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Evaluation of the possibilities of using Dynamic Spectrum Access in 900 MHz and 1800 MHz bands of mobile network in Cameroon

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Abstract

The main objective of spectrum management is to optimize the use of the spectral resource. To achieve this, cooperation between primary users (PUs) and secondary users (SUs) is necessary in a process called dynamic spectrum access. We present in this work a state of the art of the dynamic spectrum access methods. Then we evaluate the use of the spectral resource in the 900 MHz and 1800 MHz bands of the mobile networks of the city of Yaounde, capital of Cameroon by measurements with the Rhode & Schwarz spectrum analyzers. The results give us in the 900 MHz band a 30% spectral opportunity on the uplink, for the 1800 MHz band a spectral opportunity of 26.44% on the downlink and 86.82% on the uplink. These results show that there are possibilities for using dynamic spectrum access on Cameroon's mobile networks, especially in the city of Yaounde.

Keywords: Cognitive Radio, Dynamic Spectrum Access, Spectral Occupancy, Spectrum Sharing

INTRODUCTION

In recent years we see the rise of wireless communication systems with a flourishing of standards and norms in the field, due to the increasing use of smart mobile devices. Consequently, the need for commercial spectrum resources is increasing rapidly. It is clear that the limitation of licensed spectrum is the main barrier to the growth of wireless commercial systems and the related services. Similarly, we see a demand for unlicensed bandwidth due to the continued growth of short distance radio and Wi-Fi systems [1].

A study by the Federal Communications Commission (FCC) showed that some frequency bands are overloaded at peak times. However, the use of the frequency spectrum is not uniform: depending on the hours of the day and the geographical position, one frequency band may be overloaded while another band remains unused. The idea of developing tools to better use the spectrum then emerged [2].

In this work we make a state of the art of Dynamic Spectrum Access (DSA), then we conduct an experimental study on the opportunity for dynamic spectrum access in the 900 MHz and 1800 MHz bands of mobile in the city of Yaounde with the main objective of evaluating the possibilities of re-uses of the spectral resource by other telecommunications operators in these bands.

STATE OF THE ART OF DYNAMIC SPECTRUM ACCESS

The DSA technique consists in the localization of white spaces in the spectrum and uses them to communicate [3]. DSA is one of the most important applications of Cognitive Radio (CR). The SU networks connect in the PU bands opportunistically so that the interference caused to the PUs is insignificant.

We found in literature [1][4] different approaches in DSA models to manage spectrum as we can see in the Figure1 classified DSA strategies in 4 groups: Command and Control use, exclusive use, open sharing model and hierarchical access model or commons model.

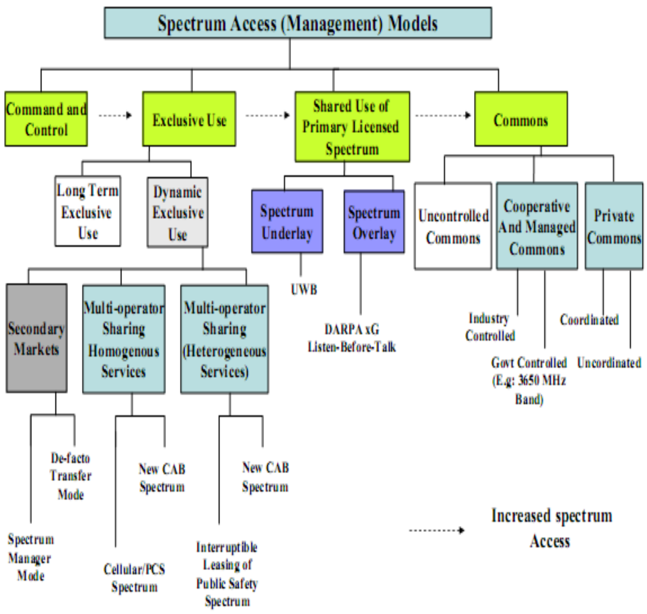

Figure1: Classification of spectrum access models [4]

Methods used in DSA

We found in literature different main approaches in DSA methods to manage the spectrum: spectrum access using auctions, game theoretical approach, fuzzy logic based system, spatio-temporal spectrum management model, Markovian model approach and Spectrum access using Multi-Agent Systems (MAS).

Spectrum access using Auctions

Auctions are used in CR networks to maximize the economic efficiency in the allocation of spectral resource. In DSA, this leads to maximum revenue, profit or added value that can be generated from a fixed quantity of spectral resource [2].

Game theoretical approach

Game Theory can be explained as a mathematical framework consisting of models and techniques used to analyze the iterative decisions behaviour of individual's interest about their own benefit [1], [2], [4]. This is a mathematical tool that analyzes and plans the interaction among the multiple decision makers. Three important parameters are to be considered: N, A, {Ui} [1]:

Decision makers (N): Each game is considered to have a finite number of decision makers or players.

Action Space (A): Each player "i" has its own action space (Ai) which is the set of actions including all possible actions that the player can choose. The total action space "A" is calculated by multiplying all the action games.

$$A = A_1 \times A_2 \times A_3 \times \dots \times A_N \quad (1)$$

Utility Space (U): This is a set consisting of utility or payoff functions for all players

$$U = \{U_1, U_2, U_3, \dots, U_N\} \quad (2)$$

The games are generally divided into two types, cooperative games and competitive games [2], [5].

i) Cooperative games: All players are concerned about all overall benefits and they are not very worried about their personal gain. Some recent works [6], [7] use cooperative game theory to reduce the transmission power of secondary users in order to avoid interfering with primary user transmissions.

The well-known property of game-theoretical approaches is called Nash Equilibrium (NE). In NE, each player is considered to know the equilibrium strategies of the other players, and none has anything to gain by changing strategy [1]. Each rational network users only cares about own benefit and chooses the optimal strategy which can maximize his/her pay off function and such outcome is termed as Nash Equilibrium in non-cooperative spectrum sharing game [1].

ii) Competitive games: Each user is mainly concerned about his personal gain and therefore all decisions are taken in a competitive and selfish way. In the existing literature, we found that the theoretical concepts of the game have been widely used for frequency assignments in CR networks [8], [9], [10]. Primary and secondary users who participate in a game have a rational behaviour to choose strategies that maximize their own gains.

Fuzzy Logic Based System

Fuzzy logic can solve problems based on inaccurate, noisy and incomplete information. Fuzzy logic uses a set of fuzzy membership functions and indirect rules to obtain the solution that meets objectives desirable. Three important elements are used in a system of control of fuzzy logic: i) fuzzifier, ii) fuzzy logic processor and iii) defuzzifier. The fuzzifier is used to plot the actual inputs by making them fuzzy, the fuzzy logic processor provides an inference engine to get a solution based on sets of predefined rules, and the defuzzifier is applied to convert the solution to real output [11].

Fuzzy logic is a multi-valued logic. Many input parameters are used to take the decision. Here distance, signal strength, throughput and spectrum efficiency are known as input parameters. The chance of taking decision is increased if the channel (offered by PU) signal is wide and distance between PU and SU is low. If the distance is small, the throughput increases, the chance of the spectrum accessing is greater [12].

Spatio-Temporal Spectrum Management Model

The static spectrum allocation causes scarcity of access to the spectral resource because of its inflexibility. Spatial-temporal dynamic spectrum access model improves user's access to spectrum because of its flexibility. This model is shown in Figure 2. In this model [13], the service area is divided into multiple regions. In the region 'k', network service provider 'i' provides wireless services to users, and spectrum demand for this service provider is denoted by D_{ik}. The spectrum of a given region is owned by RSB (Regional Spectrum Broker) which grants short time licenses for the requesters [14]. In TDSA (Temporal Dynamic Spectrum Allocation) method, the demands for spectrum to RSB are sent by the service providers of the region. The RSB allocates continuous spectrum blocks to the requesters and the blocks are separated by guard bands.

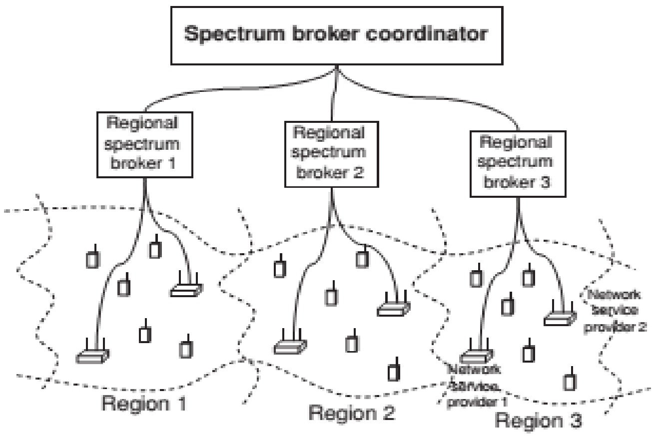

Figure 2: Spatio-temporal dynamic spectrum access model [1]

The Spectrum Dynamic Spectrum Allocation (SDSA) deals with spectrum demands coming at the same time in different regions. The main objective of the SDSA is adjusting the different demands within different regions on the way, where the least interference occurs in the overlapping regions.

Markovian model approach

Modeling the interaction between PUs and SUs for spectrum access is not made by Games Theory strategy. The markovian queues can be used to do it [15], [16], [17]. In [16] a Markov model is presented, where each SU randomly chooses its own queues instead of exchanging control messages with the other neighboring users. A good approach using Markov models is developed by the authors of [18] to evaluate the different methods proposed for sharing the spectrum.

Spectrum access using Multi-Agent Systems (MAS)

In Spectrum access using Multi-Agent Systems (MAS), the MAS association with the CR ensures a remarkable future for optimal frequency management (compared to rigid control techniques proposed by telecommunications operators). In the case of unlicensed bands, the CR terminal must coordinate and cooperate for better use of the spectrum without causing interference. In [15], [19], [20], [21], the authors propose different agent-based architecture where each CR terminal is equipped with an intelligent agent. Agents are deployed on the CR terminals of PUs and SUs and cooperate with each other to determine the condition to share spectrum without causing interference.

Comparison of different methods used in DSA

According to [2], a comparison between some techniques of DSA is made. Table 1 shows an improvement of this comparison by a new criterion, the spectrum efficiency with other techniques used.

Table 1: Comparison of techniques used for dynamic spectrum access

Techniques used by DSA	Strengths	weaknesses	Spectral efficiency
Auctions	Well adapted to the competitive environment.	-Not well adapted to the cooperative environment - Not well adapted to the modeling of the interaction Between users.	Good for economic efficiency of the spectrum
Game theory	Well adapted to both the competitive and cooperative environment.	Focuses on solving the Nash equilibrium and analyzing its properties and does not consider how players should interact to achieve this balance.	Good for functional and economic efficiency of the spectrum.
Fuzzy Logic Based System	Well adapted for predictions in radio environments with inaccurate information.	Limited use when PU signal strength is low and distance between PU and SU is great.	Good for technical efficiency.
Spatio-Temporal Spectrum Management Model	Well adapted for spectrum allocation by region	Interference problem when the regions are nearby.	Good for functional and technical efficiency of the spectrum.
Markov models	Well adapted to the modeling of the channel behavior prediction.	Not well adapted to the modeling of the interaction between users.	Good for functional and technical efficiency of the spectrum.
Multi-Agent Systems (MAS)	-Good for modeling interaction between users. - Guarantees user autonomy.	Have to use other techniques (Auctions, game theory and Markov models) to perform more complex processing.	Good for functional, technical and economic efficiency of the spectrum

At the end of the state of the art, we can say that the six techniques used for dynamic spectrum access in the context of cognitive radio networks are complementary.

EXPERIMENTAL MATERIAL AND METHODOLOGY

Experimental material

Telecommunication Regulatory Board of Cameroon (ART) has installed spectrum control equipment in the cities of Yaounde and Douala, which are the zones with high radio-frequency concentrations. The Spectrum Supervision Center housed in the city of Yaounde is interconnected with the control system of the city of Douala offering the possibility of real-time control of the Douala city from the Yaounde power station. Most of the control equipment consists of mobile, portable and transportable stations. The control equipment used for measurements is two Rohde & Schwarz spectrum analyzers:

- the ESMD with a bandwidth of 8 kHz to 40 GHz;

- the PR 100 with a bandwidth of 9 kHz to 7,5 GHz

These spectrum analyzers and the experimental platform are shown in Figure 3.


a) Rhode & Schwarz ESMD b) Rhode & Schwarz PR 100

c) Experimental Platform

Figure 3: Spectrum Analyzers Rhode & Schwarz with Experimental Platform

Methodology

Figure 4 describes the proposed method combining both instrumentation and statistical tools.

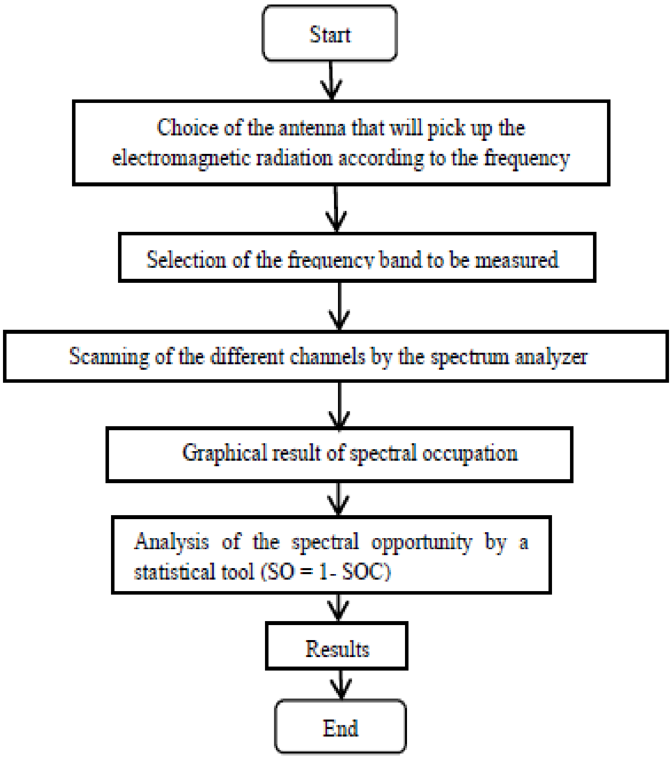

Figure 4: Method used

The spectral opportunity (SO) is defined as the complement of the spectral occupation (SOC) [22]:

$$SO = 1 - SOC \qquad (3)$$

We carried out several measurements in the 900 MHz and 1800 MHz bands of the mobile networks of the city of Yaounde, which is a zone with a high radio frequency concentration, for a period of one week. The spectral occupancy graphs are almost identical. The advantage of these various measures is to assess the opportunities for re-use by telecommunication operators of the spectral resource in the said bands.

RESULTS AND DISCUSSIONS

Results and discussions for 900 MHz bands

Figure 5 shows spectral occupancy of the 900 MHz band.

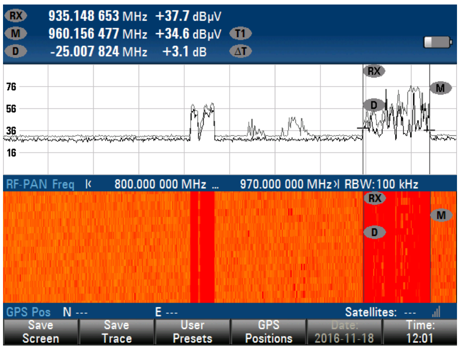

Figure 5: Spectral occupancy of the 900 MHz Band

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We carried out measurements by the PR 100 spectrum analyzer in the 900 MHz band ranging from 890.20 MHz to 960 MHz dedicated to GSM mobile services by the Regulator to the 3 local operators as shown in Figure 5. Each channel of this band has a bandwidth of 200 kHz out of the 125 available on the downlink or uplink. We note that not all channels allocated by the Regulator are used at full time, since the majority of the traffic is on the channels belonging to the downlinks as shown by the markers RX and M of the spectral occupancy graph ranging from 935.148 MHz to 960.156 MHz. So we have a bandwidth of 25 MHz in accordance with the frequency plan of Regulator from 935.20 MHz to 960 MHz of downlink. We have 100% occupancy rate (SOC) or a 0% spectral opportunity

Table 2: Spectral occupancy data for the 900 MHz band

Data	**Down Link (%)**	**Up Link (%)**
SOC	100	70
SO	0	30

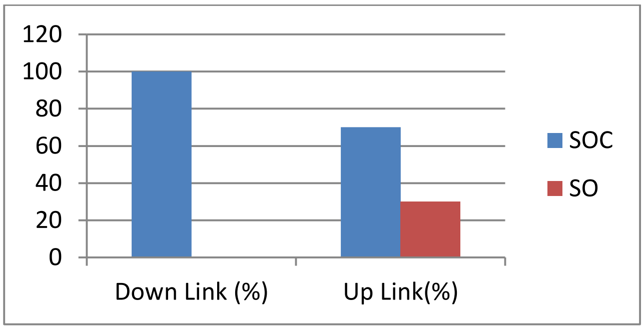

Figure 6: Spectral opportunity graph of the 900 MHz band

Results and discussions for 1800 MHz bands

The graphs in Figure 7 and Figure 8 show the measurements made in the 1800 MHz band by the ESMD spectrum analyser:

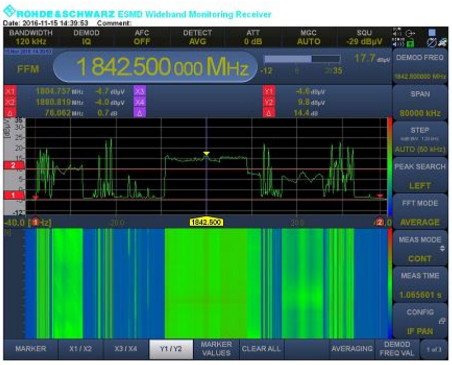

Figure 7: Spectral occupancy of the 1800 MHz band - Downlink

As can be seen from the graph of Figure 7, most of the traffic is carried out on the band reserved for downlinks ranging from 1804.757 MHz to 1880.819 MHz as indicated by the markers X1 and X2. This gives us a bandwidth of 76 MHz for the 376 channels of 200 KHz according to the frequency plan of the Regulator. We have cumulative spectrum holes of approximately 19.75 MHz bandwidth, equivalent to about 98 free channels, a SOC of 73.66% and a SO of 24.44%.

Figure 8: Spectral occupancy of the 1800 MHz band -Uplink

As shown in Figure 8 of the uplink band from 1710 MHz to 1785 MHz, the channels are almost all inactive, with a SOC of 13.18% and a SO of 86.82% representing substantially 325 free channels out of the 376 exploitable.

Table 3: Spectral occupancy data for the 1800 MHz band

Data	Down Link (%)	Up Link (%)
OCS	73,66	13,18
OS	26,44	86,82

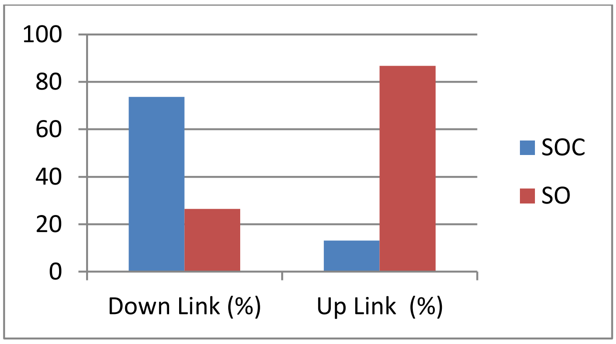

Figure 9: Spectral occupancy graph of the 1800 MHz band

CONCLUSION AND FUTURE WORK

At the end of this work, a review of the literature was carried out on dynamic spectrum access methods. Then an on-site study was made in Cameroon, particularly in the city of Yaounde, to assess the possibilities of using dynamic spectrum access in the mobile network bands, considering the interest in terms of significant demand for telecommunications operators in these bands. The observation that emerges from this analysis is relevant to the use of the spectral resource in these bands; the GSM gives us a SO of 0% on the downlink and 30% on the uplink. Among other things, for the 1800MHz band dedicated to mobile services GSM and LTE operators, we have a SO of 26, 44% on the downlink and 86.82% on the uplink. These results show that there are possibilities in Cameroon's mobile networks, especially in the city of Yaounde, for using DSA methods applied elsewhere, with and important economic impact.

Future work includes extension of this study to other cities of Cameroon and improvement of DSA methods.

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