Potential and challenges of the Licensed Shared Access approach

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***Abstract*— The Licensed Shared Access (LSA) approach represents a powerful tool to provide additional rights of use, share the frequency band between different services and applications and allow predictable Quality of Service for all rights holders. In brief, LSA holds the potential to improve spectrum efficiency and speed up the development of wireless high capacity networks. Its adoption is being advocated by an increasing number of players, but it must be warily considered prior to its adoption in live networks.**

Actually, it poses a series of technical challenges as well as regulatory and strategic issues. Many questions must be raised, and duly answered, before full-fledged LSA can leave theoretical studies and be deployed in real networks. Furthermore, spectrum management strategies, though coordinated at regional level (by CEPT, by the RSPP, etc.) will also depend on local conditions, e.g. the availability of candidate bands is not uniform throughout Europe, owing to factors such as reserved usage for military communications. Thus, studies cannot abstract from the actual situation they address.

In this contribution, we aim at shedding some light on the above issues, with general considerations followed by a case study on C-band (3.4-4.2 GHz) in Italy.

Keywords— Licensed Shared Access, Compatibility, Spectrum

I. INTRODUCTION

In the recent decades, the formulation of policies aiming at improving the efficient use of spectrum has been at the heart of the telecoms policy at national, European and international level. Approaches alternative to the traditional command-and-control and market models (e.g. unlicensed model, spectrum trading, spectrum leasing, etc.) try to answer the same need, namely satisfying the increasing demand for spectrum and avoiding the misuse of this very valuable and scarce resource. This is extremely important as we are witnessing a huge growth in wireless data traffic.

To handle this growth, the industry is challenged to introduce new technologies, whereas administrations are urged to identify the appropriate amount of spectrum, releasing additional frequencies, as well as adopting innovative policies capable to ensure transparency and efficiency in the allocation and assignment of spectrum rights of use. These must rely on the proper valorisation of spectrum and must give well-defined and clear indications to the market, and in particular to those who are called upon to finance the digital infrastructure of ultrafast broadband networks.

In this context, the possibility of sharing spectral resources among several users may constitute a valid option, whose main features are at the moment object of a wide discussion. Spectrum sharing is the collective use of a given portion of the electromagnetic spectrum by two or more parties. From a regulatory perspective, this sharing can be licensed or licence-exempt.

As far as wireless broadband applications are concerned, the licensed approach to sharing (Licensed Shared Acces, LSA) offers more robust and attractive sharing opportunities, also to complement licensed access to exclusive spectrum.

LSA is in fact an emerging and promising methodology allowing to optimise usage of spectrum resources in order to cope with the ever increasing demand of broadband wireless services. More generally, the LSA approach aims at providing additional spectrum rights of use, sharing the frequency band between different categories of services and applications, while allowing predictable Quality of Service for all rights holders.

In Europe and in CEPT (European Conference of Postal and Telecommunications Administrations) Countries, there has been an extensive activity aimed at the definition of the regulatory framework for LSA, in order to make this approach factual and fully benefit from its potential. CEPT-ECC has defined in [8] LSA as a complementary spectrum management tool that fits under an "individual licensing regime", aiming to ensure a certain level of guarantee in terms of spectrum access and protection against harmful interference for both the incumbent(s) and LSA licensees, thus allowing them to provide a predictable quality of service.

In this paper, we give an account of LSA perspectives in the short-medium term.

Section II recapitulates the current regulatory framework for spectrum sharing, particularly in Europe. Section III describes which steps must be taken by the single national administrations in order to promote LSA. These concepts are analysed in details in Section IV, while subsequent Section V discusses the main technical requirements and introduces a generic architecture for the implementation of LSA. Section VI discusses a realistic application scenario, while guidelines for good practices are introduced in Section VII. Finally, the conclusions and the way to proceed forward with this topic are in Section VIII.

II. INTERNATIONAL EUROPEAN FRAMEWORK FOR THE SHARED USED OF SPECTRUM

The EU authorities have issued a number of policy statements [2][11] aimed at promoting more flexible use of spectrum, and this principle is encompassed within the Radio Spectrum Policy Programme [REF]. In this context, spectrum

sharing is currently being discussed at EU level in order to reach a harmonised framework. In particular, the 2.3 GHz band, which is already globally harmonised for IMT, has been identified as the highest priority band for spectrum sharing.

In view of the potential to improve spectrum efficiency and speed up the development of wireless high capacity networks, CEPT, ETSI and the RSPG have all been working on the LSA framework. In particular:

- In CEPT, ECC Report 205 [8] was approved in February 2014. It provides an overall definition and guidelines for the implementation of LSA. Furthermore, an ECC Decision harmonizing the 2.3 GHz frequency band under LSA is planned for approval in June 2014. It provides the harmonised technical rules for mobile broadband use and guidelines for LSA implementation in the band.
- The RSPG released its opinion on LSA [1] that is now endorsed by the 28 Regulators of EU Member States.
- In March 2014, the European Commission issued a Mandate to CEPT to develop technical conditions for the introduction of wireless broadband (WBB) in the 2300-2400 MHz ('2.3 GHz') band including technical conditions for sharing with incumbent users. The challenge of the EC Mandate is to provide EU-wide technical conditions whilst reflecting national circumstances. In particular the long-term incumbent use of the band is facilitated in those Member States that wish to maintain such use
- The first response to the Mandate is expected in March 2015 and will regard the development for common Least Restrictive Technical Conditions (LRTC) (e.g. Block Edge Masks, BEMs) for the introduction of wireless broadband usage in the 2.3 GHz band. Furthermore, common technical solutions for the shared use of the band for WBB and incumbent services/applications will be developed by July 2015.
- ETSI had also published a System Reference Document defining the criteria and operational features for LSA at 2.3 GHz [3] and approved a work item on the requirements for LSA in the band: "System requirements for operation of Mobile Broadband Systems in the 2300-2400 MHz band under LSA regime".
- Following the activities in Europe, the International Telecommunications Union (ITU), has promoted studies for shared spectrum use techniques, such as LSA. The relevant work group is WP1B "Spectrum Management Methodologies and Economic Strategies".

III. National implementation of the LSA approach: general methodology

The international framework described in Section II has been developed under the common view that there is no need for general guidelines for the implementation of LSA at national level. Therefore, the authorisation process issued at national level should be balanced between national circumstances, with the need to account for several principles, stated also at communitarian level [11], such as:

- Ensuring coexistence through the definition of acceptable levels of interference and appropriate mitigation strategies.
- Balancing impact and usage constraints for incumbents and additional users in terms of sharing rules and costs.
- Enabling users to share spectrum with regulatory guarantees based on individual licenses.

National administrations have to consider a number of key issues in the definition of the sharing framework in granting LSA rights of use:

- Identification of the incumbent(s) to be protected;
- Terms and conditions under which the incumbent and LSA users may access the spectrum;
- Identification of frequencies, locations and times that must be protected for the incumbent, together with the level of protection;
- Mechanism for transmission of information on spectrum availability between Incumbent and LSA licensee;
- Length of the sharing framework;
- Financial terms and conditions of the sharing framework;
- Terms and conditions for the operation of the LSA repository;
- Reference to appropriate regulatory document, i.e. ECC Decisions, Harmonised Standards.

This leads to several topics that need to be considered and solved by national Administrations, such as coexistence conditions, sharing rules, licence granting and so on.

IV. LSA policy and regulatory aspects

The EU regulatory framework for electronic communications [9] seeks to facilitate access to spectrum, based on the least onerous authorisation system possible. It favours the use of general authorisations, except where individual licences are clearly necessary, e.g. to ensure protection against harmful interference. The RSPP [10] requires Member States, in cooperation with the Commission, to foster, where appropriate, the collective use and shared use of spectrum in order to enhance efficiency and flexibility.

In the Communication "Promoting the shared use of radio spectrum resources in the internal market" [11], EC considers spectrum management an essential pre-requisite for the digital single market. Reaping the full benefits of sharing spectrum requires not just the removal of current regulatory barriers to deploying innovative radio access technologies, but also the active facilitation of sharing.

LSA represent a powerful feature for the shared use of specific bands. LSA licensees and incumbents operate different applications and are subject to different regulatory constraints. They would each have exclusive individual access to a portion of spectrum at a given location and time.

The implementation of LSA relies on a sharing framework under the responsibility of the Administration/NRA: a set of sharing rules or conditions that will materialise the change, if any, in the spectrum rights of the incumbent(s) and define the spectrum, with corresponding technical and operational conditions, that can be made available for alternative usage under LSA.

National Administrations/NRA would set the authorisation process with a view to delivering, in a fair, transparent and non-discriminatory manner, individual rights of use of spectrum to LSA licensees, in accordance with the sharing

framework defined beforehand. It is important to recognize that under the LSA approach, national administrations shall remain the sole responsible entity to determine the most appropriate type of individual rights of use award and of conditions attached to operate and manage LSA networks [12].

Traditionally National Administrations/NRA manage spectrum with two tools: dedicated, licensed spectrum and license-exempt/ unlicensed spectrum. Spectrum sharing essentially involves a blended approach that fits between these extremes [14], representing a good, adaptable balance between exclusive use and license-exempt access (Fig. 1). Although opportunistic use of spectrum is particularly addressed, the concept of pluralistic licensing can be effectively developed at a national level to cope with growing spectrum demand and continuous technological innovation.

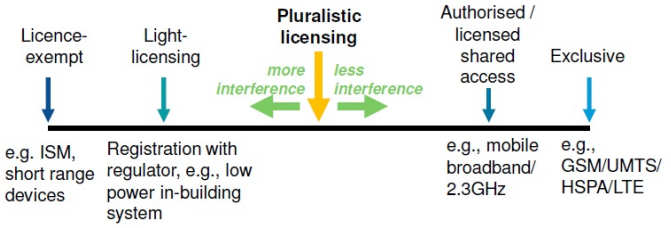

Fig. 1. Pluralistic licensing [15]

In this view, shared access licensing represents an additional tool for Administrations/NRA. As [11] points out, the key challenge for NRAs is to find appropriate ways to assess shared spectrum access rights (SSAR) to a band, i.e. to allow two or more users to use the same frequency range under a defined sharing arrangement. Regulatory challenges consist in:

- Remove uncertainty through the definition of acceptable levels of interference and appropriate mitigation strategies between users for shared access to a band, important to increase the predictability and mutual acceptance of sharing arrangements, and to achieve a predictable quality of service for all parties;
- Creating sufficient incentives and safeguards for all interested parties, not excluding financial compensation to incumbent users in order to deploy improved technologies to enable additional users' access;
- Ensure that sharing arrangements between users do not adversely affect competition;

Designing the assignment process NRAs should take into account the possible options (competitive auction, beauty contest, …) as well as the associated obligations on the licensee (in terms of coverage, use it or lose it, …). An array of further tasks have to be achieved in order to implement the above and set out award rules and license conditions.

Defining the criteria (transparent, non-discriminatory) upon which compensation measures may be owed to incumbent rights owners. On the one hand, compensation should be set in an objective process based on given indicators, on the other, incumbents need to be proactive in order to bring spectrum to the market more quickly than through band clearance, and thus may need some incentives. To this regard, the possible application of the LSA regime in a given frequency band requires the knowledge of the actual use of spectrum in that band, and analysing how efficiently that spectrum is used. Once efficiency of spectrum use is assessed [12], NRA will be able to determine the intensity of its usage by the incumbent, and the required adaptation of the primary network with associated costs.

Establish the license duration. Dedicated, licensed spectrum is usually issued for 20 years but sharing conditions may not be in line with predictable duration of spectrum availability. Primary users' (incumbent) needs may vary through time requesting secondary users' (LSA licensee) network adjustments, thus preventing certainty of investments on infrastructure. As [8] points out, LSA licensee needs to know the spectrum availability for the whole duration of the sharing framework in order to plan investments and deployment. License duration should be set upon the described certainty requirements.

Determine fees (if any) to be set on LSA licensees. Pricing is a key tool to incentivize users to take measures that maximize efficiency and fairness in spectrum usage [14]. License fees should be proportional to the QoS achievable by secondary users, overall spectrum efficiency, and fairness in spectrum usage. Moreover, spectrum pricing should be carefully balanced in a trade off with obligations set on LSA licensees. Therefore NRA should be able, first to set the conditions of licensees' spectrum usage in advance, then to monitor the actual usage keeping a continuous record of conditions and actual usage. With regards to spectrum usage efficiency, pricing tools and associated obligations, it may be crucial if licenses should be awarded through a beauty contest, whereas if the assignment should follow a competitive auction, the issue of efficiency wouldn't need to be further enhanced, since it is believed that market mechanisms represent the best way to achieve efficient distribution of a scarce resource like spectrum [16].

V. TECHNICAL REQUIREMENTS OF THE LSA ARCHITECTURE

In this section, technical feasibility of the LSA approach is addressed identifying the main requirements and functionalities of the proposed LSA architecture shown in the following figure. The first basic element of the LSA architecture is a Geographical Information System containing both geographical and technical information (channels, emitted powers, antenna patterns) of incumbent and LSA networks. Based on this information and on the defined regulatory sharing framework agreed between the different parties (NRA, incumbent & LSA users) the National Administration should be able to set up proper technical sharing rules and channel plans for the LSA licensees.

The frequency availability plan for LSA users is achieved through the implementation of a geolocation database providing real time information on available channels considering the incumbent frequency network deployment in the territory. Free channels can be used by the LSA licensee under proper conditions needed for the protection of the

incumbent. In particular, given a field threshold Trx, potential channel availability for LSA can be derived based on the following algorithm:

$$GD(f_i, x, y) = \begin{cases} 1 \text{ if (Erx(dB}\mu\text{V/m) >= Trx)} \\ 0 \text{ if (Erx (dB}\mu\text{V/m) < Trx)} \end{cases}$$

where Erx is the incumbent received field strength level, f_i is the considered frequency channel, (x, y) the receiver location and GD is the indicator for channel availability (GD=1 occupied channel, GD=0 free channel). Erx can be evaluated by means of coverage predictions performed in the LSA simulator tool. The addition of sensing techniques combined with the geolocation database could help the protection of the incumbent service provided that a proper detection threshold is selected.

LSA usage restrictions of free channel must be derived from the sharing rules, which include binding conditions mainly based on proper interference threshold levels which should not to be exceeded by the LSA user to protect the incumbent service and on QoS requirements to be guaranteed for both the incumbent and the LSA services.

The incumbent protection level can be defined according to a proper choice and combination of the following sharing parameters: Interference Level, Location Probability, C/I.

The geolocation database evaluates and provides to LSA users the allowable frequencies and the maximum value of emission power in the considered position. The estimation of the maximum power should be based on the maximum permitted degradation of the QoS parameters (% of the limit or time interval degradation) ensuring the protection of the incumbent service. By assuming C/I as the main QoS parameter the degradation of the incumbent C/I due to LSA user can be estimated according to:

$$\Delta(C/I) = \frac{C_{incumbent}}{I_{incumbent} + N} - \frac{C_{incumbent}}{I_{incumbent} + N + I_{LSA}}$$

The estimation of the maximum LSA transmitter power can be obtained according to acceptable C/I degradation which depends on the incumbent QoS requirements.

The respect of the sharing rules can be obtained with the combination of different approaches such as geographical and/or frequency separation distances between LSA transmitters and incumbent receivers, and/or limitation of LSA transmitters maximum emitted power.

Different geographical sharing solutions may be foreseen: for instance in some areas LSA transmitters can be excluded while in others zones LSA users can operate under restrictive conditions (maximum EIRP limits, antenna parameters constraints).

The identification of the sharing rules is strictly dependent on the considered coexistence scenario (e.g. incumbent fixed service FS and LSA MFCN) and on real networks systems deployments and topology. To this end the LSA simulation tool shown in figure 2 will address detailed sharing and compatibility analysis considering rigorous propagation models for coverage prediction and interference and QoS estimation.

QoS parameters are also dependent on the considered service and include some relevant key performance indicators (KPIs) such as coverage, C/I, the protection ratio, the location probability, channel throughput, packet data delay. It is worth noting that guaranteed QoS (e.g. coverage) can only be provided through licensed spectrum: LSA Licensees should have full control/knowledge of the interference they face, and therefore have full understanding of the performance that will be delivered by their network equipment.

These QoS indicators must be monitored by the LSA controller in order to check if acceptable QoS levels are maintained for both the LSA licensee and the incumbent. The LSA controller is also in charge of control and monitoring the mutual interference levels between incumbent and LSA users in order to verify the respect of the field strength thresholds defined in the technical sharing rules. Measurement results of the LSA controller are sent to the LSA repository in order to take the appropriate countermeasures if QoS requirements are not satisfied.

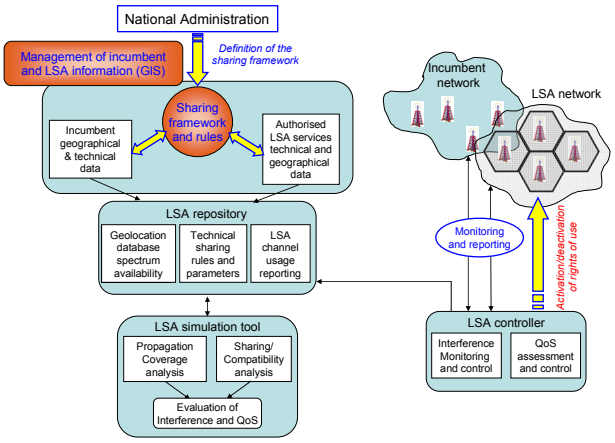

Fig. 2. LSA technical architecture

VI. USE CASE SCENARIOS OF INTEREST

As already mentioned, the 2300-2400 MHz band has been identified in Europe as a candidate band for the application of the LSA approach. At the World Radiocommunications Conference 2007 (WRC-07) this was allocated for mobile services and identified as an IMT band. However, this allocation was not exclusive nor priority was given to mobile services. This was the result of a negotiation among different (and often contrasting) views and interests of the participating administrations.

In response to this, in 2012 ECC issued Report 172 [5]. It presented compatibility studies with respect to the potential use of the band for BWS, taking into account the sharing scenarios with other services and systems both in the same and adjacent bands. The compatibility studies provided results in terms of required separation distance and/or frequency separation and/or mitigation techniques.

The great variety of services coexisting in this band and in its vicinity, as well as the different actual usages in different countries, highlighted the limits of the traditional approach based on an exclusive CEPT-wide harmonised allocation. Also the different nature of incumbent use (either governmental, planned and/or limited in time and or location suggested that use of this band for wireless broadband may be possible on a shared basis with appropriate provisions.

The most recent activities on the 2.3-2.4 GHz band in CEPT have established that a common frequency arrangement is needed, whilst maintaining the flexibility to adapt to national circumstances and market demand. To this aim, LSA, represents a powerful approach for administrations wishing to maintain current incumbent uses.

Compatibility issues with the systems currently using these bands should be taken into account to investigate the possibility for future development of wireless broadband systems under the LSA approach. One of the less investigated scenario regards coexistence between mobile and fixed services, which is the incumbent use in a few European countries (e.g. Italy).

Coexistence analysis are generally based on worst-case calculation method, such as the MCL (Minimum Coupling Loss) approach: the I/N at the victim fixed link receiver is evaluated in presence of an interfering base station. It is assumed that both the FS system and the BTS have the same antenna height, which represents a worst case scenario.

The minimum required I/N at the FS receiver is set equal to -10 dB and is evaluated according to the following expression:

$$\frac{I}{N}(\Delta f, d, \vartheta_1, \vartheta_2) = P_t + Att(\Delta f) + Gt(\vartheta_1) + Gr(\vartheta_2) - PL(d) - N$$

where P_t is the transmitted power (dBm) of the interferer, Δf is the difference (MHz) between the carriers of the interferer and the victim systems, $Att(\Delta f)$ is the net filter discrimination (NFD), G_t (dBi) is the interferer antenna gain, G_r (dBi) is the receiver gain, $PL(d)$ is free space attenuation (dB) between the BTS and the FS receiver and N is the noise level (dBm) of the receiver.

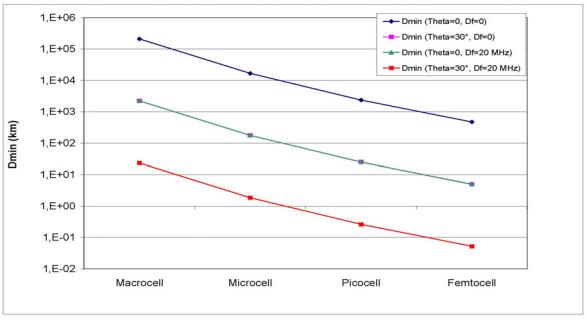

Fig. 3. Example of geographical separation distances between BTS amd FS

In figure 3 the separation distances between the FS receiver and the IMT is shown as a function of BTS cell sizes (macro, micro, pico, femto) considering different frequency and angle separations. However, it can be noticed that the MCL model provides separation distances in the worst case scenario (Δf=0 and no angular separation) which prevent any mobile deployment. Therefore, sharing conditions need to be addressed taking into account real network topology and equipment.

VII. Proposal of Good Practices for the National Implementation of LSA

From the analysis in the paragraphs above, it should be possible to draw a proposal of good practices for the national implementation of LSA.

As a general guideline, it is advisable that administrations take care of defining the incumbent services that need to be protected and the relevant coexistence criteria (in terms of frequency and/or geographical separation, transmission levels, etc.). The administration should then have a technology neutral approach, in order to favour competition and market development.

VIII. Conclusions

This paper presents the main concepts of Licensed Shared Access and the rationale for its adoption in order to achieve a more efficient spectrum utilisation and to cope with the ever increasing demand for wireless broadband services.

The case study we presented is just a first example of how the administration should determine criteria for issuing LSA licenses, under very simple working assumptions and using a very conservative interference computation method. Further studies are needed in order to determine coexistence criteria for realistic scenarios.

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