Defining "Co-Primary Spectrum Sharing"— A new Business Opportunity for MNOs?

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***Abstract*—This paper seeks to identify and discuss mobile network operators' (MNOs) business opportunities in spectrum sharing where the several MNOs would share the same spectrum band. This sharing model, here called co-primary spectrum sharing (CoPSS), aims to increase the efficiency of spectrum use by introducing licensed sharing between MNOs in new bands where two or more MNOs would get the license to operate on a shared basis, instead of separate exclusive licenses for different MNOs or unlicensed sharing. The paper starts with a discussion concerning the domains needed for defining CoPSS: a) type of spectrum authorized for sharing, b) temporal, spatial, and spectral dimensions of shared resources, c) degree of information shared, and presents a definition of CoPSS. Regarding CoPSS business opportunities for MNOs we present CoPSS enabling and limiting factors and CoPSS related challenges within a framework of value co-creation, co-capture, and co-opetition. The paper concludes with a variety of alternative ways of doing business with CoPSS.**

Keywords—Co-primary spectrum sharing, Business opportunity, MNO

I. INTRODUCTION

Spectrum sharing between mobile network operators (MNOs) has for long been discussed in research by utilizing a variety of terms, concepts and settings. However, in practice MNOS have been reluctant to consider inter-operator spectrum sharing, especially when it concerns their current spectrum bands. Research indicates that spectrum sharing between MNOs can be beneficial in bursty, fluctuating traffic/spectrum demand conditions, see e.g. [1] and references therein. In addition, it has been found that spectrum sharing between MNOs is particularly beneficial in small cells where interference can easily be controlled [2]. Additionally, the gains from sharing are seen to differ depending on the user locations within the cells [3].

Recently, spectrum sharing has been gaining momentum and become a topical high priority issue in Europe regarding e.g., LSA (Licensed Shared Access) [4] [5] and in US regarding the three-tier model [6]. The LSA concept is intended for a sharing situation where a limited number of new licensed users are authorised to enter bands where there are incumbent spectrum users whose rights are protected. There may be also spectrum bands where there are no incumbent spectrum users. Regulators in several countries have anticipated the opportunities sharing may be bringing about, but the actual benefits have not been researched nor assessed. Therefore, so far, in practice sharing has remained limited—but due to the anticipated spectrum shortage the tide has changed.

One of the emerging, dynamic and efficient concepts regarding inter-operator spectrum sharing is the **co-primary spectrum sharing (CoPSS)** [7]. Currently, the definition of CoPSS is emerging and this paper seeks to clarify the term and its relation to other spectrum sharing schemes. Also, we seek to better understand the use cases and contexts where this new emerging concept would provide opportunities and business benefits for MNOs considering using it. Thus, this paper seeks to discuss the following research questions especially from the MNO perspective:

1. How can co-primary spectrum sharing be defined?
2. What are MNOs' business opportunities regarding CoPSS?

The rest of the paper is organized as follows. We start with approaching the concept by looking at the dimensions that help us to define the CoPSS. After defining the concept we discuss the enabling and limiting factors as well as challenges of the concept. We conclude by presenting alternatives ways of doing business with the concept.

II. DOMAINS FOR DEFINING CO-PRIMARY SHARING

When considering the business opportunities of CoPSS there is a need for identifying the domains influencing and defining CoPSS as a concept. We identify the following domains: 1) Type of spectrum authorized for sharing; 2) Dimensions of shared resources; and the 3) Degree of information shared. These are discussed in the following sections.

A. Types of spectrum authorization

The methods to get access to the radio frequencies can in general be categorized based on how the rights of use for the radio frequencies are being granted. The two main authorization regimes include general authorization (license-exempt) and individual authorization (licensed). Unlike the general authorization, individual authorization avoids harmful interference and implies guaranteed quality of service (QoS). MNOs typically acquire exclusive licenses with long license durations to deploy their networks in specific frequency bands which guarantee operational certainty for the MNOs to operate without harmful interference from other radio systems. Operation in license-exempt bands does not offer the same certainty due to uncontrolled interference environment.

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New approaches are being developed to complement the two basic authorization regimes by introducing new forms of spectrum sharing. The current European sharing approaches are collective use of spectrum (CUS) [8] and licensed shared access (LSA) [4] where the former refers to enhancing the general authorization while the latter aims at allowing additional licensed users on bands currently encompassing licensed users. While these approaches are not directly about spectrum sharing between MNOs, they are showing the regulatory developments towards the direction of sharing.

B. *Dimensions of shared resources*

Several dimensions in dynamic sharing of spectrum can be identified, namely the temporal, spatial and spectral ones. The first dimension refers to the length of time scale of spectrum sharing-related decisions. The second means the geographical resolution (size of area) of the decisions, and the final one the resolution in the frequency domain (size of spectrum chunks).

Even the current fixed licensing scheme can be considered dynamic, but the resolution in all three dimensions is very coarse. In time domain it is typically around 20 years, i.e. the interval between the reallocation of frequency licenses. Spatial resolution is normally defined by the national borders, except in very large countries. Spectrum is usually licensed in blocks in the order of 10 MHz.

In the CoPSS context, we expect the dynamics to be much higher, at least in some dimensions. In terms of temporal resolution, it will most likely vary depending on the functionality in question. For instance, actions which require agreements on policies, priorities or incentives, will not happen very frequently. The resolution could be perhaps days. On the other hand, decisions regarding the resources for ongoing or pending communications may happen much more often. The scale could even be milliseconds for intra-operator functions. A side effect of this will likely be that different spectrum sharing decisions will reside in different network entities.

A natural selection for the spatial resolution appears to be one radio cell. Information on the communication needs and interference situation within the cell in question will be readily available, and data on the neighbouring cells should not be too difficult to obtain. Even finer resolution can be envisioned, but this would require much more information on the mobile nodes, such as their locations, motion, radiation patterns, etc.

Finally, there is the question of resolution in the frequency domain. Here, the carrier bandwidth for the technology in question seems appropriate. Operating on a subcarrier basis would increase the complexity, respectively lengthen the duration of a particular transmission, and hence bringing little or no visible benefits. In cases where diverse systems with varying carrier bandwidths are sharing the same spectrum, the issue may become more complicated.

It is important to note that dynamic operation calls for the exchange of control information within an MNO's network or between several networks. This entails an amount of control signalling between network entities; the higher the resolution, the more signalling will be required. Therefore, the related regulation and implementations will have to consider the balance between performance optimization and the resulting signalling loads, operational complexity and cost to manage the arrangement.

C. *Information sharing*

It is assumed that some form of coordination will be required between MNOs and the level of coordination defines how dynamic the sharing will be. The spectrum sharing rules may define the usage priorities for spectrum chunks allocated to each MNO. New entities of the MNOs, here called the spectrum controllers, may negotiate on the priorities in a semi-static way (e.g. when and where to use the priorities). The spectrum sharing rules may also define the incentive mechanisms for the sharing and negotiations on when and how to use the incentive mechanisms could done by the spectrum controllers also in a semi-static way as presented in Figure 1.

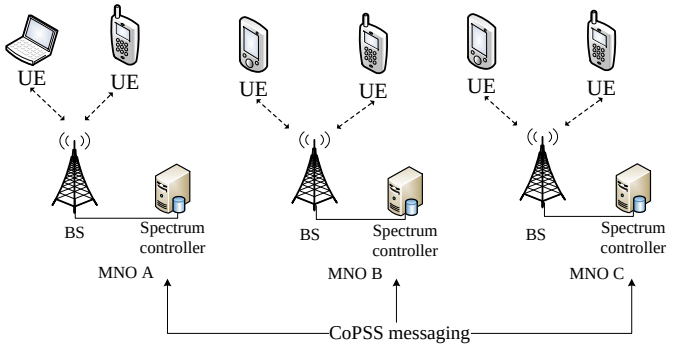

Figure 1. CoPPS information sharing.

A more dynamic spectrum sharing could be done either in a proactive or reactive way. In the proactive sharing an MNO may request a new spectrum chunk (e.g. a component carrier) from another MNO, which may then grant the request. The request may be triggered e.g. by traffic demand. The reactive sharing may be based on measurements (e.g. interference condition, QoS, etc.), which may lead to changes in the spectrum chunk allocations following pre-defined rules. In the reactive sharing, spectrum controllers will update the allocation information.

Spectrum sharing could utilize e.g. load balancing, traffic steering, inter-cell interference coordination, cell reselection and handovers at the cell level to optimize the spectrum usage. There are defined procedures including information exchange for those functions for intra-operator cases, but those procedures could be enhanced for inter-operator cases.

D. *Interdependence between co-primary spectrum sharing domains*

Handling of the shared spectrum could be partly based on a common spectrum pool for all MNOs and dedicated portions for each MNO. A national regulatory authority may define the limits for the dedicated portions and the size of the common spectrum pool in order to enable a certain level of predictive QoS, but still forcing effective spectrum usage by the common spectrum pool in dynamically varying traffic environments.

MNOs could set the policies and rules for the usage of the common spectrum pool by a mutual agreement, which may be subject to permission from the national regulatory authority. The

agreement defines the resolution of dimensions of the shared resources in frequency, time and space domains. The agreement also defines the level of information sharing i.e. what information is shared, how often it is shared and what interfaces are used for information sharing.

A predictive level of QoS is essential from a business point of view—it will constitute one of the incentives for MNOs to participate in spectrum sharing. One way to guarantee some level of QoS is to allocate a certain amount of the shared spectrum as a dedicated resource for each MNO. The other option is an agreement between MNOs over access to a certain amount of the common spectrum pool for a predefined time and/or space. The agreement could include the mechanisms on how to handle the dynamics between the spectrum demand and spectrum availability e.g. incentives and compensations among MNOs.

To summarize the discussion on CoPSS business, we define CoPSS in the following terms:

1. CoPSS concerns a specific spectrum band for which licenses are issued for at least two MNOs;
2. These MNOs enter into an agreement regarding the conditions of sharing;
3. CoPSS requires real-time information sharing between the MNOs, information about the type and level of sharing resolution, which is agreed between the MNOs so as to guarantee efficient spectrum sharing;
4. The dynamics of spectrum sharing in CoPSS is considerably high, approaching the level of intra-operator resource allocation;
5. Sufficient guaranteed QoS is part of CoPSS.

III. BUSINESS OPPORTUNITIES OF CO-PRIMARY SPECTRUM SHARING

In this section we analyse the business opportunities of CoPSS for MNOs. An opportunity can be defined as the possibility to serve customers differently and better [9]. Opportunities are framed by enabling and limiting factors as well as challenges posed by the business context. For MNOs the discovery, evaluation, and exploitation of opportunities fuel the emergence and growth of businesses [10]. In the co-primary spectrum sharing context it can be said that business opportunities are made to create and deliver value for the stakeholders [11], since value creation can be viewed as a boundary-spanning [12] process where it is *co-created* among various actors as a joint effort, and together with the customers [13]. In addition to value co-creation, an equally important aspect of value is the ability to capture value, i.e., obtain profits [14] which in the context of this research can be called value *co-capture*. The term *co-opetition* illustrates the increased complexity of the co-primary business environment, where companies simultaneously compete and cooperate with each other not only over spectrum but also over customers [15]. To summarize, value co-creation could be seen as a cooperative and value co-capture as a competitive process. Co-opetition (see [17] [18]) can be defined as the coexistence of competition and cooperation within the value creating business context. Figure 2 below depicts the framework used in this paper to analyse the business opportunities for MNOs.

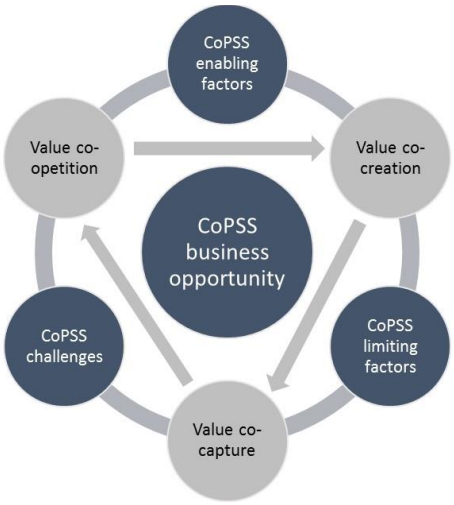

Figure 2. CoPPS business opportunity framework

A. *The domain of MNOs*

MNOs can be seen as a part of the converging mobile ecosystem [15] [18]. Interestingly, the definition of an MNO seems rather vague. European Directive on access to, and interconnection of, electronic communications networks and associated facilities [19] states that an "operator means an undertaking providing or authorised to provide a public communications network or an associated facility". In the same vein, it also refers to a significant market power (SMP) operator in the definition of shared access to the local loop as "the provision to a beneficiary of access to the local loop or local sub-loop of the SMP operator, allowing the use of a specified part of the capacity of the network infrastructure such as a part of the frequency or an equivalent". On the other hand, the European Roaming Directive (on roaming on public mobile communications networks within the Union) [20], refers to MNO and MVNO, but no clear definition of both terms is provided. Therefore, in this paper we start from the operator definition stated previously and assume an MNO provides a public wireless communications network. In addition, what differentiates an MVNO from an MNO, is that the latter must own a radio spectrum license and the network infrastructure necessary to provide a number of services to its subscribers.

In addition to MNOs, the mobile ecosystem consists of several segments such as silicon vendors, device and infrastructure manufacturers, platform providers, application software providers, service and billing providers, system integrators, MVNOs, Internet service providers, and various content providers [18]. Within the CoPSS domain, four key ecosystem roles are identified: the NRA, MNOs (dominating and challenger ones), mobile device vendors, and infrastructure vendors. Regarding spectrum sharing, it can be argued that the roles of the regulator and the MNOs are central in the adoption of Cognitive Radio Systems (CRS) technologies. Moreover, the

role of the MNO has very distinct features depending on whether the MNO has a dominant market position or a challenger role. Additionally, authors in [15] argue that there are three domains affecting spectrum sharing; regulatory, business, and technology domains. Table I below lists the enabling and limiting factors as well as challenges of CoPSS for MNOs.

Regarding CoPSS enablers for value co-creation, both regulatory and technical factors can be identified for CoPSS. As a concept sharing has existed for over ten years, and it can be assumed that the lack of spectrum will encourage the adoption of new ways of sharing in the future. In addition, CoPSS may increase MNOs' business potential especially in hotspots and small cells. However, at the same time it may also increase the likelihood of new types of operators to enter the business, depending on the regulative schemes applied to sharing. Thus, also the MNOs opportunity of value co-capture, i.e. to profit from sharing, may be influenced.

Regarding limiting factors, however, there are still some regulatory and harmonization related limiting factors for CoPSS that need to be resolved before MNOs can co-create and co-capture value from it. First, the availability of suitable spectrum for sharing may be limited and there is still need for national regulation in many countries, and the regulative choices may negatively influence the MNOs views on sharing and the subsequent evaluations of the value of spectrum. Also, the availability of technical and business knowledge among MNOs regarding CoPSS may limit the business opportunities around the concept. A specific item to be considered is the need for and degree of information sharing required between MNOs. For NRAs the information sharing means also that the potential risks of giving dominating MNOs unfair advantages over challenger MNOs need to be evaluated and that no illegal competition restricting arrangements will emerge due to the information shared between the MNOs.

The co-opetitive challenges of CoPSS reside mostly in the competitive domain created by regulation, but also some technical issues needs attention by the MNOs. First, as CoPSS entails that MNOs enter into an agreement concerning the "rules" of sharing, the question is whether attractive and active enough "spectrum market" will emerge, especially regarding the volatility and timing of spectrum demand. E.g., two MNOs with similar customer profiles may compete harder over the shared spectrum, whereas MNOs with differing customer profiles might find better opportunities for value co-capture on CoPSS. Thus, the value of the shared spectrum and the required time of recovering the investments may be seen differently by the MNOs. A specific technical challenge related to CoPSS is network optimization that may get more difficult in varying sharing conditions.

TABLE I. FACTORS INFLUENCING COPSS OPPORTUNITIES

	Factors influencing CoPSS opportunities
Enabling factors	Lack of spectrum encourages the adoption of new ways of sharing
	CoPSS can be more efficient than exclusive licensing schemes regarding spectrum usage
	Flexible spectrum use has been around for over ten years, CoPSS can be regarded as a part of that
	CoPSS may increase MNOs' hotspot business potential
	CoPSS may lower entry barriers for new challenger MNOs and new type of operators
	Additional capacity to increase offload potential and performance
	Availability of shared spectrum during (bursty) peak hours
Limiting factors	Availability of suitable spectrum for sharing
	Need for national regulation (identification, allocation)
	In case sharing conditions and service exclusions defined by the regulators become more severe, the effects of shared spectrum deteriorate and the economic value may be reduced
	Harmonization is both a precondition to enable EU-wide spectrum sharing as well as a potential benefit
	Lack of MNOs willing to discuss CoPSS. Established MNOs see CoPSS as a threat
	Availability of shared technical and business information limits CoPSS opportunities
	Information sharing may lead to forbidden competition restricting arrangements (e.g. de facto cartels)
	Standardization of CoPSS functionality for IMT technologies needed, especially for those systems intended to be used. These may include sharing, multivendor network management, and radio resource management interfaces
Challenges	Risk and uncertainty regarding sharing will be mainly driven by timing, term length, number of sharing licenses, and flexibility (e.g. future right) to modify / terminate the sharing agreement
	Will there be attractive and active enough shared spectrum 'market' for example regarding volatility of demand?
	Lack of specificity or clarity of the concept creates exposure and risk for an MNO to proceed with the investment
	How the value of spectrum is affected by CoPSS?
	Fees paid for spectrum sharing rights
	CoPSS may increase competition and may change the competitive environment. New competitors may emerge when sharing is allowed
	Increased dynamics and lifecycle speed will make it more challenging to recover the fixed costs associated with introducing new technologies, services, or business models (lack of information on the business impacts of CoPSS)
	Additional risk, operational complexities and transaction costs associated with spectrum sharing make investment by MNOs less certain
	Competence challenge for network optimization: network optimization gets more difficult as CoPSS increases
	Degree of information sharing needed / allowed by MNOs

B. *Alternative ways of doing business with co-primary spectrum sharing*

To sum up the preceding discussion, in order to realize the business potential and opportunities of CoPSS, MNOs' need to simultaneously be willing and able to co-create and co-capture value for themselves in a co-opetitive business environment where cooperation (=spectrum sharing) and competition (over customers with different services) exist parallel to each other. Next, we outline some alternative ways of doing business in CoPSS.

1) CoPSS for existing MNOs

For MNOs that already have spectrum, the CoPSS concept could offer considerable amounts of additional spectrum (e.g. 100-150 MHz) for offering extra capacity. For example, offloading from macro to small cells (intra-operator offloading) is one opportunity. Hotspot capacity both outdoor and indoor public places is usually built by using small cells, and usually all operators are building their own networks. In multi-operator cases the positive dynamics of CoPSS may come from different subscriber profiles or from uneven distribution of subscribers in time allowing the MNO to exploit the shared resource to balance their capacity demands. CoPSS could be compared to WiFi as a business opportunity as it could provide predictable QoS due to the limited number of MNOs with enough spectrum involved. Operating spectrum for indoor coverage in multi-office and multi-operator environment may also be provided by CoPSS. In such cases the dynamics of CoPSS may be a result of e.g. differing occupation levels and different subscriber profiles of the offices.

Operating spectrum for proximity services (e.g. Device-to-Device communication) might also be provided by CoPSS in multi-operator cases. This could be relevant for local businesses, where services are provided by local service providers (either by local small cells or advanced D2D). Interestingly, CoPSS might open up sharing (renting) of exclusive bands, too, as well as new incentive and compensation mechanisms between operators. For example, spectrum use as incentive or compensation e.g. in cases of national roaming, inter-operator handovers or cell re-selection, or even partial infra sharing (core or RAN networks) could be examples of this kind of mechanims.

2) CoPSS for entrants / challengers

For new entrants that currently do not have spectrum licenses, the CoPSS concept could offer considerable amounts of new spectrum to enter the market. E.g., IT content providers such as Google, Amazon, or Micorsoft might enter the MNO business through sharing as MVNOs for hotspot, especially if they have fibre connectivity to the hotspot. Alternatively, venue owners, landlords, brand owners (especially service chains such as shops, hotels, cafes, etc.) could become local operators through their venues. Although small cells / femtocells could be regarded as fragmented service, CoPSS could enable even CBS (citizen broadband services) to start to service customers. Finally, MNOs with enough spectrum could also do business with the spectrum wholesale model, if there is enough spectrum available to be sold.

IV. CONCLUSIONS

This paper has introduced the concept of co-primary spectrum sharing (CoPSS) for spectrum sharing between MNOs. We have identified the following domains for defining CoPSS: type of spectrum authorized for sharing, dimensions of shared resources, and the degree of information shared, and presented the CoPSS definition in section II D. We looked into the enabling and limiting factors related to the introduction of CoPSS as well as challenges related to operations in CoPSS by using a framework utilizing the concepts of value co-creation, co-capture, and co-opetition to substantiate the business opportunities. Especially, we saw that the concept of co-opetition can be used to characterize the business environment regarding spectrum sharing in general and CoPSS in particular. We concluded with alternative ways of doing business with CoPSS.

This paper serves as a starting point for analysing the business opportunities and business environment around CoPSS. However, future work is needed to dwell deeper into the framework of value co-creation, co-capture and co-copetition for identifying MNOs' business relations and opportunities in the new CoPSS concept.

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