Spectrum valuation***

In general, the value of additional spectrum in the outdoor deployment can be figured out by knowing the additional costs incurred if the additional spectrum needed was not acquired. Analysis using *opportunity cost* or the so called *engineering value* is presented by researchers and organizations (Australian Communications and Media Authority, 2009), (Plum Consulting, 2011), (ITU, 2012) (Mölleryd & Markendahl, 2012). In many cases the engineering value showed great variations due the assumptions made and the engineering value relation to auction prices it may vary greatly as well.

### ***Paper Contribution***

Many reports and research papers focus on what bands that can be used for LSA and how LSA can be used and implemented. The contribution in this paper is that we look into how LSA can be used by different types of actors. Based on cost structure analysis (leading to required investments) and analysis of availability of the basic spectrum resource we can identify clear differences of the commercial usability of spectrum awarded using LSA, all depending on what actors that make use of the LSA contract.

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<sup>5</sup> The Radio Spectrum Policy Group defines LSA as: ‘An individual licensed regime of a limited number of licensees in a frequency band, already allocated to one or more incumbent users, for which the additional users are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in the rights of use of spectrum granted to the licensees, thereby allowing all the licensees to provide a certain level of QoS. (RSPG, 2011)

<sup>6</sup> <http://www.cept.org/ecc/groups/ecc/wg-fm/fm-53>

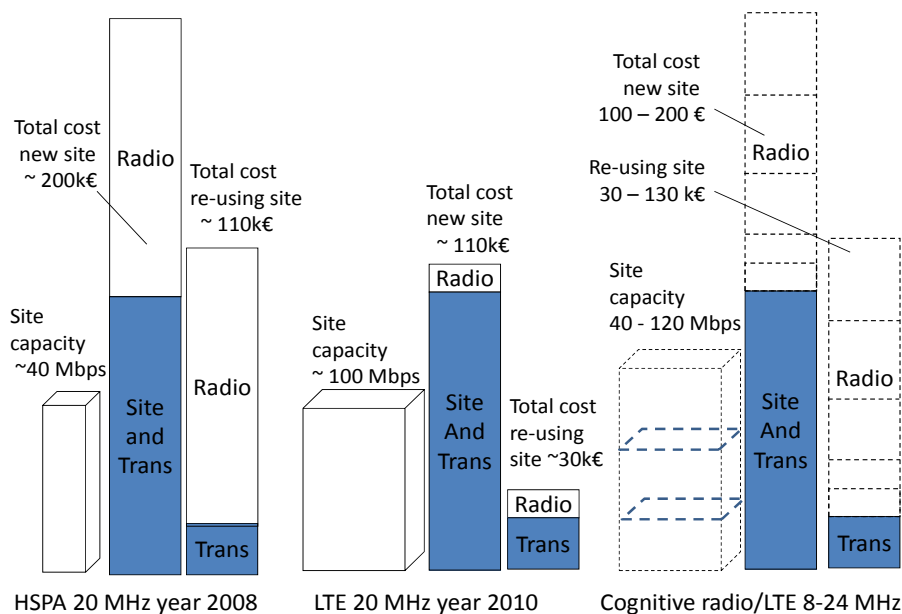


### 3. Techno-economic analysis

#### *Cost structure model and assumptions*

In the cost structure analysis we consider two main components of the cost structure for a radio access network; the radio equipment and “the sites and transmission”. In Sweden the cost for deployment of a macro base station site is typically in the range 50 – 200 k€, in this paper we will assume a cost of 100 k€ for deployment of a new site. According to Telenor the cost for upgrading existing sites with a fiber connection is estimated to 20k€ per site (Markendahl, 2011). This approach was used in the QUASAR project for analysis of mobile broadband using TV white spaces and a comparison with deployment in the 800 MHz band. The secondary spectrum access solution using cognitive radio equipment is associated with large uncertainties; i) first, the number of available TV channels and the available capacity, and ii) uncertainty in estimating costs for cognitive radio equipment. For cognitive radio we do not have any exact costs, in the analysis we assume twice the cost for the same spectral efficiency as LTE, i.e. 20 k€. Factors that may drive costs for cognitive radio are: large system bandwidth, additional systems for sensing, interference management, data bases and no large scale production

Some insights can be gained if we consider this overall network cost structure. The key aspect is what actor that makes use of the TV white space. A mobile operator with existing sites can just add new radio equipment whereas a market entrant needs to deploy a totally new infrastructure. In addition, a new actor needs to invest in marketing, customers, customer care, service and billing platforms, and to build up the operation.



**Figure 2** Example of capacity and cost structure for different types of radio access technologies. For the cognitive radio solution the indicated variations for capacity and radio costs depends on the amount of available bandwidth and uncertainty about radio complexity and implementation, from (Markendahl and Mäkitalo, 2011).

### *Estimates for LSA*

For cost structure analysis of the different network deployment scenarios using LSA we use the same overall approach as above but with some other assumptions. With LSA the conditions are as stable as for usual network deployment, standard LTE equipment (at new bands) can be used, i.e. lower complexity and large scale production. Hence, the cost for radio equipment would be the same as for LTE equipment used in licensed bands. The main aspects that will influence the cost structure will be

- If new macro sites need to be built or not, an existing mobile operator can re-use sites and transmission whereas a new actor needs to deploy a new infrastructure

Hence, with existing sites a mobile operator can add capacity using LSA at the same cost as with a new licensed band (assuming the same total amount of spectrum). This means roughly 10 k€ for a 20 MHz base station.

A new operator that needs to deploy new sites need to invest around 100 k€ for the site and transmission in order to exploit the capabilities of the LSA radio (costing 10k€). Hence, from a cost perspective it is essential that new actors can cooperate with other actors and possibly share sites or rent space at existing sites.

For indoor deployment we do not see any difference in cost structure between use of LSA and licensed operation. Pico- or femtocells would be the same type provided that vendors support the LSA bands.

#### 4. Opinions by different actors

##### *Main points from panel discussion on spectrum sharing*

At the PIMRC 2013 conference in London, 8-11 September 2013, there was panel session about shared spectrum access co-organized by one of the authors of this paper. The name of the 90 minute panel was: *Is spectrum sharing really needed?* We managed to invite a number of very experienced panel members with different background and perspectives. The panel members were:

- Dr. Tim Irnich, Senior Research Engineer, Ericsson Research, Germany
- Dr Michael Fitch, Chief of wireless research, BT Technology, UK.
- Professor Reza Karimi, Technical Policy Director, Ofcom, UK.
- Professor Petri Mähönen, RWTH Aachen University, Germany

The major part of the panel was organized as discussions from the perspective of different actors where ALL panelists gave their view about how useful spectrum sharing can be assuming they did represent that specific actor. Hence, all panelists did put on the "hat" of the different actors resulting in a large number of statements and some discussions. Some key comments are listed below for each of the actors:

- A mobile operator with licensed spectrum

This may be the only way for operators to meet the data tsunami, operators without enough spectrum resources may look for spectrum sharing as real option for future mobile broadband deployment.

Operators need to be sure that the LSA solution will work without risking the network operation and QoS. But still, why would mobile operators risk high investment cost in unlicensed bands or shared bands?

- An operator without licensed spectrum

Actors like BT in the UK investigate this but good business cases are hard to find

- IT companies like Google, Facebook

Google is interested in TV white spaces and is interested to exploit this in some countries in Africa with a relaxed spectrum regulation.

- Equipment manufacturer

Spectrum sharing will add more complexity and hence it will be a challenge for manufacturers to include in new systems and products. Who dare to take the risk?

In addition, all panelists did agree that broadcasters would not be seen as "victims". When it comes to the Telecom regulator it was stressed that regulators work for society and should make sure to make spectrum is used the best possible way. The regulation should not be a showstopper.

### ***Ericsson***

In general Ericsson representative tend to be very much in favor of licensed bands and licensed operation, see e.g. contributions in the QUASAR project. However, the last years other opinions and ideas have been proposed where other spectrum access strategies are discussed and proposed. Compared to secondary access, e.g. use of TV white space, LSA type of schemes are considered more interesting due to the more controlled operation and better quality. For operators this can be an alternative for long term investments with reasonable risk. Hence, it opens up new market opportunities for network vendors like Ericsson.

Another business opportunity is also discussed as a possible modification or extension of the managed service business, i.e. to manage and operate the mobile networks of an operator. This is an increasing part of Ericsson's overall business, last quarter 2012 it represented 42% of the Ericsson business. One possibility could be to operate a LSA network on behalf of others or to get a national LSA license and operate a nationwide network and offer services and capacity to others. This is however risky and challenging since it can lead to a situation where a network vendor in some segments can compete with its customers of network equipment.

### ***UK regulator Ofcom***

Ofcom has shown large interest in different spectrum access strategies besides allocation of licensed spectrum. Regulation for secondary trading is already in place, i.e. LSA is already possible in the UK but no LSA contracts have been signed. Use of military bands for other purposes is under investigation and MoD pays a fee for the spectrum that is actually used. In August 2013 Ofcom published a consultation on the future role of spectrum sharing for mobile and wireless data services<sup>7</sup>. Secondary access and use of TV white spaces has got a lot of attention and Ofcom estimates of TVWS available in the UK were recently published<sup>8</sup>. At the PIMRC2013 conference one contribution had the title: *TV white spaces as a stepping stone to dynamic sharing*. Although the paper presents the personal view by the author (Reza Karimi, Technical Policy Director at Ofcom), the authors agree that use of TV whites spaces and spectrum data bases can be seen as a first step towards more flexible use of spectrum .

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<sup>7</sup> <http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/>

<sup>8</sup> , <http://stakeholders.ofcom.org.uk/consultations/white-space-coexistence/>

## 5. Analysis and discussion

For use of LSA for provisioning of mobile broadband services we can identify clear characteristics or the different business scenarios. This is achieved by investigating the level of required investment, the service availability and the impact on competition

- LSA contracts awarded to all mobile operators with licensed spectrum
  - a. The investments will be relatively small
  - b. The service availability is guaranteed due to licensed spectrum
  - c. There will no change of competition between mobile operators
- LSA contract to a single mobile operators that also has licensed spectrum
  - a. The investments will be relatively small
  - b. The service availability is guaranteed due to licensed spectrum
  - c. The operator acquiring the LSA license will have a competitive advantage
- LSA contract to an independent actor that offers capacity on a wholesale basis
  - a. The investments will be high for a new actor without infrastructure
  - b. The service can be interrupted unless complemented by other spectrum
  - c. The level of competition will increase due to new actor
- LSA contract to independent actor(s) that will offer end-user services
  - a. The investments will be high for a new actor without infrastructure
  - b. The service can be interrupted unless complemented by other spectrum
  - c. The level of competition will increase due to new actor, but the that actor will have a competitive advantage due to control of own network

High level of investments especially combined with LSA as the only spectrum resource is risky for the operator and LSA usage rights can change the level of competition in any direction. The risk with LSA as the only mean to provide spectrum and capacity is most evident for macrocell deployment and wide area coverage. If a back-up solution is needed a new operator either has to have agreements with some mobile operator (a competitor) or exploit possibilities with secondary access of TV bands. This seems to be quite risky.

However, for indoor deployment the situation is quite different since there are other ways to provide capacity without causing interference to other user of the same band. Hence, LSA is not the “only” resources. Indoor capacity can be provided by LSA in combination with a multitude of spectrum access options and bands

- Unlicensed WiFi with “open” shared access in 2,x and 5,x GHz bands
- Unlicensed cellular access in 1800 MHz (in some countries like Sweden, UK )
- Use of TV bands below 800 MHz

This motivates future work where different spectrum access strategies are used for indoor deployment. It also provides new business opportunities for new actors that want to deploy indoor networks and offer wireless connectivity to companies in the building or local area/ services or to offer outsourcing services to mobile operators.

## 6. Conclusions

To conclude we can look into the answers that we can provide for the research questions presented in the introduction.

We have *identified and analyzed a set of business model and investment options* for use of LSA as described above. Cases where new actors need to invest a lot in new infrastructure do not that look that promising

When it comes to a *separate “LSA business case” that is feasible from a business perspective* (where the key resource for the operator is spectrum awarded using LSA) we would claim that the answer is no. Service availability that cannot be guaranteed due to LSA type of spectrum being the only resource seems risky, especially when combined with high investments. However this applies only for outdoor deployment.

For deployment of a new indoor network the situation is different. The cost structure is the same no matter if a new or existing actor deploys the networks. In addition, a multitude of spectrum bands and spectrum access options exist indoor so the service provisioning will be less vulnerable if some part of spectrum is not available some period of time.

## 7. Acknowledgement

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