Incentives for incumbent spectrum users in Licensed Shared Access (LSA): A dynamic capabilities view

Petri Ahokangas[1], Marja Matinmikko[2], Leo Fulvio Minervini[3], Seppo Yrjölä[4], Vânia Gonçalves[5] and Miia Mustonen[2]

***Abstract*—This paper investigates incumbent spectrum users' incentives for spectrum sharing in licensed shared access (LSA) by utilizing dynamic capabilities perspective of strategic management. To date incumbents have lacked true incentives for sharing the spectrum they use. By seeing the spectrum sharing as a collaborative action requiring the dynamic capability of sharing from both spectrum provisioning and spectrum utilization perspectives, we focus on identifying and discussing governmental and commercial incumbents' key antecedents/pre-requisites, contents/processes, and outcomes related to spectrum sharing using the new LSA concept. Based on our analysis, we discuss different incentives that potentially motivate incumbents to see spectrum sharing as an opportunity, and provide views for the regulatory bodies to be considered when developing guidelines and policies for spectrum sharing, especially within LSA.**

***Keywords*—Incentives, spectrum sharing, licensed shared access**

I. INTRODUCTION

Despite the growing trend in research and regulation towards spectrum sharing, so far there have not been true incentives for incumbent spectrum users to share their spectrum, thus using it more efficiently. Recent European spectrum sharing discussions are considering the introduction of additional licensed spectrum users, in already licensed bands, under the new Licensed Shared Access (LSA) concept [1] [2]. For such sharing to take place smoothly, the incumbents need incentives - and not only enforced regulation - for admitting other users in the bands they are currently occupying.

Although the technical elements required for LSA have been identified in e.g. [3], there is still very little work on the business impacts of LSA, especially from the incumbents' perspective. Recent research proposes that the regulatory framework around LSA represents the most influential force regarding LSA and that, to enhance the success of the concept, the business perspective plays an important role for the incumbent spectrum users. For example authors in [4] presented four business scenarios for incumbent spectrum users.

To understand what kind of incentives there could be for incumbent spectrum users in LSA, it is important to pay attention to the dynamics between the key stakeholders, i.e., the incumbents and other spectrum users, that are typically MNOs (mobile network operators). Implementation of LSA is based on a strong operational/collaborative connection between the incumbent and the additional licensed spectrum users (i.e., LSA licensees), requiring information sharing and combined technical and business capabilities. Teece et al. [5] introduced the concept of dynamic capability (DC) to refer to capability to deal with combined internal and external resources and capabilities in doing business. DCs can be defined as a "*firm`s ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments*" [5] and they can be described in terms of which actions are taken to adjust a company`s resources into new forms of competitive advantage. By looking at the LSA concept from the theory of DC perspective, this paper seeks to answer the following research questions:

- What are DCs required for the processes of spectrum sharing using LSA?
- What are the incentives for capturing the potential benefits offered by LSA?
- Could this be of help to regulators for implementing LSA?

The rest of this paper is organized as follows. First, the LSA concept is briefly introduced. Second, the theory of DCs is described including an interpretation of the LSA concept from the DC perspective. Next, incentives for the incumbents to share spectrum with the LSA concept are presented. Finally, conclusions are drawn.

II. LICENSED SHARED ACCESS (LSA) CONCEPT

The Licensed Shared Access (LSA) concept is a complementary spectrum management tool that facilitates the introduction of new users in a frequency band, while maintaining incumbent spectrum users in the band [1] [2]. These new users, i.e. LSA licensees, would share the spectrum with the incumbents under the supervision of the regulator. The goal in LSA is to offer predictable quality of service (QoS) for both the incumbents and the LSA licensee by allowing exclusive individual access to a portion of spectrum at a given location and time.

The first application area for the LSA concept described in [1] and [2] is the mobile broadband, where mobile network operators (MNOs) would gain access to spectrum on a shared basis with incumbents that operate different wireless services. A key aspect in the implementation of the LSA concept is the development of a sharing framework, i.e., a set of sharing rules and conditions. This sharing framework, typically developed in the top-down manner by the regulator, requires acceptance from all key stakeholders, namely the incumbent and the LSA

[1]Oulu Business School, Oulu, Finland. Petri.Ahokangas@oulu.fi,
[2]VTT Technical Research Centre of Finland, Oulu, Finland. Marja.Matinmikko@vtt.fi, Miia.Mustonen@vtt.fi
[3]Università di Macerata, Italy, leofulvio.minervini@unimc.it
[4]Nokia Solutions and Networks, Oulu Finland Seppo.Yrjola@nsn.com
[5]iMinds-SMIT, Vrije Universiteit Brussels, Brussels, Belgium vania.goncalves@vub.ac.be

licensee, that can propose additional items too. Thus, for the LSA concept to become reality, stakeholders need to see clear benefits from sharing.

Regarding LSA for the mobile broadband, the incumbents are likely to operate very distinct wireless services. The current studies are looking at 2.3-2.4 GHz band, where there are different incumbents in different countries, such as programme making and special events (PMSE) in Finland and military in France. Here we consider, on the one hand, the commercial mobile broadband as the LSA licensee and, on the other hand, two different types of incumbents, i.e., governmental (GI) and private commercial (PI) ones.

III. Dynamic Capabilities and LSA

A. Theory of dynamic capabilities

Strategic management literature is employing DCs to characterize the use of company resources in a dynamic environment. The concept of dynamic capabilities facilitates the identification of firm or industry specific processes that are critical to firm evolution [6]. Existing research on DCs can be divided into three foci: the elements (contents and processes), the antecedents (internal and external) and the outcomes of DCs [7].

When discussing resources and capabilities, it is common practice to conceptualize resources and capabilities as hierarchical constructs. Resources, zero-order elements, are at the bottom of the hierarchy [6]. Operative capabilities, as the skills required for utilizing resources, are higher in the hierarchy, and called first-order elements [8]. Core capabilities, the second-order elements, are the critical capabilities for doing business [9]. However, there is a difference between being able to do something (having a capability) and being able to create new ways of doing similar things, which can be seen more as a DC. Therefore, still higher in the hierarchy are third-order DCs [6] that influence the development of operational and core capabilities, thus governing the rate of change in ordinary capabilities [10]. As opposed to ad-hoc problem solving, DCs contain patterned elements and involve learning [11].

Even though there is a tendency in DCs literature to emphasize the focal firm, the approach has also been utilized in collaborative settings. Earlier research indicates that firms truly are able to access partners' capabilities as an alternative to developing capabilities themselves or acquiring other organizations' capabilities. For example, collaboration capabilities and interface competences [12] have been discussed in collaborative capability settings. Thus, maintaining partners' commitment and motivation are important. Regarding DCs and collaborative contexts, Eriksson [13] pointed up the importance for stakeholders to continuously see the value of the collaborative arrangement and pay attention to monitoring of partner activities. Also, it is important that the concurrent outputs of the partners are compatible and activities possible to be integrated.

B. LSA from the dynamic capabilities perspective

Building on the definition of LSA and the discussion on DCs, we identify five areas where incumbent spectrum users face the need for DCs in LSA, considering both spectrum provisioning and its utilization:

- **The incumbent system / Excess spectrum**—the required starting point that the incumbent controls;
- **Spectrum database**—repository of the information regarding the availability of spectrum to be shared;
- **Sharing rules**—agreed conditions and rules for sharing between the incumbent and the LSA licensee (i.e., MNO);
- **Controller**—the unit that takes care of the actual control of the sharing by employing the sharing rules;
- **Access networks**—the LSA licensee's access networks that are needed in order to utilize the spectrum.

Table I below presents those in detail, by looking at the antecedents, contents and processes, and outcomes. The starting point for understanding LSA from DCs perspective is the incumbent system and the excess spectrum. Due to incumbents' obligations and investments made in their systems, it is natural that they want to continue to use the spectrum they have access to. As an antecedent for LSA, incumbents' underutilization of spectrum has in many countries led to a situation where the regulator is pressured to give a price tag to spectrum. However, there has to be enough spectrum available to be shared. Also, control and appropriability of value related rules over spectrum have to be clear for the incumbent (as uncertainties would constitute obstacles to LSA). Regarding the key processes for LSA, the incumbent must be capable for identifying and offering the spectrum for sharing. Based on these LSA antecedents and processes, the outcomes must include good enough interference protection and possibility for additional revenue for the incumbent. Also, incumbents could be able to avoid re-farming with sharing, reach increased efficiency of spectrum use, and earn savings in spectrum fees (if price tags are enforced by regulation). The incumbents could also make additional use for the underutilized spectrum as well as try to enhance collaboration with other incumbents.

The second area for DCs in LSA is the spectrum database. As an antecedent we can consider that a standardized database, with defined interfaces, must exist and the required level of security must be maintained; moreover, unnecessary complexity has to be avoided, despite the interoperability taking place between the incumbents and LSA licensees. The key processes in this area are related to making the spectrum available for sharing and employ the rules and conditions embedded in the database. In case of multiple databases, the coordination between databases is necessary. Finally, tracking spectrum usage should be enabled e.g., to use the data to define LSA license fees or fines imposed to stakeholders due to violations of sharing rules.

TABLE I. LSA IN THE DYNAMIC CAPABILITY VIEW.

	Antecedents (pre-requisite)	Processes (content, way of working)	Outcomes
Incumbent system / Excess spectrum	Underutilization of spectrum Pressure from regulator to price tag the spectrum Incumbent's need to continue their current service provision Enough spectrum available in desirable areas and spectrum bands for long enough time Clarity over the control and appropriability of spectrum	Identifying and offering spectrum for sharing	Get additional income, or save on spectrum fees Interference protection for incumbents Maintain rights to use the band (no re-farming) Make additional use for underutilized spectrum Collaboration between PIs
Spectrum database	Standardized database with interfaces Required security, inter-operability, controlled degree of complexity	Making spectrum available for sharing in time, space, frequency for the LSA licensee(s) Employing rules & conditions embedded in database, with coordination between databases if there are many Tracking or monitoring the use of spectrum	Quality of service (QoS) and guaranteed spectrum use Possibility to monitor and trace the use of LSA spectrum, possible harmful interference, and other phenomena Possibility to use data for license fees and possible fines
Sharing rules	Supporting legislation and regulators' willingness to go for sharing (in selected bands) MNOs' need for capacity leading to demand for spectrum Government finds financial resources (from spectrum sharing), drives innovation, requires fair and transparent granting of access rights, promotes competition, information for sharing, use of price tags to spectrum, guarantees QoS and long-term spectrum availability	Establishment of sharing framework between regulator, incumbent(s) and MNO(s), agreement of rules and conditions concerning technical, commercial and information sharing related aspects	Lower entry barrier to access spectrum, flexibility in spectrum use (for MNO without coverage obligations) More competition, and more efficient use of spectrum use Better valuation of shared spectrum (price tag)
Controller	Deep insight into network to control the networks based on needs and security	Configuration and optimization of network according to rules and conditions, and LSA band availability; calculation of interferences; decisions on where and how to use LSA band	Ensures the incumbents' protection from harmful interference from LSA licensee Optimized use of MNO's LSA spectrum
Access networks (radio+core +network management)	Harmonization of technology, scalable LTE ecosystem, market position of MNO (dominant, green-field operator), type of cells (macro/small cell), balance between demand/current network load and existing spectrum resources	Network planning based on LSA band availability, and existing network assets, traffic steering and load balancing	Access to flexible extra capacity, optimized use all MNO's spectrum assets

The sharing rules can be seen as the key to LSA success. As an antecedent for LSA we identify supporting legislation and regulators' willingness to go for sharing, therefore selecting the LSA bands, with QoS guarantees and long-term availability. On one hand, the MNOs' need for additional spectrum, to be used under fair and transparent access rights, serves as a starting point. On the other hand, governments' aim to drive innovation and enhance competition should support this. For incumbents themselves (including those in the public sector), the degree of information required for sharing and the price tags put to spectrum need to be acceptable. Regarding the key processes, the establishment of a sharing framework between the regulator, incumbent and MNOs - with technical, commercial, and information sharing issues - plays a crucial role. As an outcome from the sharing rules, we identify lower entry barriers and flexibility in spectrum use. Also, increased competition, efficiency of spectrum use, and better pricing for spectrum can be seen as the outcomes of LSA.

At the controller level we identify as an antecedent the understanding of the networks as a whole. The key processes we see are the configuration and optimization of the network, according to rules and conditions of the sharing framework in order to avoid any harmful interference.

Finally, at the access network level, as antecedents for LSA we identify technology harmonization, emerging and scalable LTE ecosystem, existing market positions of MNOs (dominant, green-field operator), the type of cells utilized (macro/small cell), balancing between demand/current network load and existing spectrum resources. At this level, the key processes and outcomes are more direct to the LSA licensees rather than to incumbents.

IV. Incentives for LSA in Dynamic Capabilities' Framework

Building on our analysis, spectrum sharing based on LSA offers new opportunities to both government and commercial incumbents (i.e., GIs and PIs). The previous section has highlighted and discussed how incumbents' DCs can be effectively used to take advantage of LSA. This section goes further into the analysis and focuses on the incentives that can plausibly be triggered to exploit the LSA framework using incumbents' DCs. The major incentives are listed in Table II. By and large, GIs and PIs face a similar group of incentives. However, some of those incentives may be stronger for GIs rather than for PIs, or vice versa.

The option, opened up by LSA, to receive a compensation for sharing spectrum in designated LSA spectrum bands, is a strong direct incentive for GIs and PIs to sign LSA agreements, depending on the national situation. These agreements - likely, with commercial spectrum users seeking spectrum for their operations - could include financial clauses that would enable generating additional revenues. Another option could be to agree upon in-kind compensations, instead of money transfers, between GIs or PIs and other spectrum users, e.g. in the form of utilizing MNO licensees' infrastructure or technology.

For GIs and PIs, the option to share their spectrum in exchange for compensation can be an incentive to check whether their inputs are efficiently combined to provide their public or commercial services. Indeed, spectrum is one of the inputs used to provide electronic wireless services and, in the absence of market-based mechanisms, spectrum may not be valued at its opportunity cost. As LSA involves agreements between parties, LSA is also a means to introduce prices for spectrum which has been assigned on administrative basis. Recognition of the opportunity cost of spectrum might lead incumbents, for instance, to upgrade their technology in order to save on spectrum use and then free some of it for profitable LSA agreements. Net benefits are likely to be greater in those cases where LSA compensations are higher than the cost of technological upgrading.

The strength of such incentives, however, depends on a few surrounding conditions. For GIs, one possibility is that financial compensation from spectrum sharing feed into the national treasury budget, instead of remaining with the GI body sharing its resources. Therefore, it seems to be relevant to check national regulations for spectrum use as well as budget rules for government agencies, and change them - where appropriate - in order to enable GIs to retain any proceeds from LSA agreements. Common incentive schemes may help to achieve this goal (e.g., incentive schemes traditionally used for top manager compensations). For PIs, such as wireless cameras or PMSE operators, a great number of parties involved may impose relatively high transaction costs on LSA agreements (in particular, in deciding on how to share LSA revenues among operators themselves). However, if a band manager exists, transaction costs may be lower, as the band manager could act on behalf of all operators using the shared band.

The regulator's attitude with regard to spectrum re-farming (or re-deployment) may also act as a powerful incentive to nudge incumbents toward sharing their spectrum. Indeed, regulators may decide to move incumbents' operations to frequency bands other than those currently used (perhaps offering incumbents some financial compensation) but this is a time-consuming and costly process. The LSA could avoid the need for re-farming. For incumbents, LSA agreements with other spectrum users could offer also a means to improve their public reputation and image.

Another regulatory tool to promote efficient use of spectrum is to apply use-it-or-lose it clauses. LSA may pave the way to introducing share-it-or-lose-it rules. Forced sharing, however, is unlikely to be efficient, whereas acting on the right LSA incentives can promote mutual agreements and deliver better outcomes. This leads to considering the level of fees that could be paid under LSA. Arguably, the greater the progress that national regulators have made toward liberalization of spectrum use, the greater the freedom regulators may leave to LSA parties in setting fees. In other words, the more spectrum is (already) subject to market prices, especially in bands which can be considered as substitutes for LSA designated bands, the more LSA compensations may reflect players' willingness to pay for spectrum.

TABLE II. INCENTIVES FOR INCUMBENTS IN LSA.

Governmental incumbent	Private incumbent
Get additional income Possibility for in-kind compensation between an incumbent and MNO as alternative for monetary exchanges	Get additional income Probability for it could be higher than for GIs as PIs are not typically so strictly defined by legislation
Maintain rights to use the band (no re-farming) Use it or lose it <–> use it or share it	Maintain rights to use the band (no re-farming) Use it or lose it <–> use it or share it
Typically spectrum costs for GIs are lower than for PIs as they are not market-based The need for savings in spectrum fees in the future is increasing as the pressure to charge market prices from GIs is emerging	Savings in spectrum fees through collaboration
Enhance public image (avoid interference incidents, improve efficiency of spectrum use)	Number of PI on same bands can be higher – the sharing of incentives should then be negotiated between PIs
Use of MNO network (LTE ecosystem) for incumbent services / purposes (e.g. for public safety)	Use of MNO network (LTE ecosystem) for incumbent services (e.g. for wireless cameras)

V. CONCLUSIONS

This paper has presented a framework for analyzing the incentives for LSA among incumbents, in order to help with capturing the potential benefits offered by the LSA concept. By using the DC approach, we have identified the antecedents, processes, and outcomes of LSA in five basic areas for spectrum sharing between users. Building on this analysis, we have highlighted and discussed a number of specific incentives that could work in the context of LSA. Thus, we have tried to provide some guidance for stakeholders (including regulators) about additional ingredients and actions which may be relevant to further promote spectrum sharing in the form of LSA. Indeed, the LSA regulatory framework can be considered an incentive in itself. However, realizing and fine-tuning incumbent spectrum users' incentives could be very helpful in implementing LSA.

Our work suggests therefore how LSA can become an effective means of spectrum sharing. By pointing up the DCs involved in taking advantage of the LSA opportunity, this paper has tried to show how LSA could be used to provide better QoS or new services. This would be, on one hand, valuable to customers and citizens, and, on the other hand, beneficial for incumbents too - e.g., by avoiding re-farming, by providing a source of additional revenues, or by lowering expenses (for instance on spectrum fees). Furthermore, the incentives triggered by LSA may contribute transitioning from administrative to market-based spectrum management. In particular, where regulators are introducing (incrementally) flexible spectrum management, market mechanisms for GIs' spectrum use are less developed, compared with their commercial counterparts. Therefore, expected benefits from implementation of LSA involving GIs may well be higher than those involving PIs only.

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