Citizens Broadband Radio Service Spectrum Sharing Framework - A New Strategic Option for Mobile Network Operators?

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Abstract - **The paper seeks to identify mobile network operators' business opportunities and strategic options in the new Citizens Broadband Radio Service shared spectrum access framework. More flexible and scalable utilization of the 3.5 GHz 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 5th Generation. The opportunity analysis and created simple strategic rules indicated that the mobile network operators could benefit significantly from the new, shared Citizens Broadband Radio Service bands enabling them to cope with increasing asymmetric media data traffic, and to offer differentiation through improved quality and personalization of services. 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. The concepts of co-opetition and simple rules strategic framework were found useful to characterize the business environment regarding spectrum sharing. Heterogeneous network assets leveraging the Third Generation Partnership Program's Long Term 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.**

Keywords - business model; Citizens Broadband Radio Service; mobile broadband; spectrum sharing; strategy.

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 leading to increasing spectrum demand, and need for novel spectrum management techniques, and related new business models discussed in the COCORA 2016 [1]. 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 needs [3], and to tackle 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 wireless local area network (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) [4][5] 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) [6] from Europe and the Citizens Broadband Radio Service (CBRS) from the US [7]. This paper investigates:

1) How can the CBRS spectrum sharing be defined for Mobile Network Operators (MNOs)?
2) What are MNOs' business opportunities, and how are they framed regarding the CBRS?
3) What kind of strategic choices do MNOs have to make regarding spectrum sharing?

The rest of the paper is organized as follows. First, the state of art and the research gap is shortly discussed in Section II. Second, the CBRS 3-tier sharing framework is presented and defined for a MNO in Section III. Theoretical background for co-opetitive business opportunity framework and the Simple Rules strategic approach is introduced in Section IV. The elements framing business opportunities and

Simple Rules strategic options are derived and evaluated in Section V. Finally, conclusions are drawn in Section VI.

II. STATE OF THE ART

For the prominent spectrum-sharing concepts currently under research, particularly the CBRS, there is not much prior work available regarding their business model or strategic analysis. An initial evaluation of the general spectrum-sharing concept from the business modeling point of view can be found in [8] and the LSA focused analysis from [9][10]. The feasibility and attractiveness of the LSA and the CBRS spectrum sharing concepts were analyzed in [11]. Furthermore, key stakeholders' capability to deal with combined internal and external resources and capabilities in doing business utilizing the CBRS concept was analyzed in [12] based on the Dynamic Capability strategic management framework. That work is extended by focusing on the dynamic CBRS sharing concept, and analyzing the MNO business opportunities using the co-opetitive (co-operation and competition) business opportunity framework and the Simple Rules strategic framework [13].

III. CITIZENS BROADBAND RADIO SERVICE SPECTRUM SHARING FRAMEWORK

The key policy messages of the PCAST report were further strengthened in 2013 with the Presidential Memorandum [14] stating "*…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 [7]. 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.

The FCC prefigures CBRS as an "*innovation band*", where they can assign spectrum to commercial MBB systems like the 3rd Generation Partnership Program (3GPP) Long Term Evolution (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 Fig. 1.

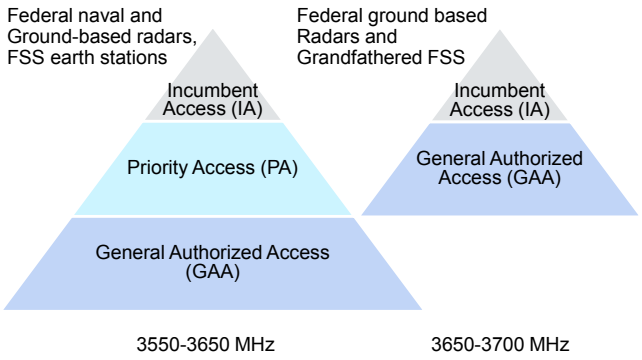

Figure 1. The US CBRS 3-tiered authorization framework with the FCC's spectrum access models for 3550-3650MHz and 3650-3700MHz spectrum segments.

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. The 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 the 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 the 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 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, the FCC approved CBRS devices, and must register with a SAS with information required by the rules, e.g., operator identity (ID), device identification, and geo-location information.

In the CBRS functional architecture [15] depicted in the Fig. 2, *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. In case of a CBSD is a managed network as in the typical case of MNOs, CBSD network includes a *domain proxy (DP)* and a network management functionality as shown in the Fig. 3. A DP's function is to accept a set of one or more available channels and select channels for use by specific CBSDs, or alternatively pass the available channels to the operators Operation Administration and Maintenance (OAM) Network Management System (NMS) for CBSD channel selection. In practical implementation, OAM NMS may be co-located with the DP. The DP back reports selected channels to a SAS optionally received via a NMS, and receives confirmation of channel assignment from a SAS.

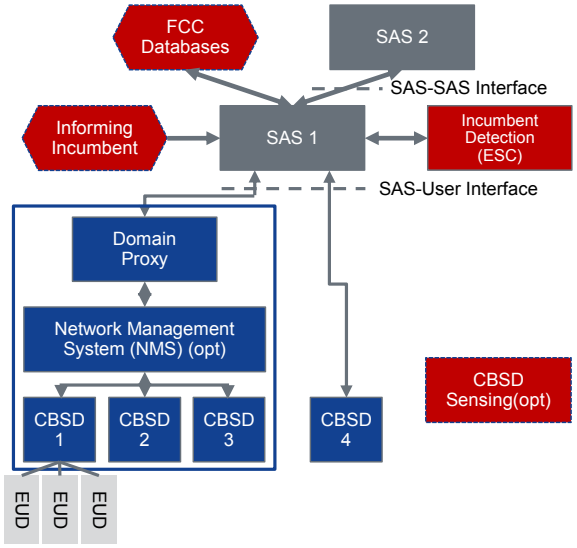

Figure 2. The CBRS functional architecture.

Furthermore, the DP performs bidirectional bulk CBSD registration and directive processing through operator NMS if present. Additional bidirectional information processing and routing function may include, e.g., interference reporting.

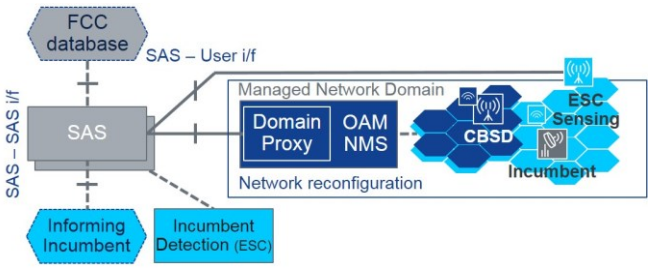

Figure 3. The Domain Proxy in the CBRS functional architecture.

To summarize, the DP could be a pure bidirectional information processing and routing engine, or a more intelligent mediation function, e.g., combining the small cells of a mall or a sports arena to a virtual CBSD entity that covers the complete mall or sports arena. The latter option allows flexible self-control and interference optimizations in such a network. End user devices (EUD), e.g., handsets are not considered as CBSDs.

The 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 the 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. The SAS would obtain the FCC information, e.g., about registered or licensed commercial users, exclusion zone areas requiring sensing from the FCC database. *Informing incumbent* architecture option allows the federal IA to inform the SAS ahead of plans to use the spectrum in some area, e.g., related to planed use of the spectrum. The SAS could be administrated by a third party or a mobile operator as an *operator SAS*. By operating own operator SAS, MNOs may better control their business operation critical information flow and sharing between their MBB network and the third party administrated SAS. However, all the SAS systems should be FCC certified and meet all the SAS requirements set forth by the FCC and the WINN Forum specifications.

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 two 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 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 300 seconds after the ESC communication of a detected federal system signal, the SAS must confirm either 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 in 2016 -2017. 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 (SSC) [16] with representatives from the MBB, Wireless broadband, Internet, Internet of Things (IoT) / machine to machine (m2m) and defense ecosystems has started standardization work on interfaces between a MBB system and a SAS work targeted to allow sharing of the CBRS till end of the year 2016.

The US Government has initially identified an additional 2 GHz of spectrum below 6 GHz owned by the 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 Wi-Fi success through lowering the entry barrier QoS spectrum for new entrants and verticals, e.g., enterprise, utilities, healthcare, public safety, smart cities, etc.

IV. Business Opportunity Based Simple Rules Strategic Framework

In this section, we introduce business and strategy frameworks used in analyzing the business opportunities and strategic options for a MNO utilizing CBRS spectrum.

A. Co-opetitive Business Opportuntiy Framework

An entrepreneurial opportunity can be defined as the possibility to serve customers better and differently [17] framed by enablers, limiting factors, and challenges caused by the business context. Fig. 4 below depicts the framework used in this paper to develop and frame the business opportunities for MNOs.

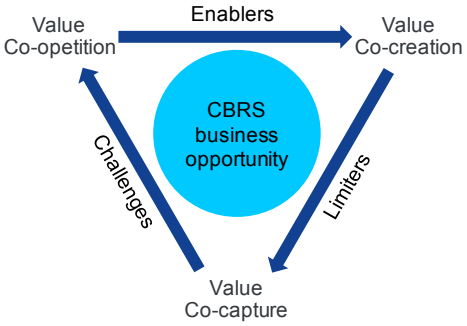

Figure 4. The Co-opetitive business opportunity framework.

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 [18], 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 [19]. 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 resources but also over customers.

B. Business Model Typology

A coherent 4C typology was created to classify Internet era business models, and to make the business model analysis easier and more structured [20]. The typology introduces four prototypical models, each with varying value propositions and revenue models [20]:

1) *Commerce* enables low transaction costs for buyers and sellers of goods and services; Direct sales revenues and indirect streams as commissions,
2) *Context* provides structure and navigation for Internet user to increase transparency and reduce complexity typically based on transaction independent online advertisement revenues,
3) *Content* delivers various types of consumer centered, personalized content; Mainly indirect revenue streams like online advertisement, premium content increasingly with subscription or usage pricing, and
4) *Connection* provides network infrastructure and related services that enable exchange of information and users' participation having both the direct and indirect revenue stream models.

Different stakeholders of the ecosystem can implement these business models alone or combined as a hybrid, which is an important aspect in relation to sharing. The business potential of the whole ecosystem depends on the ecosystem players' synergies when providing their services. Furthermore, the 4C typology can be interpreted as "layers" where a "lower" layer business models are required as enabler and value levers for higher layers to exist as depicted in Fig. 5 in the analysis Section V.

C. Simple Rules Strategic Framework

Business literature provides us with numerous examples of business strategy approaches and strategic elements applied. Traditional strategic logic based on position focuses on answering the question: *where* should we be through identifying an attractive market segment and sustainable position and then establishing, strengthening and defending it, e.g., [21]. In structured businesses, another widely used approach is built around leveraging core competences and resources, i.e., *What* to achieve sustained long-term market dominance, e.g., [22].

In rapidly changing complex markets, like today's wireless communications, traditional approaches have faced several limitations: they do not build around the business

opportunity, have only weak linkages to the key business processes, depict resources rather than activities, and lack needed flexibility to seize fast changing opportunities. In this paper, the strategic *Simple Rules* approach presented in [13] was adopted, that partly helps to answer to the concerns discussed above.

In emerging and dynamic business environments, the novel Simple Rules approach sees business strategies as built around the opportunity and the key processes needed to seize them flexibly and timely. The strategic approach provides practical guidelines within, which opportunities could be pursued with selected key processes. The proposed framework consists of five categories:

1) *How-to* rules for conducting business in an unique, differentiating way,
2) *Boundary* rules for defining the boundaries of the business opportunities of the stakeholders,
3) *Priority* rules that help to identify and rank the criteria for opportunity decision making,
4) *Timing* rules that help in synchronizing, coordinating and pacing emerging opportunities, and
5) *Exit* rules that help in identifying basis for exit or selecting initiatives to be stopped.

V. Analysis of the Strategic Opportunities

The business opportunities and strategic choices as Simple Rules created and their analysis are summarized in this section.

A. Elements Framing Business Opportunities

In the analysis for the business opportunity elements of the CBRS, five key ecosystem roles were identified: the NRA, federal incumbent, MNOs, SAS administrator, infrastructure vendors and device/chip manufactures. In the systemic framework change like the CBRS, all the stakeholders play a vital role in adopting of the 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 a MNO are next discussed and summarized in Table I.

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, and 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 spectrum capacity to MNOs HetNet, e.g., through modern techniques like Carrier Aggregation (CA) [23], LTE Unlicensed (LTE-U/LAA) [24] or MulteFire [25], and Self Organizing Network (SON) load balancing and traffic steering [26].

Furthermore, as content is increasingly over-the-top (OTT) video and multimedia, Mobile Edge Computing (MEC) platform can rapidly process content at the very edge of the mobile network, delivering an Quality of Experience (QoE) that is ultra-responsive as latency is significantly reduced. The MEC will take a full advantage of the localized shared spectrum resources and telco cloud, enabling new possibilities to serve the operator's radio network and to co-exist with other virtualized network functions [27]. Big data analytics capabilities will play a major role in coping with the SAS dynamic requirements and enabling low transaction costs, and in the future enabling spectrum aggregator and broker models.

Regarding *limiting factors*, sound, sustainable and harmonized regulatory environment can be the limiter that needs to be addressed before a 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 influence 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. MNOs traditionally used to operate with exclusive spectrum rights framework will see strategic risks with moving towards interference-protected rights only provided by the CBRS. 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 it is 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. Furthermore, the IoT and 5G era also opens up opportunities for new competition, especially in the traffic hotspots with specific venues with very specific interest to be fulfilled, e.g., hospitals, sporting events, shopping malls, universities will attract new players.

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.

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 Europe 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 and local services • May lower entry barriers for challenger MNOs and new alternative type of operators • Harmonized LTE technology base leverage HetNet asset optimization and offers scale • Mobile Edge Computing improves QoS and QoE of localized services • 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

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. On the other hand, introduction alternative local operators offer co-opetitive collaboration opportunities for a MNO, e.g., through sharing infrastructure and or network capacity.

B. Business Opportunities

In this section, business opportunities are discussed based on their key framing elements from Sub-section A, and summarized utilizing the 4C business model typology.

There is a need to fundamentally design future spectrum sharing enabled and complemented networks not just to service new use-cases, but also enable new business models. The industry is moving from today's "bit pipe" connectivity business models for MBB monetizing connectivity and 3rd party content (like video) towards "smart pipes" capturing value from digital content & information from the cloud and consider offering connectivity, in some cases free-of change. This will turn mobile broadband business from competitive value creation and capture thinking toward co-opetitive sharing economy, multitude of ecosystems to work with.

In order to realize the business potential of the novel dynamically shared spectrum resources, MNOs have occasion to simultaneously co-create and co-capture value with ecosystem players in a co-opetitive business environment where co-operation (spectrum, infrastructure assets) and competition (customers & services) exist parallel to each other. MNOs are in unique position to leverage additional multi-tiered capacity the 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 more locally when and where needed. Additional scalable and flexible spectrum resource leveraged with LTE technology enablers will enable them to better retain and grow existing customer base with changing demand and consumer habits.

MNOs business models and opportunities are powered by premium network performance, information brokering and network as a service. The premium performance level of networks enables novel broadband services such as High Definition (HD) video and Virtual Reality (VR)/Augmented Reality (AR) services in the home, on the move, and for the business world. These *Premium Connectivity* business models provide new opportunities by guaranteed high service levels not only with end users, but also with content and other service providers. As content is increasingly OTT video and multimedia, *Mobile Edge Computing* capabilities can rapidly process content at the very edge of the mobile network, delivering an experience that is highly responsive as latency is significantly reduced. Premium connectivity enables partner-based propositions and allows for faster development and launch of these partner services at the benefit of all.

The increasing number of control and transaction *data* produced by the network can be particularly leveraged in new vertical segments. The innovation possible in the IoT and 5G use cases involves bringing massive internal and external data sets together to uncover new insights to add value in new sharing economy based services. MNOs with needed big data and analytics dynamic capabilities will be optimally positioned to broker information with different business domains such as providers of augmented reality services, smart cities, factories, logistics, health, and utilities.

Dedicated virtual sub-networks, the *network slices*, can be modelled as *Network as Service (NaaS),* which provide exactly the functionality needed for different verticals and industries with their diverse use cases. E.g., use case of consumer health sensors is completely different to ultra-high quality video delivery. On-demand, as-a-service business models play essential role in the timely sharing economy concept, defined as "*the value in taking the underutilized assets and making them accessible online to a community, leading to a reduced need for ownership of those assets [28]*."

In the NaaS concept, all elements of the network from radio access, core network and Operations Support System (OSS) to security and analytics can be virtualized through Network Function Virtualization (NFV), and sliced out as one integrated service. This enables an operator to create an instance of an entire network virtually relying on whatever underlying infrastructure is available for the defined geography. With the power of programmability in the Software Defined Networking (SDN) of the networks, it should be further possible to customize such a 'network instance' for vertical *Anything-as-a-Service* (XaaS) solutions, e.g., for logistics, automotive, healthcare, utilities, or retail.

In Fig. 5, discussed business opportunities are mapped into the 4C Internet business typology. Currently, the main source of revenue for MNOs drives from subscriber retail markets based on the connectivity. Through leveraging additional flexible capacity, MNOs are in good position to expand their business model to cover wholesale, where one party gets spectrum, build, owns and operates the LTE access network and leases bandwidth to virtual operators, subject to QoS controlled by dynamic Service Level Agreements (SLAs). Utilizing discussed NFV and SDN technologies, the model could be further developed to provide connectivity as a Service to new alternative operators. Edge computing and data monetization enables MNOs to enter higher layer content and context models in collaboration with new customer from verticals and other industries with new growth opportunities.

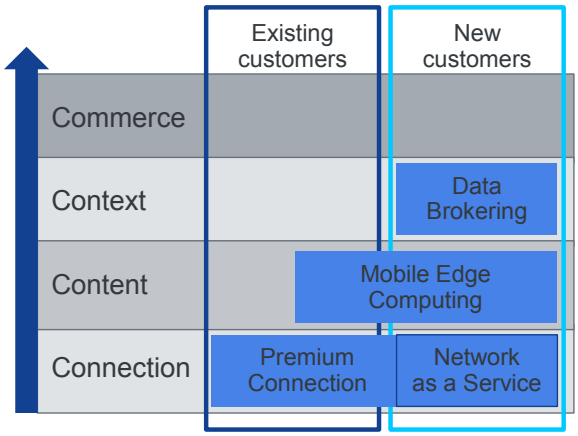

Figure 5. The MNO business opportunties mapped into 4C business model typology.

C. *Simple Rules*

In this Sub-section strategic rules applying the Simple Rules strategy approach from [13] for MNOs deploying the CBRS were created and analyzed for the business opportunities identified and discussed in the Sub-section B. Created Simple Rules are summarized in Table II.

MNOs' *How-to rules* for conducting business in a unique and differentiating way continues to be based on the dominant market position and lock-ins through Customer data and Experience Management (CEM). This could be reached by gaining access, if possible, to all available exclusive spectrum, and by combining existing and new shared CBRS spectrum assets to deliver premium connectivity service in QoS and QoE. Sharing terms and conditions, particularly at the PAL layer, such as term, predictability, certainty and geography limitations, impair the economic benefits of shared spectrum. Becoming a MEC and NaaS platform provider for new customer segments could enhance utilization of the dominant market position. MNOs could utilize their big data platforms, analytic skills and CEM capabilities to monetize their unique subscriber data for other industries, without jeopardizing the trust of their customers. Brokering telco data and co-creating value by combining it with vertical data will enable MNOs to capture value from context driven business models.

To strengthen market *boundaries* of the business opportunities, established MNOs could leverage their existing infrastructure investments in radio, core, OSS, as well as in the fixed network assets. Furthermore, the 3GPP evolution offers scale and harmonization in investing in and the build-up of spectrum sharing based businesses. MNOs could also try to turn alternative and new local micro operators into co-opetitive partners thru virtualization and XaaS. As the MBB spectrum management in general and novel shared spectrum initiatives in particular are highly dependent on spectrum policy and regulatory actions, it is essential to play active role in regulation and standardization, and to have direct contact with the national regulator. E.g., in order to protect own entry to new local area collaborative business opportunities, and to keep entry barrier for new non-MNO entrants, MNOs could try delay the introduction of neutral host enabling technologies like MulteFire. As MulteFire could utilize license by rule GAA spectrum, cable companies, Internet Service Providers (ISPs), small businesses, enterprises, venue owners and building owners, can readily deploy it. For new entrants, it offers the chance to own and control their own 'standalone' LTE network. It also offers a number of benefits, including outdoor coverage, wide coverage and improved performance and safety of data and voice applications.

Priority rules help a MNO to identify and rank emerging opportunity. For MNOs, key decision priority is to retain control over the spectrum, and prefer CR network techniques and solution that keep control in the operator domain. Having spectrum control integrated with the OSS NMS enables a MNO to utilize its advanced HetNet SON features, and to protect operation critical network information. Spectrum sharing could start first with other domains like federal users in the case of the CBRS. Furthermore, from the regulatory perspectives, it is central to keep sharing voluntary and binary with the incumbent. At the early stages of spectrum sharing businesses, a MNO will appreciate premium Average Revenue Per User (ARPU) services over operational efficiency to utilize their customer base. In the second phase, MNOs could explore value co-capture opportunities with verticals and other industry domains.

Synchronization, coordination and *timing* of emerging opportunities is the fourth simple rule category. In-house HetNet intersystem spectrum sharing could be implemented first in order to develop needed dynamic capabilities to optimize utilization of spectrum resources across layers. In order to leverage existing business models, operators should prioritize the QoS guaranteed and predictable PAL sharing opportunities first. Offering could then be complement with offloading and local sharing at the GAA layers with better QoS compared traditional Wi-Fi offloading. Thirdly, with full set of spectrum assets a MNO could explore opportunities with local alternative operators and verticals utilizing wholesale, XaaS, MEC and data brokering platforms.

Finally, *Exit rules* help in identifying basis for exit, or initiatives to be stopped. Regardless of the technology enablers or business models utilized in spectrum sharing, MNOs should never give up spectrum, even if not fully utilized. MNOs should try to avoid co-primary sharing concepts that introduce sharing between MNOs, which may have negative impact on their competitive positioning, and the availability of the exclusive spectrum in the future. In the CBRS FCC regulation [7], the term *unused* is important as according to FCC rules GAA users may utilize unused PAL spectrum if unused. Furthermore, exclusive spectrum will remain first priority having important strategic value in keeping the entry barrier for new entrant high and protecting high investments in spectrum and infrastructure.

TABLE II. SUMMARY OF DEVELOPED SIMPLE RULES

Opportunities	*How to rules*	*Boundary rules*	*Priority rules*	*Timing rules*	*Exit rules*
Premium connectivity service to existing customer base with growing demand Premium connectivity with extra capacity and *mobile edge computing* Wholesale and *NaaS* offering to focused market demand based on access to local lower-cost spectrum Telco *data monetization* with verticals locally	Invest to maintain dominant market position Gain access to all exclusive spectrum available Strengthen existing customer lock-in Utilize shared CBRS spectrum assets to deliver premium and localized services Become edge computing and XaaS platform provider for new customer segments Broker telco data to enter verticals with context	Leverage existing infrastructure Utilize scale and harmonization of 3GPP evolution Active lobbying and contribution to regulation Delay the introduction of neutral host technologies to keep entry barrier Turn alternative operators to co-opetitive partners thru virtualization and XaaS.	Maintain control over spectrum Protect operation critical network information Prioritize sharing with other domains Keep sharing voluntary and binary with the incumbent Appreciate premium ARPU services Actively look value capture opportunities in verticals and other industry domains	Base sharing with others on in-house HetNet dynamic capabilities (inter-system sharing and optimization first) QoS guaranteed and predictable PAL sharing Offloading and local sharing at GAA layers Explore opportunities with local alternative operators	Exclusive spectrum is first priority Avoid co-primary sharing concepts between MNOs Protect critical operational network data Monetize customer and telco data

In the MNO strategic decision making, strategic value may in many case overrule technology based avoided cost engineering value and business driven market surplus value. Protection of the critical operational network data remains important source of competitive advantage. Entering co-opetitive business with other industries with content and context based business models; customer and telco data will become critical assets, and create competitive advantage when optimally combined with the use case specific vertical data, or Internet company's customer data assets

VI. 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. Opportunity analysis was used in creating and discussing strategic options as simple rules.

We argue that policy and regulation will be on the one hand the key enablers 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 and related simple rules 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 the CBRS. We saw that the concept of co-opetition could be used to characterize the business environment regarding spectrum sharing. The strategic choices as simple rules provides a dynamic framework for MNOs for exploring and exploiting emerging opportunities, developing dynamic capabilities to respond transforming environment, and building business models to leverage new shared spectrum access approaches. However, future work is needed to expand research to cover also other key stakeholders, in particular alternative new local operators, 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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