Citizens Broadband Radio Service Spectrum Sharing Framework - A Path to New Business Opportunity for Mobile Network Operators?

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***Abstract*—The paper seeks to identify mobile network operators' business opportunities in the new Citizens Broadband Radio Service (CBRS) shared spectrum access framework. More flexible and scalable use of the 3.5GHz spectrum aims to increase the efficiency of spectrum use in delivering fast growing and converging mobile broadband and media services while paving way to new innovations, e.g., in the area of Internet of Things and 5G. The opportunity analysis indicated that the mobile network operators could benefit significantly from the new, shared CBRS bands enabling to cope with increasing asymmetric media data traffic and to offer differentiation through improved quality and personalization of services. Heterogeneous network assets leveraging 3GPP LTE evolution were found to be the key enabler while regulatory actions may frame the availability of spectrum and limit the economic value for an operator. The concept of co-opetition was found useful to characterize the business environment regarding CBRS spectrum sharing.**

Keywords-business opportunity; mobile network operator; mobile broadband; cognitive radio; Citizens Broadband Radio Service.

I. INTRODUCTION

We have witnessed the rapid growth of wireless services with a large range of diverse devices, applications and services requiring connectivity. The number of mobile broadband (MBB) data subscribers, connected 'things' and the amount of data used per user is set to grow significantly [1] leading to increasing spectrum demand. The US President's Council of Advanced Science & Technology (PCAST) report [2] emphasized the need for novel thinking within wireless industry to meet the growing spectrum crisis in spectrum allocation, utilization and management. The essential role of spectrum sharing and dynamic spectrum access were underlined to find a balance between the different systems and services with their different spectrum requirements and system dynamics. For any spectrum sharing framework, where several radio systems operate in the same spectrum to be a feasible and attractive, early cooperation across regulation, business and technology domains is essential. Collaboration in the technology and innovation domain between industry and research enables validation of the enabling technologies and new concepts while ensuring economies of scale and scope in implementation. Furthermore, regulation has a key enabler role through spectrum harmonization and providing incentives for early adopter while on the other hand defines limiting factors and competition framework. The spectrum regulation has played central role in the wireless ecosystems in creating current multibillion business ecosystems, for MBB operator businesses via exclusive Quality of Service (QoS) spectrum usage rights and at the same time for unlicensed Wi-Fi ecosystem drawing from the public spurring innovations.

So far, only a subset of the spectrum sharing research has reached the regulation domain, the early studies on cognitive radio (CR) on license exempt access with intelligent user terminals and spectrum sensing as the general interference mitigation technique as one example. Furthermore, several spectrum sharing concepts widely studied, standardized and supported by national regulatory authorities (NRA) has not scaled up commercially as expected, TV White Space (TVWS) [3] and [4] being the latest example. Based on the decade of profound CR and in particular unlicensed TVWS concept studies, a couple of novel licensing based sharing models have recently emerged and are under regulatory discussion and early stage standardization, the Licensed Shared Access (LSA) [5] from Europe and the Citizens Broadband Radio Service (CBRS) 3 tier Spectrum Access System (SAS) from the US [6]. For these prominent spectrum sharing concepts currently under research, particularly the SAS, there is not much prior work available regarding their business model analysis. An initial evaluation of the general spectrum sharing concept from the business modeling point of view can be found in [7] and LSA focused analysis from [8] and [9]. That work is extended by focusing on more systemic, complex dynamic CBRS SAS sharing concept and analyzing the Mobile Network Operator (MNO) business opportunities using co-opetitive (co-operation and competition) business opportunity framework. This paper investigates:

1) How can CBRS spectrum sharing be defined for MNOs?
2) What are MNOs' business enablers and opportunities regarding CBRS?

The rest of the paper is organized as follows. First, the CBRS 3 tier sharing framework and the SAS models are presented and defined for a MNO in Section II. Theoretical background for co-opetitive business opportunity framework is introduced and elements framing business opportunities derived and evaluated in Section III. Finally, conclusions are drawn in Section IV.

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II. CITIZENS BROADBAND RADIO SERVICE SPECTRUM SHARING FRAMEWORK

The key policy messages of the PCAST report were further strengthened in 2013 with Presidential Memorandum [10] stating that "…*we must make available even more spectrum and create new avenues for wireless innovation. One means of doing so is by allowing and encouraging shared access to spectrum that is currently allocated exclusively for Federal use. Where technically and economically feasible, sharing can and should be used to enhance efficiency among all users and expedite commercial access to additional spectrum bands, subject to adequate interference protection for Federal users, we should also seek to eliminate restrictions on commercial carriers' ability to negotiate sharing arrangements with agencies. To further these efforts, while still safeguarding protected incumbent systems that are vital to Federal interests and economic growth, this memorandum directs agencies and offices to take a number of additional actions to accelerate shared access to spectrum*."

Followed by intense discussion and consultation with the industry the Federal Communications Commission (FCC) released Report and Order and Second Further Notice of Proposed Rulemaking to establish new rules for shared use of the 3550-3650 MHz band in April 2015 [6]. The FCC sees the opening of the 3.5 GHz Band as "*a new chapter in the history of the administration of one of our nation's most precious resources—the electromagnetic radio spectrum."* The framework defines a contiguous 150 MHz block at 3550-3700 MHz for MBB that the FCC calls Citizens Broadband Radio Service. The 3550-3650 MHz spectrum is currently allocated for use by the US Department of Defense (DoD) radar systems and Fixed Satellite Services (FSS) while the 3650-3700 MHz spectrum incumbents are the FSS and the grandfathered commercial wireless broadband services. FCC prefigures CBRS as an "*innovation band*" where they can assign spectrum to commercial MBB systems like the 3GPP LTE on a shared basis with incumbent radar and FSS systems and promote a diversity of Heterogonous Network (HetNet) technologies, particularly small cells. The sharing framework consists of three tiers: Incumbent Access (IA), Priority Access (PA) and General Authorized Access (GAA), as shown in the Figure 1.

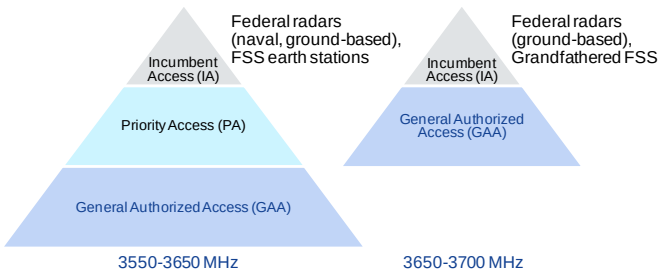

Figure 1. The US CBRS 3-tiered authorization framework with the FCC's spectrum access models for 3550-3650MHz and 3650-3700MHz spectrum segments.

The PA users will obtain a FCC PA license (PAL) to operate up to 70 MHz of the 3550-3650 MHz spectrum segment and are protected from harmful interference from the GAA operations. PA layer covers critical access users like hospitals, utilities and governmental users and non-critical users, e.g., MNOs. PA users receive short term priority authorization to operate within designated geographic areas with PALs such as 3 year 10 MHz unpaired channel in a single census track, awarded with competitive bidding. During the first application window only, an applicant may apply for up to two consecutive three-year terms for any given PAL. Licenses will be permitted to hold no more than four PALs in one census tract at one time. This will ensure availability of PAL spectrum to at least two licensed users in the geographic areas of highest demand. PALs are assigned specific frequencies within their service area, and their frequency assignment should not be dynamically controlled by the SAS database. At the end of its term, a PAL will automatically terminate and may not be renewed.

The third GAA tier will operate under a licensed-by-rule framework and will be allowed throughout the 150 MHz band without any interference protection from other CBRS users. This framework aims to facilitate the rapid deployment of compliant small cell devices while minimizing administrative costs and burdens on the public, licensees, and the FCC. GAA users may use only certified, Commission approved CBRS devices and must register with the SAS with information required by the rules, e.g., operator ID, device identification, and geo-location information.

CBRS Devices (CBSDs) which are fixed stations, or networks of such stations will be assigned spectrum dynamically by the FCC selected SAS which could be multiple. User equipments, e.g., handsets are not considered as CBSDs. SAS controls the interference environment and enforces exclusion zones to protect higher priority users as well as takes care of registration, authentication and identification of user information. As the IA users have primary spectrum rights at all times and in all areas over PA and GAA, all the CBRS users must be capable of operating across the entire 3.5 GHz band and discontinuing operation or changing frequencies at the direction of the SAS to protect IA. Automated channel assignment by a SAS will simply involve instructions to these users to use a specific channel, at a specific place and time, within 3550-3700MHz.

It will be mandatory for all the CBRS users to protect the IA users in the band. Based on nature and critical requirements of the federal incumbent the FCC adopted rules to require Environmental Sensing Capabilities (ESCs) to detect federal spectrum use in and adjacent to the 3.5 GHz the band. The federal IA user protection will be adopted in 2 phases. In the first phase, a large portion of the country outside the static exclusion zones will be available after SAS is commercially available and FCC approved, at the second phase, the rest of the country, including major coastal areas, will become available as exclusion zones will be converted to protection zones through the ESC system detecting federal incumbent use. The SAS receives input from ESCs and if needed, could order commercial tier users to vacate a

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spectrum resource in frequency, location, or time which when in proximity to federal incumbent presents a risk of harmful interference. Prospective ESC operators must have their systems approved through the same process for SASs and SAS administrators. An ESC consists of one or more commercially operated networks of device-based or infrastructure-based sensors that would be used to detect signals from federal radar systems in the vicinity of the exclusion zones. Within 60 seconds after the ESC communication of a detected federal system signal, the SAS must either confirm suspension or relocation of operations to another unoccupied frequency.

The opportunistic GAA with no interference protection from other CBRS users is planned to provide a low-cost entry point into the CBRS band for a wide array of users and services first while PAL system operations have to wait auction process estimated to start after the US 600 MHz incentive auctions targeted for 2016. For the meanwhile, the FCC has encouraged multi-stakeholder groups to consider various issues raised by the rules. The Wireless Innovation Forum (WINNF) Spectrum Sharing Committee [11] with representatives from the MBB, Wireless broadband, Internet, Internet of Things (IoT) / machine to machine (m2m) and defense ecosystems has started initial standardization work on interfaces between a MBB system and a SAS work targeted to allow sharing of the CBRS within 2016. The US Government has initially identified an additional 2 GHz of spectrum below 6GHz owned by DoD and other users for future shared commercial use conditionally if the spectrum sharing at 3.5 GHz proves successful. This paves way to make licensed spectrum sharing a third mainstream way of licensing spectrum to commercial users complementing traditional exclusive licensing and unlicensed spectrum access. The FCC has vision to repeat WiFi success through lowering the entry barrier QoS spectrum for new entrants and verticals, e.g., enterprise, utilities, healthcare, public safety, smart cities, etc.

III. BUSINESS OPPORTUNITIES OF CBRS FOR MNOS

A. *Co-opetitive business opportunity framework*

In this section, we analyze the business opportunities of CBRS for MNOs. An entrepreneurial opportunity can be defined as the possibility to serve customers better and differently [12] framed by enablers, limiting factors as well as challenges caused by the business context. In the CBRS context, business opportunities are made to create and deliver value for the stakeholders, value that is co-created among various actors from MBB, wireless and incumbent ecosystems as a joint effort. An equally important aspect is the ability of the stakeholders to capture value, i.e., obtain profits [13], which in the context of this study can be called value co-capture. Furthermore, value co-creation can be seen as a cooperative and the parallel value co-capture as a competitive process [14]. The third term co-opetition illustrates the increased system complexity of the CBRS business environment, where companies simultaneously compete and cooperate with each other not only over spectrum but also over customers. Figure 2 below depicts the framework used in this paper to develop and frame the business opportunities for MNOs.

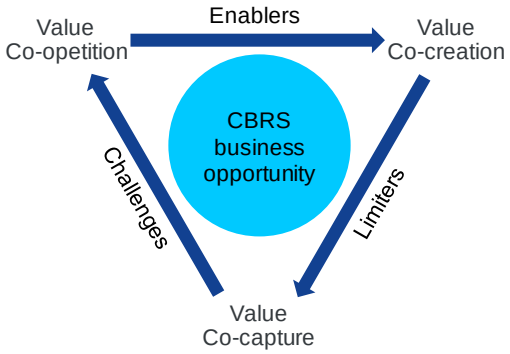

Figure 2. The Co-opetitive business opportunity framework

B. *Analysis of the business opportunities*

In the analysis for the business opportunity elements of the CBRS, five key ecosystem roles are identified: the national regulator authority, federal incumbent, MNOs, SAS administrator, infrastructure vendors and device/chip manufactures. In the systemic framework change like CBRS, all the stakeholders play a vital role in adopting of novel CBRS concept and spectrum sharing in general. In addition when developing and analyzing the opportunity frame authors argue that three domains; regulation, business, and technology, affecting spectrum sharing concept should proceed in tandem. Enabling, limiting and challenging elements framing the business opportunities for the MNO are next discussed and listed in Table 1.

Business and technology elements can be identified as enablers for value co-creation. Fast growing demand and lack of exclusive spectrum combined with the drastic changes in the consumption habits will urge the adoption of novel more flexible and efficient spectrum management concepts. Framework radically unbundles investment in spectrum, network infrastructure and services, which enables novel services and business models. Furthermore, different spectrum sharing schemes are high in regulators agenda with aims to lower the entry barrier to spectrum for new alternative types of operators which could consider entering the wireless broadband business. Utilization of the LTE ecosystem scale and harmonization will reduce risk related technology maturity and provide tools to seamlessly integrate additional capacity to MNOs HetNet, e.g., through Carrier Aggregation (CA) [15], LTE Unlicensed (LAA) [16] and Self Organizing Network (SON) [17] technologies. Big data analytics capabilities will play a major role in coping with the SAS dynamic requirements and enabling low transaction costs.

Regarding limiting factors, sound, sustainable and harmonized regulatory environment can be the limiter that needs to be addressed before MNO can co-create and co-capture value from it with ecosystem partners. The limited spectrum availability in frequency, time or location with potential restriction and uncertainties may negatively

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influence the MNOs outlook on shared use and the spectrum valuation. A specific technology item to be considered is the degree of business (MNOs) and mission (DoD) critical information needed to share and resulting need for the ESC system. In addition to MNO opportunities, it is essential to consider reciprocal incentives for the current federal spectrum holders to further transition to CBRS.

Policy risk and uncertainty are the main elements of the co-opetitive challenges in the competitive domain. Fragmented national and global market structure deprives economies of scale and scope, raising costs and hampering innovation in the ecosystem. Furthermore, introduction of sharing models may influence the MNOs current exclusive spectrum licensing model and availability in the future. The regulatory approach and in particular the 3-tier concept could unbundle investment in spectrum, network infrastructure and services. Faster access to spectrum with lower initial investment (annuity payments for spectrum rights) enables local 'pro-competitive' deployments and further expands sharing mechanism for pooling spectrum and infra resources between operators. At the same time, the complexity of the CBRS framework and the SAS might influence the value of the spectrum and the required time of recovering the network investments. On the competence domain, MNOs need to pay attention to dynamic capabilities needed to deploy, manage and optimize multilayered HetNets under sharing conditions. Traditional MNOs support for the 3.5GHz spectrum in their networks is paramount to encourage chip and device manufacturers to support the whole 3.5GHz band introduction with competitive terminals. Attractive and dynamic spectrum market with potentially lower transaction costs may increase and change competition, e.g., through introducing new and alternative operator types locally and from other business domains.

TABLE I. ELEMENTS FRAMING BUSINESS OPPORTUNITIES

	Business opportunity framing elements
Enablers	• Lack of exclusive spectrum triggers new spectrum access approaches • Consumers MBB consumption habits are changing towards asymmetric multi-device usage • Shared spectrum allocation improves overall spectrum use efficiency • Regulators considering shared spectrum framework in the EU and the US • Unbundles investment in spectrum, network infrastructure and services • Additional lower cost capacity to cope with asymmetric traffic and improve performance • Better QoS spectrum may increase dense urban area business • Additional GAA capacity for offloading • May lower entry barriers for challenger MNOs and new alternative type of operators • Harmonized LTE technology base leverage HetNet asset optimization and offers scale • Big data and analytics capabilities with Internet domain
Limiters	• Limited spectrum availability and predictability limit MNO business opportunities • Need for global and national regulation outside of the US may slow down entry - Harmonization is a precondition to scale and enable potential benefit fully. • Real incentives for the federal incumbents unclear or missing • Federal incumbent special requirements in particular related to security and need for sensing • Regulatory framework restrictions may reduce the economic value • Degree of information sharing of business critical (MNOs) and secret information (Federal incumbent) and needed ESC system • Standardization of SAS functionalities for 3GPP ecosystem and technologies needed
Challenges	• Uncertainty and risks related to regulation in timing, term, licenses and flexibility creates exposure and risk for a MNO to proceed with the investment. • Impact on exclusive spectrum licensing model and availability in the future • Attractive and dynamic spectrum market with potentially lower transaction costs. • May increase and change competition. New operator types, and from other business domains. • Increased technical and operational complexity (SAS) with related capital and operational costs • New competencies and capabilities needed for network management and optimization • Timely availability of full band base stations and terminals and potential impact on cost and complexity

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In summary, in order to realize the business potential of the CBRS, MNOs have occasion to simultaneously co-create and co-capture value with ecosystem players in a co-opetitive business environment where co-operation (spectrum) and competition (customers & services) exist parallel to each other. MNOs are in unique position to leverage additional multi-tiered capacity CBRS concept offers. Faster access to QoS licensed small cell optimized spectrum without mandatory coverage obligations will help them to timely cope with booming asymmetric data needs. Additional scalable and flexible spectrum resource leveraged with LTE technology enablers will enable MNOs to better retain and grow existing customer base with changing demand and consumer habits, offer differentiating services and explore new vertical segments.

IV. CONCLUSION AND FUTURE WORK

This paper discussed the transformative role of the novel Citizen Broadband Radio Service framework in the future mobile broadband networks as an endeavor to meet the growing traffic demand and changing consumption characteristics of the customers while paving the way to make licensed spectrum sharing a third mainstream way of licensing spectrum to commercial users complementing traditional exclusive licensing and unlicensed spectrum access. We utilized co-opetitive business opportunity framework for understanding mobile network operator's enablers and opportunities and how they are framed from policy, technology, and business perspectives in the future, CBRS shared spectrum networks.

We argue that policy and regulation will be on the one hand the key enabler in the path toward shared spectrum access and on the other hand will play key role in removing limiting and challenging elements critical in the first steps of that path. In particular, the sharing framework for the priority access licenses should be attractive and feasible to encourage mobile broadband industry to invest which could lower the barrier for change and furthermore create economies of scale across tiers and for the whole ecosystem.

More flexible and scalable use of the spectrum aims to increase the efficiency of spectrum use in delivering fast growing and converging mobile broadband, media and Internet content to meet changing consumer needs. The proposed opportunities enable mobile network operators to retain existing customers, acquire new customers and strengthen overall market position by offering improved personalized mobile broadband data services timely. Furthermore, through unbundling investment in spectrum, network infrastructure and services co-operative business opportunities may open with vertical segments, new alternative operator types and the internet domain.

Mobile operators are optimally positioned towards these business opportunities in parallel with their traditional business model leveraging technology enablers from mobile broadband 3GPP LTE evolution and big data analytics while waiting for the more optimized cognitive 5G solutions.

This paper serves as a starting point for analyzing the business enablers, opportunities and business environment around CBRS. We saw that the concept of co-opetition could be used to characterize the business environment regarding spectrum sharing. However, future work is needed to expand research to cover also other key stakeholders and to dwell deeper into the framework of value co-creation, co-capture and co-opetition for identifying MNOs' business models and ecosystem relations in the new CBRS concept and in the third opportunistic GAA layer in particular.

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