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Dynamic Spectrum Sharing for Future Wireless Networks: Regulators Perspective

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Abstract: Radio Frequency spectrum is the superhighway enabling a myriad of wireless ICT services and applications. Spectrum scarcity and expensive licensing cost has resulted in research and innovations by the CSIR, wireless network providers and telecom regulators, which helped to develop techniques to dynamically share & manage spectrum, thereby enabling efficient spectrum utilization. Spectrum management based on spectrum sharing techniques such as LSA & SAS are being considered by spectrum regulators, aiming at efficient use of spectrum as a scarce natural resource, while ensuring non-interference & fairness between different radio spectrum users and wireless services. This paper recommends the improvement of spectrum management by regulatory authorities using recent research and technologies developed for spectrum sharing and application of new spectrum licensing frameworks. The paper presents spectrum licensing & management approaches and focuses on the enabling role smart spectrum sharing can play in spectrum efficient and affordable broadband wireless networks. A comparative analysis of advantages and disadvantages of a regulator licensing spectrum, as compared to allowing mobile operators to sub-license allocated spectrum is also discussed in the paper.

Keywords: Dynamic spectrum management, Radio Frequency spectrum, regulation.

1. Introduction

Radio frequency (RF) spectrum is a finite resource that consists of frequencies in the range of 3 kHz to 300 GHz. It is used for wireless communication and supports billions of applications and services that are drastically increasing due to the flexibility of wireless communications and bandwidth demand of emerging smart phone applications. Hence RF spectrum as a scarce and expensive wireless network resource needs to be dynamically managed to enable efficient usage [1]. RF Spectrum regulators around the world are increasingly becoming aware of the importance of efficiently managing national RF spectrum resources. Spectrum management decisions are made by the regulator. The decision made by the regulators aim at efficient use of spectrum as a scarce natural resource while ensuring fairness between different radio spectrum bands [2][3].

Traditionally RF spectrum management has been managed statically by national spectrum regulators such as the Independent Communications Authority of South Africa (ICASA), on a service-by-service basis exclusively for a while and covering the national boundaries. This has resulted in inefficient utilization of valuable spectrum resources that recently has prompted the requirement for changes from the philosophy of “static” to “dynamic” spectrum management [4]. The exponential increase in mobile data-traffic propelled by the smartphone revolution is also another factor that prompted stakeholders of the wireless ICT eco-system to consider the paradigm shift to dynamic spectrum management (DSM). DSM is regarded as a process of regulating the use of RF spectrum to promote efficient utilisation of spectrum resources.

Spectrum management involves layered stages of regulatory mechanisms, starting at the international level with the International Telecommunication Union (ITU) planning process, followed by national planning processes and down to spectrum licensing and interference management frameworks to gurantee QoS.

Spectrum authorization typically involves the licensing of frequency assignments and radio communication equipment by the spectrum manager. Licensing places restrictions on the use of assigned frequencies and the transceiver power levels to prevent harmful interference. Under either administrative or market based methods, utmost clarity is required about what license conditions are entailed by the license. These must be specified in respect of technology, geography and time [5]. This process also involves type approval of transceiver devices with respect to the specific technical regulatory formulation.

This paper discusses dynamic spectrum management from a regulatory perspective focusing on the licensing methods. Spectrum management approaches are presented and the role of spectrum sharing in wireless networks is explained. A comparative analysis of advantages and disadvantages of a regulator licensing spectrum, as compared to mobile operators sub-licensing allocated spectrum are discussed in this paper.

2. Dynamic Spectrum management techniques

It is now evident that licensed wireless networks and the use of spectrum requires a technique shift from inefficient and static spectrum management to a flexible and highly-efficient spectrum management techniques. Application of current spectrum management can be classified into three types [6][7] namely administrative allocation, market-based mechanisms, and unlicensed commons approach. The aforementioned approaches are explained in [7]. In this paper we will mainly focus on the techniques that will enable efficient spectrum utilization through dynamic spectrum management.

Enabling technologies for efficient spectrum utilization and management have been an active research area, spurring development of smart spectrum sharing technologies [5,13]. The mobile industry, with the following technologies allow spectrum sharing between a primary licensee and secondary user of the band. These are based on regulations that have been designed and placed to allow flexible spectrum sharing, while at the same time keep a low interference level. Below we discuss some of the spectrum sharing technologies namely Licensed Shared Access (LSA), Spectrum Access System (SAS) and TV white space (TVWS). In this paper we will focus on role of the regulator in LSA an SAS. LSA and SAS enable regulators to manage spectrum sharing between existing licensed and unlicensed secondary networks [8]. Dynamic spectrum management relies on a centralised database [9]. Both LSA and SAS are database assisted technologies.

a. Licensed Shared Access (LSA)

This is a spectrum sharing approach aiming to facilitate the introduction of radio communication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users. Under the Licensed Shared Access (LSA) approach [9]. The additional users are authorised to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorized users, including incumbents, to provide a certain Quality of Service[10][11]

The LSA approach is primarily intended to ensure immediate access to the spectrum to commercial operators, without binding their investments to the times of the traditional process of refarming. The generic LSA concept encompasses sharing between any types of radio systems, most activities in standardization and regulation are concentrating on the application of LSA in the IMT bands [12] This could enable mobile communication systems to access the bands available on a shared basis that are currently not available for them on an exclusive basis.

The 2.3-2.4 GHz band is under study as the first use case for LSA. In the regulatory domain, European Conference of Postal and Telecommunications (CEPT) has considered harmonized implementation measures and introduced crossborder coordination procedures for this band [13][8]. From a standardization perspective, European Telecommunications Standards Institute (ETSI) has published a system reference document describing at a high level the mobile broadband services for the 2.3-2.4 GHz band under the LSA regime. ETSI is in the process of specifying the requirements, functional architecture and protocols for LSA.

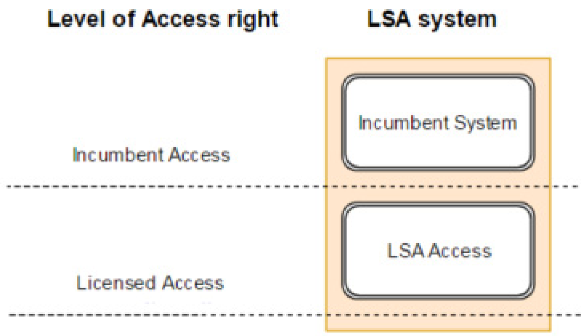

Figure 1: LSA system

Application of the LSA system is efficient utilization of spectrum in mobile communications networks. It allows also for a secondary and affordable networks to be deployed, as an extension to the existing mobile networks. Furthermore, the absence of a national spectrum regulator, in the sub-licensing process of the LSA system, makes it attractive for rapid deployment of secondary networks.

i. The role of the regulator in LSA

The role of the regulator in LSA is to set the boundaries and rules to protect the incumbents of the band while also provides the quality of service to the LSA licensees. The regulator should enforce the mobile network operators (MNO) to share the spectrum where it is not used for the services it is licensed to provide.

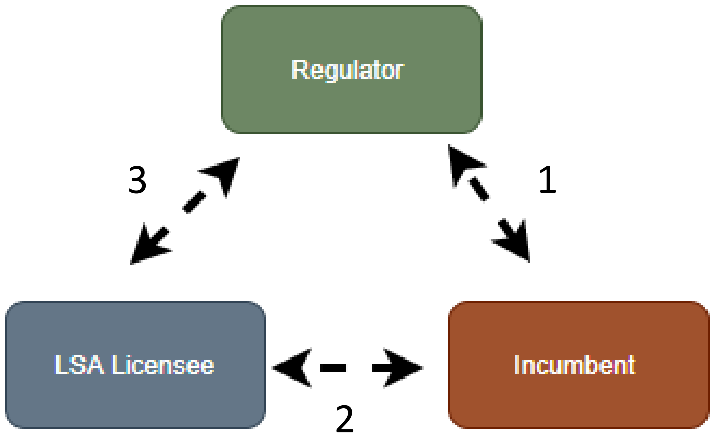

Figure 2: LSA 3 phase Regulatory framework

The LSA spectrum regulatory process as shown in figure 2 is composed of the following 3 phases indicated by the arrows:

1. Regulator and Incumbent network provider exchange spectrum license agreement. They also identify the rules and spectrum areas for secondary LSA licensing by Incumbents. This is fed to the R-GLSD by the regulator for spectrum data handling and incumbent regulation.
2. The LSA licensee sends request to the incumbent, for deployment of a secondary network in a geolocation availing secondary LSA spectrum. The Incumbent registers the LSA network provider and provides the secondary license parameters. And communicates the information to the R-GLSD.
3. The LSA secondary network licensee will be registered by the regulator and get confirmation of commencement of operation by the regulator through the incumbent.

b. Spectrum Access System (SAS)

SAS is a database centric sharing model and is mainly attracting interest in the USA at the moment [9]. SAS supports spectrum sharing with three levels of hierarchy in spectrum usage as shown n Figure 2. The incumbent systems are accorded the highest level of usage rights including exclusive spectrum access and guaranteed protection from harmful interference when and where they deploy their networks[14]. Secondary licensees occupy the middle level and are generally expected to be a commercial service provider i.e. a cellular service provider.

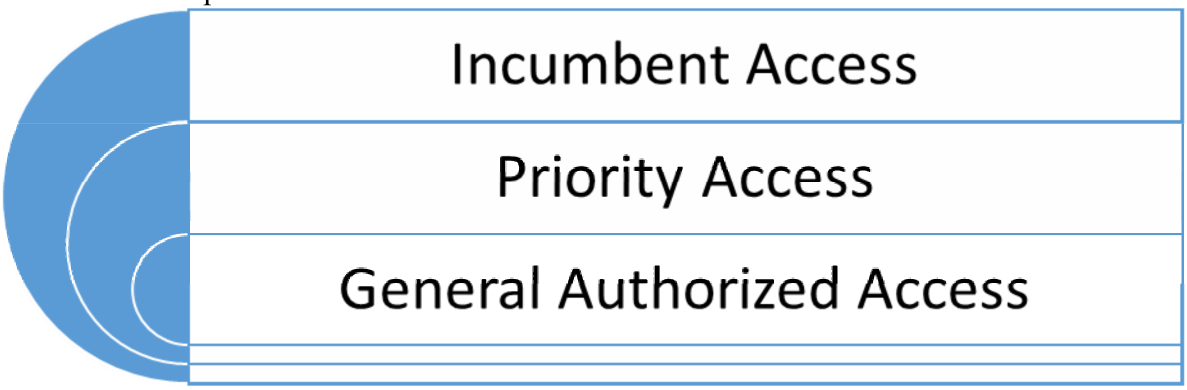

Figure 2: SAS system

The secondary licensee would have short-term priority operating rights, that is, Priority Access License (PAL), for a specified geographic area[8]. PAL is issued for a predefined term and bandwidth, such as, one minute or even one year for a 10 MHz unpaired channel with possibly varying spectral location. PAL could also guarantee the secondary licensee interference protection from the third level of the hierarchy often referred to as opportunistic use. Third level of 12 access is called the General Authorized Access (GAA) and is light licensed similarly to a Wi-Fi with the critical distinction that the GAA device or system must be capable of effectively interacting with the controlling SAS[9]. GAA users are allowed to opportunistically access a specific spectrum band in a geographical area or time period when it is otherwise unoccupied by both the incumbent and the PAL licensee. The amount of spectrum reserved for PAL and GAA and the PAL license durations will strongly influence their demand.

i. The role of the regulator in SAS

The role of the regulator in SAS is the same as in LSA; to set the boundaries and rules to protect the incumbents of the band while also provides the quality of service to networks operating in PAL. For GAA quality of service is not guaranteed.

3. Improved ICASA spectrum management and licensing

Spectrum regulatory authorities such as ICASA can learn from LSA, SAS and TVWS technologies to dynamically manage national spectrum thus improving efficient usage of the IMT band. This section discusses current ICASA spectrum management systems and how it can be improved by using spectrum sharing techniques such as the CSIR GLSD.

A main objective of regulatory reform in the transition to DSSM regimes has been to provide flexibility to operators to make choices regarding spectrum use and technology while balancing concerns of market failures with respect to universal coverage and competition [16]. The regulatory process and efficient management of spectrum resources for dynamic spectrum management is a complex undertaking [17].

The regulatory objectives for dynamic spectrum sharing (DSS) [15]are as follows:

(i) Improved and effective utilisation of national spectrum resources in all bands of interest.

(ii) Development of reliable spectrum monitoring and co-existence tools with legacy licensed networks to enable non-interfering DSS.

(iii)Enabling broadband network innovation in support and provision of affordable broadband for the unconnected, and the fulfilment of the national development plan for future ICT and wireless broadband services.

(iv) Harmonisation of the DSS rules along country boundaries and international telecommunication union (ITU) standards and guidelines.

(v) Developing DSS policy with a foresight and aim to promote new wireless communications technology and emerging business models

Even though the above objectives mainly focus on dynamic spectrum sharing, they can be applied on dynamic spectrum management as well. The research work done by [15] supports the formulation of the dynamic spectrum regulatory framework including co-existence techniques, interference avoidance and network device technology aspects in support of telecom regulators in emerging economies.

There are two major areas of transitioning from traditional spectrum management regimes to market regimes [15]. The first is called deregulation of assignment (DASS). DASS refers to switching to auctions in the primary market and trading in the secondary market. The second is called deregulation of allocation (DALL). This refers to liberalisation of spectrum by which the band user is given flexibility to adopt a service and technology of choice. The author also [15] presented international experiences of spectrum management reforms, aiming at strategies to introduce market-based mechanisms for spectrum management.

The Cloud Based Spectrum Manager (CBSM) is proposed by [19]. The CBSM provides an end-to-end integration of existing and new spectrum management solutions to allow national spectrum regulatory authorities to automate the RF spectrum management function. It aims to leverage a number of recently developed technologies and techniques with the aim of advancing the RF spectrum regulatory environment.

Towards the end, we propose a framework for DSSM from the Perspective of South African Independent Communication Regulatory Authority of South Africa (ICASA). Currently ICASA acquired the R-GLS system [5] for 470 MHz to 694 MHz (excluding the Radio Astronomy sub band: 606 MHz to 614 MHz), to be shared on a secondary basis by White Space Devices (WSDs) for providing broadband services. R-GLS is limited only to the TV band where spectrum is shared dynamically without causing harmful interference to the incumbent users of the band.

They are also developing the system called automated spectrum management system (ASMS), which automates all the processes of applying for the license. Previously, to apply for the license the applicant either mail the document or hand deliver them to ICASA.

The current spectrum management systems do not solve the problem of inefficient utilization and management of the RF spectrum and furthermore it is not tune with current advancement in technology. Figure 3 shows the formulated dynamic spectrum management system.

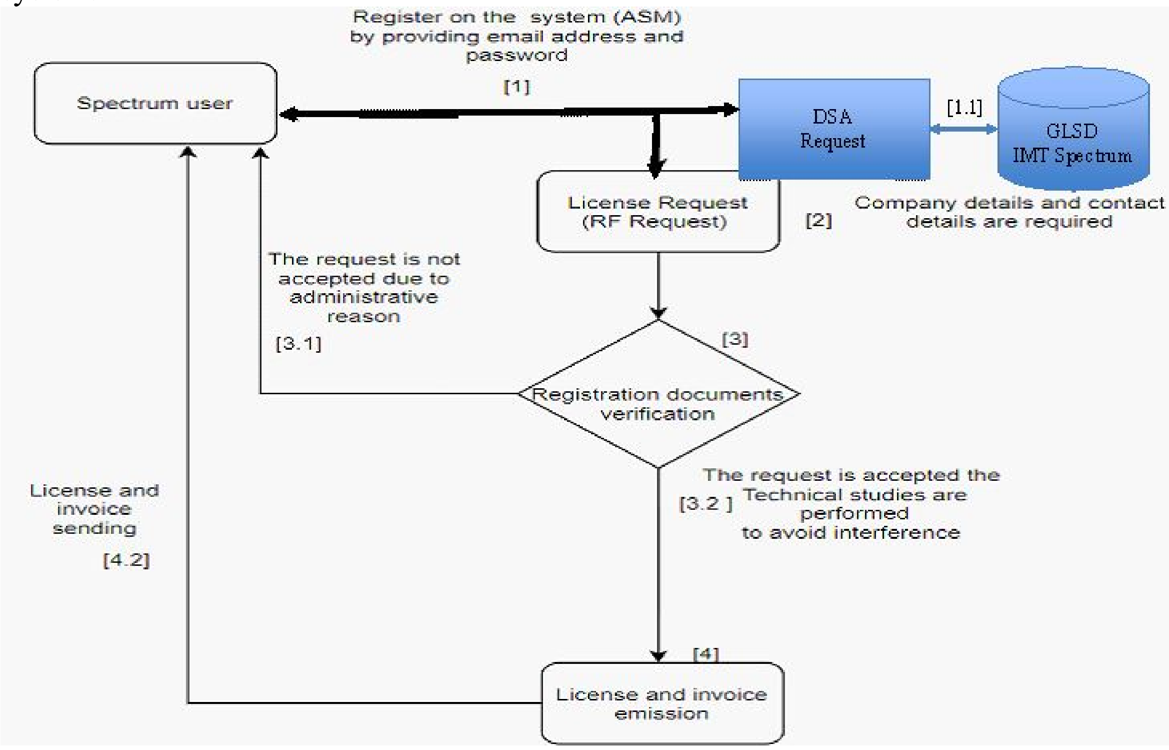

Figure 3: ICASA dynamic spectrum management system

For ICASA to dynamically mange spectrum in the IMT bands, there is a need to integrate spectrum sharing techniques such as the GLSD, in its current spectrum licensing model, as shown in figure 3. Where the Spectrum User/Network provider Initiates request for dynamic spectrum access (DSA) in allocated IMT bands, and also provides location information. The DSA Request block registers the request and sends IMT spectrum availability query to the IMT band through the Reference GLSD spectrum database.

4. Conclusions

In this paper LSA and SAS are discussed as technologies that facilitate efficient spectrum usage enabling future wireless networks. The role of the regulator in implementing smart spectrum sharing through the techniques such as the GLSD spectrum database, and integrating it with LSA and SAS is also discussed. The efficient management spectrum resources through GLSD database and assisted technologies is described. LSA and SAS techniques are easy to integrate as database assisted technologies where operational parameters and secondary user information, enabled by incumbents of the band is efficiently managed. Updating current spectrum licensing using spectrum innovation technologies such as the GLSD, was also discussed based on the ICASA spectrum management model. The role of the national regulatory authority in SAS and LSA is thus found to be the setting of boundaries and rules to protect the incumbents of the band while also provide the overall quality of service of both the incumbent & secondary networks. The SAS will be explained more in the future in respect to regulatory framework.

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