Cognitive Radio and UHF Spectrum Revitalization

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Abstract - *In this paper an overview of the recent developments in UHF band is presented, with special attention given to techniques for spectrum sharing and utilization of white spaces and newly available spectrum for mobile services. The concept of cognitive radio is discussed as a background for mobile multimedia content delivery in newly available band and white spaces.*

Keywords - *Cognitive Radio, Spectrum Sharing, White Spaces, Digital Dividend*

1. INTRODUCTION

In the light of recent development of the wireless communication technology, a usage of wireless multimedia applications can be considered as a technology out of early adopters phase and very close to early majority phase [1]. This is especially valid for the developed markets, but the rest are increasingly keeping the paste. According to that, more and more users are expecting to be provided with the immediate access to multimedia content from almost every place, thus keeping broadband and mobility as the most important feature of future communication habits. This development puts a special attention to content delivery technologies and brings spectrum policy in focus once again, cooping with the request for new services to provide large bandwidth, good quality of service and short delay. Many technologies have been considered in order to fulfill those requirements, but the general impression is that spectrum availability for new technology implementations is very low or practically non-existent. According to an overview shown in Fig. 1, where the example of UK spectrum chart of existing licensed services is presented, such impression could be easily obtained.

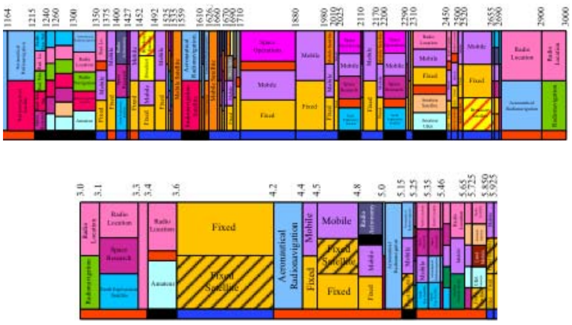

Fig. 1. The example of frequency allocation density, UK allocation in L, S and C bands, [8]

A new stimulation to this topic is given with the emersion of newly available analog TV bands. The principle of distributed multimedia transmission over the secondary user network with the use of opportunistic spectrum access is becoming of great interest. This potentially available UHF band is very valuable and attractive from a perspective of propagation and power control [2], providing larger distances and better indoor coverage comparing to higher frequencies, making it especially interesting for mobile operators.

2. REVITALIZATION OF UHF TV BAND

The allocation of frequency spectrum for the purpose of analogue terrestrial broadcasting in Europe was regulated by the ITU 1961 Stockholm Plan. With the appearance of digital terrestrial broadcasting, namely DVB-T and T-DAB services, it was necessary to reconsider spectrum allocation for broadcast service. Therefore, a new frequency plan was adopted at the Regional Radiocomm-unications Conference (RCC) in 2006. According to ITU-R Geneva 2006 frequency plan (GE06), three frequency bands are assigned for digital terrestrial broadcasting for the next decade and for 118 countries [9]:

- Band III: 174-230 MHz;
- Band IV: 470-582 MHz;
- Band V: 582-862 MHz.

The Geneva Plan is aiming at the digital services only, leaving therefore analogue broadcast services unprotected from the interference with each other and with another services after official switchover.

With the awareness that digital television service in general is using less frequency bandwidth comparing to analogue broadcast, a certain amount of spectrum will be released after the analogue television service termination. This procedure is known as the digital dividend. Once released, this newly available spectrum is becoming a desirable target for a number of potential services including:

- DVB-T service itself - coverage of underserved areas, High Definition TV broadcast and other new services;
- DVB-H - mobile broadcast service;
- Fixed or mobile broadband services.

As an extension to GE06 frequency plan, The World Radiocommunications Conference (WRC-07) allocated the 790-862 MHz band in Region 1 to the mobile services (3G, 4G, WiMAX) with a co-primary status with the broadcast service beginning in year 2015. European countries are allowed to start mobile services immediately if they protect broadcasting services in neighbouring countries.

Although some amount of the spectrum will certainly be left unused, the European Broadcast Union is strongly representing the view of major European broadcasters that a market-based spectrum allocation on a service and technology-neutral basis would endanger public interest and dual nature of broadcasting system in Europe - public and commercial. They are especially stressing two important issues. First, interference problems with new services placed in UHF band will be noticeable, especially with the wireless microphones and in-ear monitors [14], so the initiatives for moving it to other channels are actual already [15]. Second, beside the fact that broadcast service will be shortened in spectrum and thus restrained with the future expansion toward HDTV broadcast, the transmission capacity of UHF band for wireless broadband services will still remain limited [10], [11]. According to all mentioned above, in geographic areas where channels 61 to 69 (790-862 MHz) will be used for mobile services, broadcasting services using adjacent channels (channel 60 and below) will be affected by interference causing the necessity for technical restrictions to mobile services concerning guard bands, power limitations and restrictive spectrum masks.

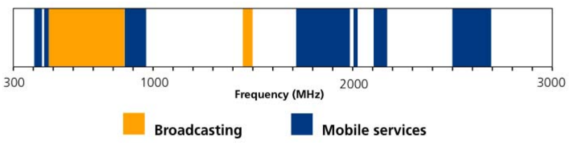

Fig. 2. Broadcast and mobile services allocation comparison, [16]

As presented in Fig. 2, while mobile communications are allocated in the broad amount of the spectrum in the UHF band, majority of which is used inefficiently, broadcast terrestrial services are given only UHF band 470-862 MHz. Similar debates are active in other parts of the world as well [18].

Despite of all mentioned above, a strong boost is given in the mobile services direction with France, as the first major European country, recently announcing a reservation of the part of UHF band for mobile broadband and video services [12]. Encouraged by the European Commission, other countries like Sweden, Finland, Germany and Switzerland have already decided to use the sub-band for mobile services. In some other countries decision will be made soon as well. According to plans announced in France, by the end of year 2009, 18 percent (72 MHz) of the UHF band (790-862 MHz) will be shared by television broadcasters and mobile operators, in compliance with WRC-07.

3. SPECTRUM SHARING PRINCIPLES

Present spectrum licensing procedures are based on the principle of national, regional or multi-regional regulator, a government agency with the mandate to assign a frequency spectrum divided in bands to competitive users. Regulation agency is issuing licenses to users on a long-term period and normally for wide geographic areas. Having in mind a rapidly changing nature of communication needs and expectations from a modern service provider perspective, this concept is proven archaic and unsuitable in near future, especially from the mobile operators point of view. Under present policy spectrum is fragmented, therefore making bandwidth relatively expensive and good frequencies already taken with the existing services. The largest recent innovation in effort to increase spectrum efficiency is implementation of the unlicensed band principle.

Recent research done by the Federal Communications Commission (FCC), a government agency regulating spectrum in the United States, showed that 70-90% of the allocated spectrum is not utilized [4]. The other research showed that a typical utilization in the frequency band below 3 GHz is around 30%, while utilization in 3-4 GHz frequency band is just of 0.5% and dropping to 0.3% in the 4-5 GHz band [5], Fig. 3. Moreover, a time frame of the spectrum utilization varies from the seconds to the hours.

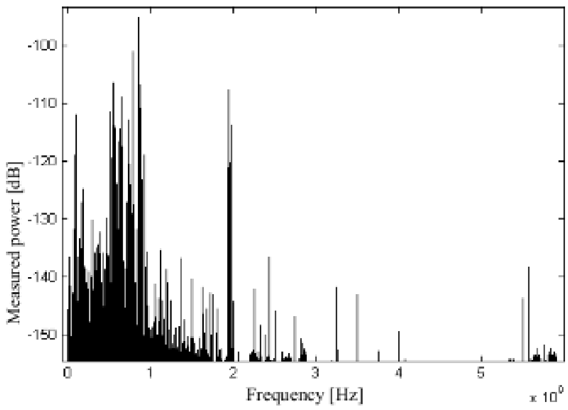

Fig. 3. Spectrum utilization scanning result, [5]

Another interesting opportunity concerning spectrum sharing, apart from the UHF band reallocation, is white spaces phenomena. The term "white spaces" is referring to the frequencies licensed for a broadcasting service but not used on designated geographical area. Therefore, many initiatives emerged recently to reallocate those parts of the spectrum as unlicensed and made it accessible to the unlicensed devices under the guaranty that they will not interfere with existing or future broadcasting services. Those initiatives were joined together in the United States under the White Space Coalition, a group of 8 large technology companies planning to deliver broadband wireless access targeting unused television frequencies between 54-698 MHz (TV channels 2-51).

The dimension of the white spaces in the case of UHF band is designated with a guard bands, although not used, still assigned to broadcast service. White spaces are recently being emphasized with the switchover to digital television. The size of white spaces depends of geographic areas and some research shown that the percentage of TV spectrum released after transition to digital TV could be between 30% and 82% of totally allocated bandwidth [17]. One example of spectrum scanning in order to visualize white spaces is shown in Fig. 4.

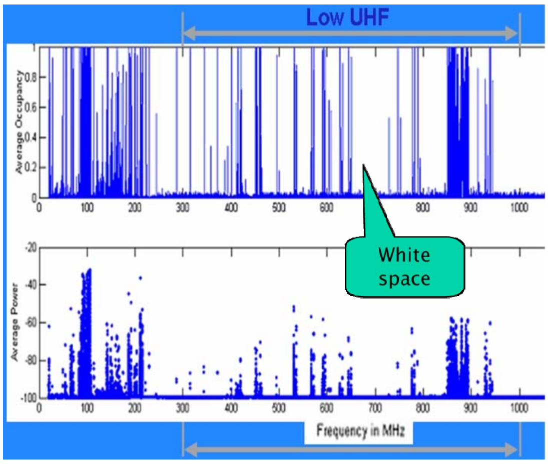

Fig. 4. White spaces scanning example, [21]

According to all discussed, the principles of spectrum sharing are demanding a fundamentally new approach. Several spectrum sharing methods for broadband access have been introduced to address this feature, including:

- Unlicensed bands, ISM (WiFi 802.11 a/b/g);
- Opportunistic spectrum sharing, [6];
- Spectrum recycling based on the signal-to-interference-plus-noise ratio (SINR) margin of existing systems, [13];
- Spatial multiplexing and beamforming, [7].

While giving a considerable improvement on effectiveness of spectrum usage, above mentioned methods are not ensuring any sense of spectrum availability because they are based on the predefined parameters. Accordingly, they are providing a limited adaptability to spectral environment.

Therefore, a new sharing principle has been introduced recently, allowing usage of licensed spectrum by secondary users with the sharp requirement concerning the limits of the interference with existing primary users.

Cognitive radio design recently emerged as paradigm based on the adaptability of all parameters, enabling the benefits from monitoring external and internal radio parameters, [20]. This includes radio frequency spectrum, present condition of the available network and user behavior.

In general, two different principles of spectrum sharing could be distinguished, [22]:

- Underlay approach - based on the transmission power restrictions with a requirement to operate over ultra wide band;
- Overlay approach - usage of spectrum sensing and adaptive allocation cognitive radios, based on avoidance of primary users.

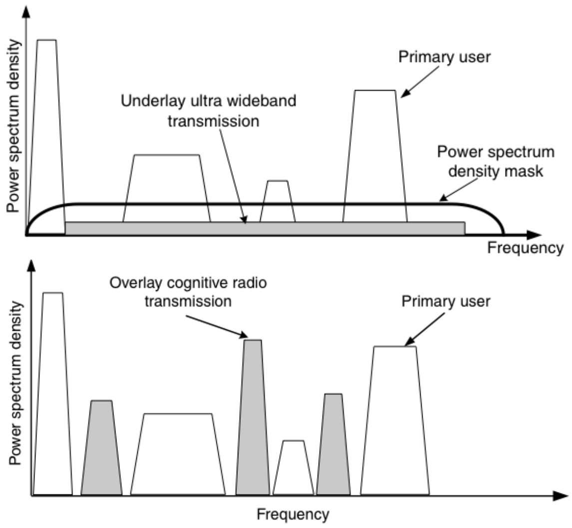

Fig. 5. Underlay and overlay sharing approach

Both of these approaches are representing immense improvement from the traditional licensing, in which once assigned frequency band requires absolutely no interference for the primary user.

4. COGNITIVE RADIO

Cognitive radio is one of the recently emerged directions in wireless technologies, designed to enable a smart and dynamic approach to more efficient usage of existing spectrum. Cognitive radio provides a mechanism for smarter band utilization using dynamic radio resource allocation and adaptive transmission through advance methods of spectrum sensing. The fundamental idea of cognitive radio is to achieve a significantly improved spectral efficiency by coexisting with the licensed users. Cognitive radio is considered as a lower priority service in allocated spectrum or as a secondary user of frequency band allocated to a primary user.

The recent efforts on the field of cognitive radio definition are gathered in the standardization process with establishment of the IEEE working group - IEEE 802.22. First wireless system based on the principle of cognitive radio is introduced under the name Wireless Regional Area Network (WRAN) and is aimed to operate in the commercial broadcast television bands on a non-interfering basis, [3].

Cognitive radio system is able to sense its environment and learn how to adapt to it, optimizing intelligently its own performance in response to user requests and relevant regulations. Having in mind large temporal and geographic diversities in the usage of licensed spectrum as described above, cognitive radio was presented as an ideal candidate for copping with the common misconception of spectrum availability deficiency.

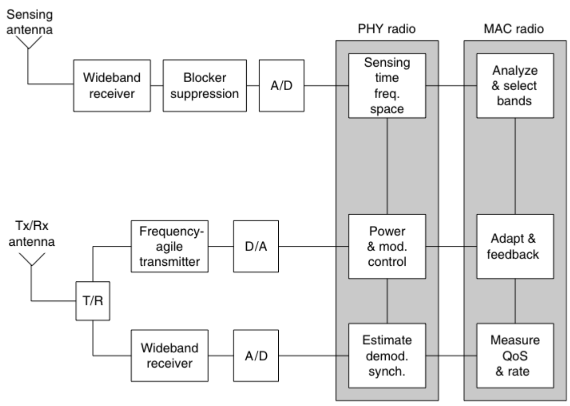

Fig. 6. Cognitive radio transceiver block diagram

In Fig. 6 a basic functionality of cognitive radio transceiver is presented. Cognitive radio system design assumes a separate sensing receiver section with separate antenna, which is critical point for achieving a cognitive functionality. This part of the system is constantly active in finding white spaces by sampling a potentially interested frequency band. Once when appropriate frequency is detected, a transmission schemes are used to achieve best spectrum utilization. The distribution of unoccupied spectrum is updated with every sensing period and is dependent of geographic area and time of use.

5. FUTURE DIRECTIONS

Cognitive radio presents one of the most interesting concepts presently in focus concerning new radio technologies, but taking new trends in the considerations, another step forward can be anticipated. It goes for the functionality of the end-to-end reconfigurability with the goal to provide the end-user with the seamless experience combining in such a manner the principles of Reconfigurability, Software Defined Radio and Cognitive Radio in one system - cognitive systems, Fig. 7, [19]. Moreover, the intelligence of cognitive system is often not placed in the radio part.

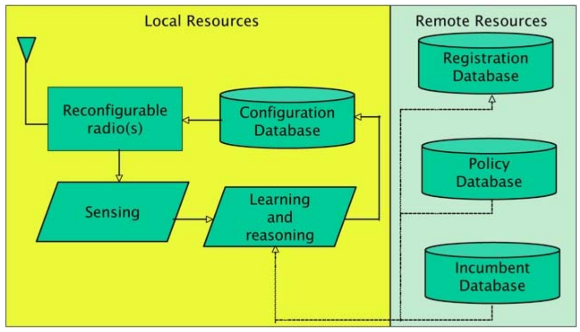

Fig. 7. Cognitive radio system architecture, [21]

Further developments on the cognitive systems will be focused on the standardization under the IEEE 802.22 group protection. As shown in Fig. 8, 802.22 is one more step in the evolution of the IEEE cognitive standards.

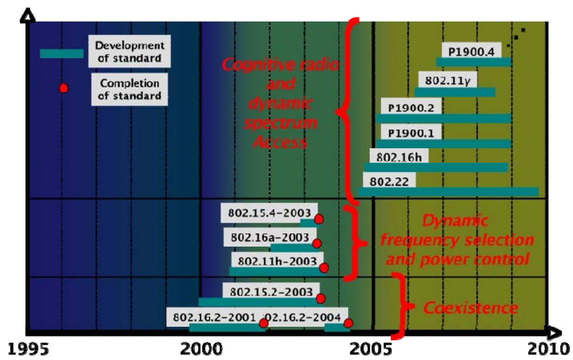

Fig. 8. Evolution of IEEE cognitive standards, [21]

6. CONCLUSION

Spectrum sharing has become a new focal point in radio technology. Plain frequency allocation has been the only technique used for ensuring interference-free service since the interference first became an issue. Acting in that way, a limited resource like the spectrum was rapidly exhausted, particularly in most attractive bands. Today, with the emersion of the new service, especially mobile service, a much more vigilant approach is inevitable. A first phase in improving the inherited policy is to recycle existing situation and therefore advanced spectrum management is not a hot topic for the future, but is the topic of present movement and development.

Among all other technical requirements, probably the main interest in recent efforts toward more efficient spectrum utilization will be focused on the challenge of developing coexisting radio systems that are only mandatory to meet the requirement of not creating harmful interference as opposition to the requirement to produce no interference at all. This is a major change in spectrum consideration and it provides a great opportunity to achieve new principles for wireless systems to coexist beyond simple frequency allocation.

Cognitive radio is so far the most potential technology providing all the tools needed for present state of spectrum licensing reconsideration. Therefore, cognitive systems will be in the focus of radio technology researches in the next couple of years.

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