New Business Strategies and Marketing Opportunities Utilizing a Liberalized Spectrum Management Framework

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Abstract: - The current global move to switch from analogue to digital terrestrial television has opened up an opportunity for the re-allocation of valuable spectrum resources in VHF/UHF frequencies. In one way, spectrum bands once used for analogue TV broadcasting will be completely cleared, leaving a space for deploying new licensed wireless services, and in another way, digital terrestrial television technology geographically interleaves spectrum bands to avoid interference between neighboring stations, leaving a space for deploying new unlicensed wireless services. In this context, this paper studies spectrum availability in VHF/UHF frequencies, elaborates on their exploitation under a dynamic management approach and discusses their potential business strategies for introducing secondary systems/services within primary bands (i.e. TV bands). Following existing technological and scientific approaches for dynamic spectrum access, it presents a liberalised spectrum exploitation, based on "spectrum commons" and "spectrum markets" regimes rather than the custom "command and control" one.

Key-Words: - Liberalized Spectrum Management, Spectrum Markets, Business Strategies, Marketing Opportunities

1 Introduction

The advent of high-definition bandwidth-hungry services along with the growing user-needs not only for accessing/receiving them but also for being able to ubiquitously/wirelessly provide their own content at guaranteed QoS, have raised the network demands for spectrum availability (i.e. the fundamental resource in wireless systems), and the technology requirements for error-resilient transmissions. Although utilization of advanced wireless systems could provide for better radio resources exploitation as well as for improved performance under various propagation environments, besides paving the way towards spectrum and frequencies release, two major obstacles hinder their deployment: a) the existing spectrum management frameworks and the frequency licensing status that follow a "command and control" regime, and b) the network design and frequency agendas that make use of mature and outof-date planning tools.

For example, while the advent of DVB and its exploitation over terrestrial wireless channels

(DVB-T/H), since early 2000, enabled for efficient utilization of VHF/UHF frequencies, exploitation of the unused/underutilized TV spectrum in the postanalogue era still remains an issue. This spectrum comprises not only frequencies that will be released/freed when digital switchover (DSO) is accomplished, but also a number of frequencies that are totally unexploited (mainly at local level) due to frequency planning issues and/or network design principles, since the analogue age. More specifically, this locally available spectrum is the result of frequency planning models in a National TV Coverage Implementation, according to which only a certain number of the VHF/UHF channels is used for delivering the national TV services in a given broadcasting area, while all others (in the same broadcasting area) remain unused due to interference issues. These unexploited frequencies [1], constitute a premium resource of some hundreds MHz [2] of bandwidth, or of some hundreds of Mbps, which is unused and unexploited at local level.

Exploitation of these unused frequencies falls within the current spectrum management regime, where "command and control" of VHF/UHF allows only the operation of primary systems for the provision of primary services (or ancillary to them), such as TV, interactive TV, PMSE, etc., while excluding any other secondary utilization/ transmission. As a result, most of the licensed VHF/UHF frequencies are currently either underutilized or totally unexploited, making the issue of spectrum unavailability rather a matter of the existing management framework and frequency/ network planning techniques, than an issue of spectrum shortage.

Therefore, novel management frameworks are required that will enable for the exploitation of the available resources and the utilization of the unused/unexploited spectrum by both primary and secondary systems/services. However, any change in the current spectrum management framework (allowing the introduction of secondary systems/services in primary bands) requires the relevant decision making and regulatory bodies to be aware of the technical aspects of each candidate technology, as well as of its impact at social, cultural and economic levels, prior to any decision/change.

In this respect, this paper studies the spectrum availability issue in VHF/UHF frequencies, elaborates on their potential exploitation for introducing secondary systems/services within a primary band (TV band), and investigates technological and scientific approaches for introducing them under a common-sharing regime. Finally, the paper concludes by presenting potential business models that prevent existing/established economies to be jeopardized, while paving the way towards new activities in the market and economic fields.

2 Spectrum Availability in the VHF/UHF Bands

The advent of Digital Video Broadcasting standard (DVB) and its exploitation over terrestrial wireless channels (VHF/UHF channels each one of 8MHz width) provided for a spectrum release, in the assigned to the broadcasting sector bands, as a result of the superior transmission efficiency of digital technology (i.e. DVB-T/H). This spectrum release will be available for further exploitation when transition from analogue to digital broadcasting is accomplished (digital switchover - DSO), which in European level is scheduled for year 2012. More specifically, studies and reports [3], [4] have shown that after the analogue switch-off an unprecedented amount of spectrum (usually of some hundreds of MHz [5]) will be freed-up by analogue broadcasters, which could be offered/exploited for fulfilling the "spectrum availability" demands and meet the fast growing needs for wireless services access/ provision. To do so, however, a couple of technological and managerial issues have to be solved, in order to harvest the maximum benefits of the available spectrum resources. One of them is the issue of "Frequency Fragmentation". The available spectrum will be highly fragmented into relatively narrow bands, scattered over many frequencies, and intertwined with digital broadcasting channels. This is a consequence of spectrum planning options adopted at the ITU Regional Radio communication Conference, which produced an international plan, the Geneva 2006 agreement, on the basis of traditional broadcasting use. It is therefore difficult or impossible to make alternative uses of the resources, as long as the spectrum bands to be liberated will be too narrow to be really costeffective for new services, and the scope for their development is further reduced by the fragmented implementation of the Geneva 2006 agreement at national level. As a result, innovative uses of the spectrum, if possible at all, would be impeded by low spectrum efficiency and require specific adaptations of operating equipment to local conditions. "Many potential uses of the available resources will simply not occur if access to spectrum is not better coordinated" [6], reducing, in

turn, the overall value of them. Overcoming this major hurdle calls for "tidying up" the available spectrum in order to make it more usable and more consistent; an issue, however, of spectrum reallocation and re-planning, not only within each EU Member State but also among all of them, as long as a high degree of spectrum planning interdependency exists across their borders. Such a frequency clustering under a national and pan-European spectrum harmonization framework, calls-upon novel frequency management with liberalized spectrum exploitation approaches, so that utilization of the available resources in primary VHF/UHF bands to be possible by other secondary technologyand services- neutral systems. This would facilitate national and EU-wide interoperability, thus reducing distortions of competition in the single market that favor certain sectors or market players, besides creating opportunities for existing and new entrants to launch innovative wireless services.

2.1 Interleaved Spectrum

Interleaved Spectrum is the large slice of "prime" broadcast frequencies, which remains unused at local level since the analogue TV broadcasting age, due to network planning principles in a National TV Coverage Implementation (NTVCI), i.e. where 98% of the population/country must have access to the national TV programmes/bouquets. This by-product of national TV networks comprises guard frequencies and unexploited TV channels, which are intentionally unutilised for preventing interference among adjacent broadcasts, either in space or in frequency.

More specifically, Geographically Interleaved Spectrum represents the amount of frequencies which remain unused between adjacent broadcast coverage areas in a NTVCI plan, according to which "frequencies used in one area are excluded from use in the neighbouring ones". In other words, to prevent interference, the channels used in one region are different from those used in adjacent regions [7]. For example, and in the case of a NTVCI plan with 6 national TV services/bouquets, every transmission/broadcast area utilises 6 UHF channels/ frequencies for delivering the national ΤV programmes. These frequencies cannot be used by any other adjacent broadcasting area for avoiding interference, which means that at least half of the available spectrum is Interleaved and locally unexploited (in every broadcasting area). In practice, Geographically Interleaved Spectrum is five or six times wider than the exploited/useful one, as long as more than 6 adjacent areas are usually considered in NTVCI planning.

Interleaved Summarising, Spectrum (both geographically and in frequency), constitutes an unprecedented amount of spectrum, locally available even before the advent of digital broadcasting technologies, which still remains unexploited and/or underutilised. Its exploitation arises as a very promising solution for the deployment of Future Wireless systems at local level, enabling access/provision to high quality audiovisual services. To achieve these, however, a liberalised spectrum exploitation approach is needed for allowing secondary technology and services neutral systems to operate in the primary bands (provided that the signal would be sufficiently rugged in the local area and no interference is caused to other transmissions, especially to TV broadcasts), establishing Interleaved Spectrum as a potential Future Wireless commonly exploited infrastructure with enhanced range of services and applications.

2.2 TV White Spaces

In many areas of a county with high terrain variations and/or of low population density - rural and dispersed areas - national TV broadcasts are either totally absent, or delivered over other medium that VHF/UHF, such as satellites. Effectively, in these areas the unexploited VHF/UHF spectrum is very large, often comprising the entire TV Spectrum (e.g. when no local TV programmes are provided). Such geographical White Spaces of TV coverage can be found in rural areas, which tend to be underserved with other broadband options such as Digital Subscriber Line (DSL) or cable. This makes White Spaces of particular interest for Wireless ISP operations in rural areas where the population is normally un-served or underserved with broadband access. White Spaces, i.e. geographically vacant/ unexploited TV channels, are perfectly suited for Wi-Fi and other unlicensed wireless Internet services. Access to them would facilitate a market for low-cost, high-capacity, mobile wireless broadband networks. Using these white spaces, the wireless broadband industry could deliver low-cost Internet access to every citizen in these areas, providing for an enormous social benefit and a catalyzing economic engine, particularly in rural areas. Some example applications for White Space exploitation at local level include in home multimedia distribution, WLAN networking and long range bridging, self organizing-mesh connected community and campus networks, gaming, home

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automation and control, non-critical monitoring applications, etc. These applications may already be offered in other frequency bands than the VHF/UHF spectrum but there currently a strong industry-wish to exploit specific benefits of the UHF spectrum. In particular, the superior propagation characteristics of UHF enable wider range connectivity and thus assist applications that require real-time delivery of data (home multimedia distribution, gaming, etc). Towards these, new devices have to be designed for White Space operation both at the transmitter and receiver ends, including personal/portable devices (such as Wi-Fi cards in laptop computers, smart phones, PDA's, personal media players, etc.) and fixed-access devices that are operated from a stationary location e.g. for wireless broadband Internet access. However, for the same reason, e.g. the superior propagation of UHF, interference that could be generated by these new devices (not only towards primary or other prioritised services but also among them) is a major issue that imposes certain constraints on the operation of new White Space devices.

Furthermore, the European Conference of Postal and Telecommunications Administrations (CEPT) identifies white space as a part of the spectrum, which is available for a radio-communication application (service, system) at a given time in a given geographical area on a non-interfering nonprotected basis with regard to primary services and other services with a higher priority on a national basis. The TV White Spaces arise because in a multiple frequency network any television channel is carried on a number of different frequency channels around the service area. On any given frequency channel there will be a geographical zone where use for high-power broadcasting is not possible because of the interference it would cause, but use for low/moderate power applications is possible, provided these are carefully designed so as to be compatible with the primary users DTV and other secondary users such as PMSE (Programme Making and Special Events).

3 Potential Exploitation of Interleaved Spectrum

Currently, DTT networks use a number of regional transmitter sites to achieve national coverage. However, so far these multiplexes have tended to operate at full capacity and the scope for regional "additional services" to serve local TV interests may not be great. A possible way forward to provide additional services is therefore to use the so-called Interleaved Spectrum rather than to reduce the already occupied spectrum on the national DTT networks. The principle of the Interleaved Spectrum consists in using those 8 MHz-wide channels in a nationwide network that have to be reserved to avoid interference. Such an Interleaved Channel could for example carry two additional local programme services.

It is evident that the issue of spectrum scarcity in VHF/UHF is currently a matter of frequency licensing and network planning rather than a matter of spectrum shortage, calling for novel liberalised spectrum management frameworks, based on "bitrate and resource rental" instead of "command and control" of spectrum. These will allow for the exploitation of Interleaved Spectrum as а technology neutral and services wireless infrastructure, commonly utilised by primary (e.g. Broadcasters) and secondary actors stemming from the Internet, telecommunications and active-citizen fields, so that important social and economic uses can have access to this valuable resource. These arise as a unique opportunity to give impetus to the whole of the wireless communications industry as well as the broadcasting industry. It can significantly contribute to the Lisbon goals of competitiveness and economic growth and satisfy a wide range of the social, cultural and economic needs of European citizens. There are at least three broad categories of services for which the available spectrum would be well suited:

Additional terrestrial broadcasting services at local level. Broadcasting is entering a period of intense transformation and high innovation as it makes the transition to digital and high-definition services. Increasing the number of broadcasting channels, especially at local level, holds out prospects for increased media pluralism, growth in media content production of higher-quality, as well as for more interactive services for viewers. It is therefore appropriate that local and regional broadcasters should be able to claim a fair portion in the Interleaved Spectrum, serving a closely defined geographic area, such as a city, a local community or a region of a given state. Local TV may be operated on a wholly commercial basis, as a not-forprofit community model, or as a combination of both. Binding and enhancing Local television with interactive capabilities, enabling user/citizens not only to consume predefined content but also to create, manipulate and deliver their own services, will elevate it towards a more dynamic stage: the realisation of neutral wireless infrastructures, capable to accommodate user-generated high quality Future Internet services. This, calls for novel radio

architectures and liberalised frequency management approaches, allowing for Interleaved Spectrum exploitation not only by existing but also by any potential service/content provider. The active participation and vis-à-vis exploitation of Interleaved Spectrum by this critical mass of potential content/application providers (stemming from traditional users) is the key element towards generating revenue, gearing up rich activity in the market chain and spearing new progress in local, national and pan-European levels.

Mobile multimedia may be regarded as one of the most innovative application areas with impressive social, cultural and economic prospects in the ICT sector. Those applications will be enabled by the new standards for mobile networking, such as triple services for mobile networks, digital television in a converged environment, video streaming, interactive gaming, navigation services, context aware services, emergency and healthcare applications, and immersive communications in virtual environments. The efficient delivery of multimedia applications services over and emerging diverse and heterogeneous wireless networks is a challenging research objective. The research effort for the 4G vision of inter-working among heterogeneous achieve multimedia technologies to session continuity and to retain multimedia OoS characteristics amplifies the need to evaluate the conditions and restrictions under which the delivery of such services can be accomplished.

Wireless broadband communications. "Ubiquitous broadband access for all" is among the Europe's challenges towards bridging the "broadband gap" and overcoming the "digital divide", especially in remote and rural areas. Providing rural communications is often challenging due to the mismatch between costs and demand. Most rural areas have low population density and the demand for services per individual or household can be much lower in rural areas if compared to urban areas. To create a viable business, operators must aim for low-cost solutions. However, the deployment and maintenance \mathbf{of} rural communications networks can be costly due to large areas requiring coverage, and/or difficulties due to terrain variations. This is particularly true for wired networks because wires or cables must be laid all the way to the destinations. As a result, wireless technologies usually are preferred for rural connectivity. Interleaved Spectrum exploitation arises as a very promising solution for speeding up broadband deployment and improving wireless broadband access, especially in dispersed and rural areas.

3.1 Interleaved Spectrum

Digital Video Broadcasting (DVB-T2): The most widely adopted and deployed standard for Digital Terrestrial Television (VHF/UHF operation) is the European breakthrough, commonly known as the DVB-T. A mature and well-established standard, it benefits from economies of scale that lead to very low receiver prices and is flexible enough to enable a wide range of business models. Nonetheless, the approach of ASO (Analogue Switch-Off) in Europe and other developed DTT markets has generated an impetus to update the standard, as has already been achieved with DVB-S2 for satellite broadcasting. Although there will be many competing demands for the spectrum that will be released at ASO – with DVB-T2 the DVB Project offers broadcasters a means of using that spectrum in the most efficient ways possible using state of the art technology.

DVB-T2 introduces the latest modulation and coding techniques to enable highly efficient use of valuable terrestrial spectrum for the delivery of audio, video and data services to fixed, portable and mobile devices. As such, the final specifications of DVB-T2 technology are based on a set of Commercial Requirements, including increase in capacity and improved robustness (current projections suggest that capacity gains of around 45% will be achieved), and the ability to reuse currently existing receive antennas and downlinks.

specifically, DVB-T2 uses More OFDM (orthogonal frequency division multiplex) modulation, with a large number of sub-carriers delivering a robust signal. Also in common with DVB-T, the new specification offers a range of different modes, providing for flexibility. In the realm of error correction, DVB-T2 uses LDPC (Low Density Parity Check) coding combined with BCH (Bose-Chaudhuri-Hocquengham) coding, offering excellent performance in the presence of high noise levels and interference, resulting in a very robust signal. Several options are available in areas such as the number of carriers, guard interval sizes and pilot signals, so that the overheads can be minimised for any target transmission channel. A new technique, called Rotated Constellations, provides significant additional robustness in difficult channels. Also, a mechanism is provided to separately adjust the robustness of each delivered service within a channel to meet the required reception conditions (e.g. in-door antenna/roof-top antenna). This same mechanism allows transmissions to be tailored such that a receiver can save power by decoding only a single programme rather than a whole multiplex of programmes. Finally, DVB-T2 has defined a way that the standard can be compatibly enhanced in the future through the use of Future Extension Frames.

Although DVB-T2 constitutes the current stateof-the-art mainly for broadcast services provision within Interleaved Spectrum, a number of technological enhancements need to be made for establishing it as a potential Future Internet technology, enabling citizens to access personalised content at guaranteed QoS. For example, real-time spectrum customisation according to specific network's/services' QoS requirements, call for services adaptation mechanisms and variable coding and modulation schemes, which will be dynamically according adapted to OoS estimation metrics/analysis provided by users over reverse path channels.

Long Term Evolution (LTE): Even though the 3GPP Release 5, 6 and 7 for HSPA have improved UMTS's capabilities significantly, to ensure competitiveness of the UMTS in the long term, 3GPP is currently working on its newer Release. The 3GPP's Release 8 or the so called "Long-Term Evolution" (LTE) has set its target to develop a high-speed, low-latency, low-cost and packetoptimized radio access technology which closely meets the definitions of the so-called 4G mobile network.

Some of the initial targets for the specification effort of LTE include:

- Peak data rate of more than 100 Mbps on the downlink and more than 50 Mbps on the uplink, given available bandwidth of 20 MHz, 2 receiving antennas and 1 transmitting antenna at the User Equipment (UE).
- Average user throughput should be several times better than that of Release 6
- Reduced latency both in control and user planes. A small IP packet for the user plane should also experience latency only around 5 ms in an unloaded condition.
- Scalable system bandwidth deployment of 20, 15, 10, 5 MHz or even less should be supported.
- Inter-working between UTRAN, GERAN and non-3GPP networks. Roaming between other 3GPP's Radio Network Technologies (RAT) must be possible. Also, the system must be able to co-exist with previously deployed GERAN or UTRAN.
- End-to-end QoS should be supported. VoIP services should have comparable quality to circuit-switched voice services of UMTS.

There are some aspects to be considered in this case. LTE was mainly designed to serve for

individual point to point communication like phone services. Also the frequency range for LTE is above the VHF/UHF spectrum which is envisaged in this paper. The lowest possible frequency range for LTE in an uplink mode is located between 830 MHz and 840 MHz. According the decisions made in the Geneva 2006 Radio Regulation Conference the upper end for the UHF band reclaimable for broadcast services terminates at 790 MHz. In addition the LTE specification does not foresee a specific broadcast mode at the moment. Although it was planned to define such a broadcast mode, similar to the MBMS functionality known from GSM, its specification was postponed to a later time. Currently the MNOs (Mobile Network Operators) do not identify a business case that would justify such a specification effort. If it finally turns out that a broadcast mode in LTE is requested, certainly two or more years will pass by until the appropriate UE (user equipment) will be in the market.

IEEE 802.22: The IEEE 802.22 Working Group was formed in 2004 to develop a standard for wireless regional area networks (WRANs), based on cognitive radio technology [8]. WRAN systems will operate on the VHF/UHF TV bands, that is, from 54 MHz to 862 MHz, by opportunistically making use of the unused TV channels. While doing so, it must ensure that no harmful interference is caused to the incumbent users, which include TV receivers and FCC Part 74 wireless microphones. The WRAN must ensure that interference caused to all TV receivers within the TV protection contour (around 150 km from the TV station) is below a predefined threshold. Similarly, there is a protection area for the microphone system, but with a much smaller (a few hundred meters). size For rural communications, 802.22 technology offers two main advantages, that is, no dedicated spectrum is required, and the coverage is large. These two advantages help service providers address the costdemand mismatch, in particular, as no dedicated spectrum is required, service providers can save the cost of obtaining a spectrum license. In addition, wide coverage is essential to reach a large customer base in rural areas. 802.22 technology is designed to provide the average coverage of 33km and can increase to 100 km. Although most of the 802.22 related work has focused on various technical challenges, such as designing advanced spectrum sensing to detect weak TV and microphone signals or providing coexistence for multiple WRANs, these issues may not be critical for remote rural WRAN deployments, especially for White Spaces exploitation. In particular, in remote areas where large amount of White Spaces is available and more TV channels are unused, IEEE 802.22 is a very promising solution for Wireless Broadband Access, without any need of spectrum sensing. Based on the previously mentioned arguments, this paper anticipates that 802.22 could be potentially utilised for exploiting mainly White Spaces, and preferably in rural/dispersed areas. Nevertheless, it should be noted that a major technology drawback of 802.22 in rural areas White Space exploitation is system's efficiency, especially when TDD is used: in WRANs with large coverage areas, the long TDD turn-around time will significantly reduce the system throughput.

4 Dynamic Spectrum Access (DSA)

The growing demand, for the provision of ubiquitous heterogeneous services utilizing wireless networks, is straining the effectiveness of traditional spectrum allocation policies (i.e. "command and control" regime) and increasing the requirement for additional radio resources. DSA radio techniques promise to increase spectrum sharing, helping to overcome the lack of the available spectrum (i.e. spectrum scarcity) for new wireless communication services. Currently, spectrum sharing is limited to simple approaches such as low-power unlicensed devices. New types of spectrum sharing enabled by DSA include higher-power transmission at times when the primary users of a band are inactive, realtime trading of spectrum access rights and collaboration among unlicensed users to share spectrum resources more efficiently. DSA significantly increases opportunities for spectrum sharing, stimulating trading in the spectrum market. Sharing is increased by the coexistence of secondary users with (non-cooperative) primary rights holders and by the increased number of situations, where spectrum managers can safely allocate co-primary licenses [9].

DSA allows new services to replace legacy services more gracefully. A new entrant can begin with inexpensive, limited spectrum access rights, scaling its usage rights to match its capacity needs as business grows. Finally, increased lifecycle speed makes it more challenging to recover the fixed costs associated with introducing new technologies, services, or business models.

4.1 Spectrum Commons

"Spectrum commons" and "spectrum markets" are the main alternative regimes to the "command and control" spectrum assignment scheme. "Spectrum commons" addresses demand problems but relies strongly on the supply side for its implementation and "spectrum markets" considers private property rights (i.e. solution that addresses spectrum demand and valuation considerations).

According to "spectrum commons" regime new spectrum sharing technologies are utilized allowing a virtually unlimited number of persons to use the same spectrum without causing each other interference eliminating the need for either property rights or government control of spectrum. In a "spectrum commons" regime there is no spectrum manager to preside over the resource allocation. In order for "spectrum commons" regime to be viable, a spectrum manager must control the resource and set orderly sharing rules to govern its use. If the government is the controller, allocating and managing the common spectrum, then similar to the "command and control" regime processes are employed resulting in an inefficient way of spectrum management [10].

"Spectrum commons" model offers several benefits, including greater freedom to experiment with local variations on spectrum usage and a greater incentive to develop technologies for spectrum sharing (such as spread spectrum radios or technology). ultra-wide-band Additionally, regulating the spectrum as a commons might facilitate efficient transactions among competing users, and make economies of scale feasible for cross-boundary uses. The potential benefits are great enough to justify serious consideration of the commons as a regulatory possibility [11]. The need of a spectrum controller is essential when "spectrum commons" regime is adopted in order to manage the available resources and prevent degradation. In this respect the owner of the spectrum internalizes the cost of its actions and therefore makes efforts to avoid the type of "tragedy" that affects an open access regime. Common spectrum owners should have the power to manage the resource by setting and enforcing rules and excluding others from its use. Ownership or at the very least legal control, is therefore essential in order for "spectrum commons" regime to be useful and not an open access regime that increases inefficiency in spectrum usage. In this direction an owner, a group of joint owners or the government must control spectrum and set rules that restrict how resources are used. These owner-set rules permit sharing of a scarce resource to be more efficient.

"Spectrum commons" model utilizes no market mechanisms as a tool for allocating scarce resources among competing users. In this respect, there is always the risk that free access will eventually lead to interference and over-saturation (i.e. "tragedy of the commons"). These problems can be overcome to some extent through regulatory guidance, requirements such as power and emission limits and sharing etiquettes. But if actual spectrum scarcity still occurs, rights may need to be redefined and market mechanisms to be introduced in order to avoid inefficient use of spectrum [10].

There are various approaches to the "spectrum commons" regime. One approach, that was described above, permits spectrum access and usage without limitation to all potential users and is usually referred to as the "open access" regime. This regime is not what is generally viewed as the standard "spectrum commons" regime. The standard model is a co-management regime that draws from successful co-management experiences with other types of scarce common resources and is known as the "common property" regime. In this approach, the government legitimises and protects the boundaries of spectrum usage by a group of users (including criteria for group membership) but takes no part in its intrinsic governance. The spectrum management community so defined, composed only of end-users, has sole authority for spectrum uses, setting standards and dealing with interference. In essence, this model excludes individual property rights over the core resource exploited but tolerates access restrictions, thus conferring some degree of joint-ownership by membership to spectrum communal users. Approaches that confine access to and usage of frequency band by a group of users under private property rights are referred to as "privately run commons" or "commons parks". The benefits of the "spectrum commons" approaches include low barriers to entry (which is a source of competition), no or little uncertainty about band access, low lead times from innovation to market, less pressure on licensed portions of the spectrum, creativity through information sharing and diversity. This model may also be more compatible with international harmonisation and standardisation efforts as it offers a collaborative rather than competitive environment for equipment standards (i.e. manufacturers first collaborate on standards and then compete in markets) [12].

4.2 Spectrum Markets

"Spectrum commons" regime promotes sharing but do not provide adequate Quality of Service (QoS) for some applications. For applications that require sporadic access to spectrum and for which QoS guarantees are important, licensed spectrum with real-time secondary markets (i.e. spectrum markets model) may be the best solution. Trading allows players to directly trade spectrum usage rights, thereby establishing a secondary market for spectrum leasing and spectrum auction. This model has the potential to enable small companies to enter the spectrum market, boosting competition and innovation in the wireless telecommunications sector. Unlike today's unlicensed bands, primary and secondary users would coordinate directly, making it possible to protect QoS for both primary and secondary users. In this explicit coordination, license holder runs admission the control mechanisms, which allow secondary users access to spectrum when QoS of both primary and secondary would be adequate. The license-holder also uses an intelligent frequency assignment algorithm for determining the frequency at which a secondary user should be allowed to operate and the economics of such transactions which provides incentives to maximize spectrum utilization. Secondary users dynamically request access to spectrum when spectrum is needed. The trading of secondary use may occur through intermediaries such as a spectrum broker. In general, the mechanisms of searching for a match between the primary and the secondary users largely rely on types of services, access characteristics and service levels requested by secondary users. The access types could consist of a long-term lease, a scheduled lease and a shortterm lease or spot markets. Each type requires different discovery mechanisms and applies with different levels of service agreements.

5 Business Strategies and Marketing Opportunities

The radio spectrum is a scarce resource that has been historically allocated through "command and control" regulation. This spectrum management regime retains the government in its traditional role of providing centralized allocation and bureaucratic enforcement of monopoly rights to the spectrum. This regime functions as a barrier to entry for those mid-level players that might have the most innovative ideas about spectrum usage. "Command and control" regime does not permit license trading, which provides no incentives to licensees to maximize the value of their spectrum holdings, restricting to adapt to new market conditions. In this context, "command and control" regime can be characterized by slow progress of innovation to market, slow spectrum reallocation for new wireless systems and is considered inefficient and

unsustainable by most spectrum analysts and many regulators [13]. The "command and control" regime weaknesses have been thoroughly indentified and extensively analyzed in [13], [14], [15].

There is a near-unanimous agreement that sole reliance on "command and control" regime does not result in efficient outcomes. Regimes, where regulators assign radio spectrum to specific uses, do not necessarily maximize social welfare and do not respond to new spectrum-using product developments and their associated technology [16]. Also, the distinction between spectrum allocation (specific quantities for specific uses) and assignment (specific users in specific numbers) is artificial and inefficient as it creates a wedge between the expertise and its application [17]. "Command and control" regime created market frustration characterized by long lead times from innovation to the market and the dominance of large incumbents with little dynamism. With the increased demand for wireless products in recent years, the consequences are congestion and huge welfare costs in terms of lost, productivity public revenue delayed improvements and missed opportunities in international markets [18], which eventually led to calls for more efficient ways to allocate and manage spectrum.

Regulators have realised the need to involve market makers in the wireless networks space, including service providers, equipment manufacturers, network operators, entrepreneurs, researchers and the end users. Their involvement is vital for the development of more efficient spectrum allocation strategies (i.e. DSA regimes), providing support for innovation and entrepreneurship as well as to the whole economic growth [19]. An obvious result of greater trading and more spectrum sharing is that spectrum access gets cheaper. This is of course the major driver for the wide interest in DSA. What is not so widely discussed is that cheaper spectrum and an active secondary spectrum market will reshape the radio services market and industry value chain. This enhances competition in data communication services, driving down service prices. As a result, incumbent business models built around spectrum scarcity will be less viable. Incumbents will need to introduce more value differentiated services to justify price margins. In this respect. DSA stimulates innovation in wireless communications even from operators who do not exploit it [9]. DSA provides significant economic and social benefits if it becomes widely available and utilized. For this to occur, the wireless services market itself must evolve. New value chains, market incentives and ways of managing risk must grow up around the new features of DSA radios. Product features and technical capabilities that support the necessary changes in the market are just as important as the core spectrum access features of DSA radios.

Furthermore, the economic potential and consequent social value in Europe, arising from a wise management of the cleared spectrum and and TV White Spaces, has been the object of many studies in last 3 years. The major findings of most of the studies are correlated and identify the following potential uses of this part of spectrum:

- Digital Terrestrial Television (DTT)
- Mobile TV
- Commercial wireless broadband services (fixed and mobile)
- Wireless broadband services for public protection and disaster relief (PPDR)
- Services ancillary to broadcasting and program making (SAB/SAP)
- Cognitive Radio technologies

Due to the differences and peculiarities of each Member State, the potential growth and demand on each of the aforementioned potential uses may vary significantly. However, studying a representative sample from a wider categorization of all Member States, illustrated that the UHF band used for terrestrial broadcasting is estimated to generate €750bn to €850bn in Net Present Value (NPV) for the European Economy. Additionally, the excellent propagation and coverage characteristics of this band are, without doubt, of great interest for the major stakeholders and will require a common approach and harmonization of the actions, especially on behalf of neighboring countries.

In this respect, the conservative trend in Europe is to allocate a part of the UHF spectrum (ranging from 72 to 92 MHz at a first stage) to mobile operators, which is estimated to generate between €63bn to €232bn NPV, measuring the benefits for a 20 year period. A further expansion will probably be reconsidered at a second stage, after reevaluation of the market as a whole, taking into consideration updated data on demand, market growth and technological innovations.

At a broader view, the market can be analyzed under different scenarios (e.g. pessimistic, conservative and optimistic) in which, the main key drivers are the DTT and Wireless Broadband Service growth/demand and the relation between them. These parameters are then interpreted into economic figures considering, either a very specific UHF spectrum allocation for each service (e.g. 790 MHz – 862 MHz sub-band for mobile operators) or different ranges of spectrum allocation for the each service, in order to identify the optimal distribution of the band to the different potential uses of interleaved spectrum and TV White Spaces.

In order to quantify the forecasting of the growth and demand of the Wireless Broadband Service and finally interpret them into direct and indirect economic benefits and externalities, the models are using measurable key activities such as Video and downloading (streaming measured in minutes/month), Browsing (pages/month), Music (tracks per month), Email (emails/month), Mobile (minutes/month) and Other TV Business Applications, all referring to a representative "file size per use".

Direct benefits are those arising from the direct consumption of mobile broadband services and are split into the cost/benefits due to the producers and those due to the consumers. For producers of mobile broadband services, direct benefits primarily accrue as a result of a reduction in network costs. If these cost savings were retained by the operators or their shareholders, this would add to the producer Surplus. However, since the specific market is considered to be highly competitive, it can be safely assumed that almost 100% of cost-savings are ultimately passed on in price changes. Reduced prices for mobile broadband will facilitate increased consumer usage of the service and the incremental benefit to consumers or consumer surplus is this additional usage, combined with lower prices for existing usage.

Indirect benefits result from indirect effects that the market for these services have on other product markets and, as a result, can further increase total consumer and producer surplus. For example, some of the incremental revenues from a mobile broadband service could be generated by advertisements or incensement of e-commerce and not only by the subscribers. However, especially for the advertising revenues, they do not represent an economic benefit but a financial flow or an expense by the advertiser as part of its marketing strategy which results in higher sales and profits for the producers in other parallel markets.

Externalities are wider economic benefits to society as a whole which are not generally taken into account by the consumer or the producer when selling the product or service. These would include increased productivity of workers, since the business applications will be available easier and in more efficient ways, additional job generation, boosting of related industries, etc. Moreover, as a further social add on, can be considered the improvement of Quality of Service, as well as the enhancement of the safety and security related applications, which promote a better quality of life to the citizens.

6 Conclusion

This paper studied the spectrum availability issue in VHF/UHF frequencies, presented existing technological and scientific approaches allowing for dynamic spectrum management and elaborated on their potential exploitation following "spectrum commons" and "spectrum markets" regimes, rather than the "command and control" one. Business strategies were discussed, outlining the marketing opportunities introducing in secondary systems/services within a primary band (TV band).

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