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Minimum Jamming Probability Based Spectrum Sensing Method for Cognitive Radios

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ABSTRACT:
CR is equipment that can be programmed to sense the communication environment according to need so as to use it for communication purposes and then allocate appropriate resources to support best of the need. These systems operate in a very wide range of frequency spectrum and are computationally intelligent systems. These systems search for a frequency slot in the spectrum which has least interference at an instant of time and then makes decisions for choosing best methods of communication according to the environment conditions. For such systems, decision making and learning are two major challenges. Decision making problems are synonymously referred as dynamic configuration adaptation (DCA) problems. Such problems are solved with the help of some a priori knowledge. Many decision making techniques are categorised on the basis of this a priori knowledge.
In this study, we developed a novel communication spectrum sensing technique based on computation of minimum jamming probability along the entire spectrum. This method considers both false positive i.e. absence of primary user and false negative i.e. presence of primary user cases and tried to optimize the power consumption while sensing the environment. Results reveal that the proposed method has good performance.

KEYWORDS – Cognitive Radio, DCA,

INTRODUCTION:

The increase of computational capacity associated with (rather) cheap flexible hardware technologies (such as programmable logic devices, digital signal processors and central processing units) offer a glimpse into new ways to designing and managing future non-military communication systems. As a matter of fact in 1991, Joseph Mitola III argued that in a few years, at least in theory, software design of communication systems should be possible. The term coined by Mitola J. to present such technologies is software defined radio (SDR) [1]. For illustration purposes, today's radio devices need a specific dedicated electronic chain for each standard, switching from one standard to another when needed (known as the Velcro approach [2]). With the growth of the number of these standards (GSM, EDGE, Wi-Fi, Bluetooth, LTE, etc.) in one equipment, the design and development of these radio devices has become a real challenge and the practical need for more flexibility became urgent. Recent hardware advances have offered the possibility to design, at least partially, software solutions to problems which were requiring in the past hardware signal processing devices: a step closer to SDR systems.

In specific, several possible definitions exist--and are still a matter of debate in the community--to define SDR systems. For consistency reasons, we briefly describe software related radio concepts as agreed on by the SDR Forum [3]. This matter is further discussed in [4]. The SDR Forum defines SDR as “radio in which some or all of the physical layer functions are software defined” where physical layer and software defined terms are respectively described as:

• **PHYSICAL LAYER**:
The layer within the wireless protocol in which processing of radio frequency,

Intermediate frequency, or baseband signals including channel coding occurs. It is the lowest layer of the ISO seven-layer model as adapted for wireless transmission and reception.

• **SOFTWARE DEFINED**:

Software defined refers to the use of software processing within the radio system or device to implement operating (but not control) functions

Thus, SDR systems are defined only from the design and the implementation perspectives. Consequently it appears as a simple evolution from the usual hardwired radio systems. However, with the added software layer, it is technically possible with current technology to control a large set of parameters in order to adapt on the fly radio equipment to their communication environment (e.g., bandwidth, modulation, protocol, power level adaptation to name a few). Nevertheless the control and optimization of reconfigurable radio devices need the definition of optimization criteria related to the equipment hardware capabilities, the users' needs as well as the regulators' rules. Introducing autonomous optimization capabilities in radio terminals and networks is the basis of cognitive radio (CR), term also suggested and coined by Mitola III [5,6].

Mitola [6] defined CR, in his Ph.D dissertation as follows: The term CR identifies the point at which wireless personal digital assistant (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer to computer communication to:

• Detect user communication needs as a function of use context, and
• Provide radio resources and wireless services most appropriate to these needs.

Thus, the purpose of this new concept is to autonomously meet the user's expectations, i.e., maximizing his profit (in terms of QoS, throughput or power efficiency to name a few) without compromising the efficiency of the network. Hence, the needed intelligence to operate efficiently must be distributed in both the network and the radio device.

Latest research address trending issues like cooperative spectrum sensing [7], sensing-throughput trade-off's [8, 10, 11], design and development of software and hardware [9].

Next secrion i.e. section 2 discusses in detail fundamental concepts of cognitive radios, its definitions, history, classification of CRs, decision making learning in CRs, cognition cycles and CR applications.

1. COGNITIVE RADIO: FUNDAMENTAL CONCEPTS AND IMPLICATIONS:

BASIC COGNITIVE CYCLE:

After the original definition given by Joseph Mitola III, many other definitions were proposed to define the reach of cognitive radio [4, 15-17, 12-14]. .Defining cognition is a harsh task. In the context to cognitive radios, basic cognitive abilities are considered to be are as:

• Reasoning (or decision/analysis). and
• Environment perception (or sensing)

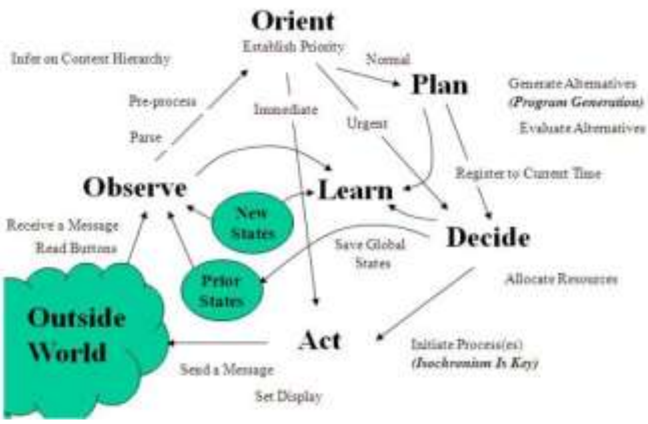

Figure 1: CR working cycle as by Mitola III [6]

On the basis of these cognitive abilities, a cognitive radio needs to take appropriate decision to adapt itself to the ongoing environment.

Further the cognitive cycle is simplified into the following three steps

1. Observe: With the help of spectrum sensing devices, the CR acquires information about the communication environment. This information is further preprocessed and makes the knowledge base for the CR system.
2. Analyze/ decide: this is more or less a black box where the entire processing takes place before CR is reconfigured for transmission. This is a very important step in CR communications.
3. Act: this step mainly includes parameter reconfiguration and waveform transmission. Reconfiguration management architecture is needed for efficient and quick reconfiguration. [18]

DECISION MAKING PROBLEMS IN CR:

This is the most important and most challenging aspect of design of CR systems. This involves how to decide, when to decide, what's best under given scenario, and rapid dynamic configuration adaptation. Now here are some constraints upon which the design of CR depends.

- The environment constraints
- User's expectations
- Equipment's operational abilities

DYNAMIC SPECTRUM ACCESS:

The DSA accepted all suggested technologies that emerged from the definitions of "free" and efficient spectrum access or trading. An article in 2007, suggested one simple and possible taxonomy to classify the various suggested spectrum management approaches which are illustrated in Figure 5 on the next page. Three key approaches can be discriminated into the following:

- Dynamic exclusive use model,
- Hierarchical access model:
- Open sharing model

DECISION MAKING TOOLS FOR DSA:

The "a priori" knowledge acquired by CR is a set of rules made by the designer on the representation and amount of the available knowledge to the decision engine when it first works in the environment. In fact, by the dictionary (Oxford English), "knowledge" is defined as: (a) familiarity or awareness gained by experience of a situation or fact. (b) What is known in particular fields or total; information and facts or (iii) skills and expertise acquired by a human through education or experience; the practical or theoretical understanding of a subject. Similarly, within the cognitive radio framework, one can define the "a priori" knowledge as a set of practical or theoretical assumptions given by the designer to the radio's decision making engine.

Some of the DSA techniques that use 'a priori' knowledge are

- Expert approach
- Genetic algorithms
- Clustering
- Partial monitoring

2. METHODOLOGY:

In this section, proposed methodology is explained in details with the help of self-explanatory steps and flow chart. In this section, data used in the study, hardware/software used and detailed methodology followed in this study is discussed.

PROBLEM DEFINITION:

After an exhaustive and extensive literature survey, finally a problem statement is formed. It was found that in conditions like limited power supply and limited spectrum, for design of spectrum utilization efficient cognitive radios, the problem of decision making needs to be properly addressed. For this in turn, an a priori knowledge of the environment is required. Learning method also plays an important role efficient functioning of such systems. Hence need of a good decision making approach has evolved which in turn generates need of a good learning strategy. The learning strategy must be simple, fast, efficient and hardware intensive.

OBJECTIVE:

Once the problem statement is defined, the objective becomes clear. In this case the major objective of this work is to develop a simple, fast, highly reliable, threshold adaptive and spectrum utilization efficient decision making methodology which can intelligently sense the environment (spectrum & primary user) and can adapt its operating parameters (transmission power, modulation technique etc.) thereby making highly reliable decisions

Other minor objectives are to

- Detection of primary users in the given spectrum in short span of time
- Development of dynamic threshold based decision making system
- Development of a CR system which can provide better Quality of Service.

DATA USED:

Table 1 Operating Characteristics

Operating Characteristics	Adjusted values
Signal type	Random signal
Signal Energy	Variance/2
Noise Type	Additive White Gaus
Decision Boundaries	Probability of Detection and, Probability of false Alarm
Threshold for probability of Detection	Minimum 60%
Threshold for Probability of false Alarm	Maximum 50%

HARDWARE/SOFTWARE SPECIFICATIONS:

Hardware: Lenovo 'Ideapad' with Core Intel i5 with 2 GB NVIDIA Graphics Card and 4 GB internal RAM

Software: Microsoft Windows 8.1 professional with Matlab 2013 installed.

Approach

Abbreviations used further are

CU: Cognitive Radio user
LU: Licenced User

Step 1: Spectrum Sensing

In the distributed scenario for detecting the LU's signal, each CU conducts a spectrum sensing process called local spectrum sensing. Local spectrum sensing is essentially a binary hypothesis testing problem

$$H_0 : x(t) = n(t)$$
$$H_1 : x(t) = h(t)s(t) + n(t)$$

Where H_0 and H_1 are hypothesis of absence and presence of the LU's signal, respectively, x(t) represents the received data at the CU, h(t) denotes the gain of the channel between LU and CU, s(t) is the signal

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transmitted from the primary user, and n(t) is the additive white Gaussian noise (AWGN). In addition, channels corresponding to different CUs are assumed to be independent, and all CUs and LUs share a common spectrum allocation

Step 2: Energy Detection

Among the various methods for spectrum sensing, energy detection has been demonstrated to be simple, quick, and able to detect the primary signal, even if the feature is unknown. In this paper, energy detection for local spectrum sensing is considered. A block diagram of the energy-detection scheme is shown in Figure below. To measure the signal power in a particular

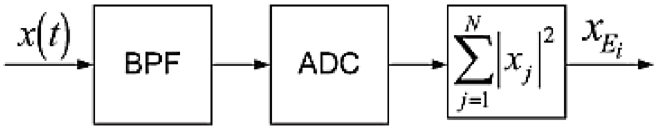

Figure 2: Block diagram of the energy detection scheme used in this study

frequency region in the time domain, a bandpass filter is applied to the received signal, and the power of the signal samples is then measured at the CU. An estimation of the received signal power is given at each CU by the following equation.

$$x_E = \sum_{j=1}^{N} |x_j|^2$$

Where, x_j is the sample of the received signal and N = 2TW; where T and W are the decision time and signal bandwidth in Hertz respectively. When N is relatively large (say N > 200), x_E can be approximated as Gaussian random variable under both hypothesises H1 and H0, with mean µ1, µ2 and variances σ1, σ2 respectively, such that

$$\begin{cases} \mu_0 = N, & \sigma_0^2 = 2N \\ \mu_1 = N(\gamma + 1), & \sigma_1^2 = 2N(2\gamma + 1) \end{cases}$$

Where γ is the SNR of the primary signal at the CU The SNR is a constant in the nonfading AWGN environment and a random variable in the fading channel scenario.

Step 3: Decision Making

By using values of thresholds for probability of detection and probability of false alarm we decide whether primary user is present or not

D1 = Maximum threshold for probability of false alarm (it should be less than 60%)

D2 = Probability of detection

E1 = It is energy of received primary user

We make three decision zones:

Zone 1:

When E_1 is less than D_1

$E_1 < D_1$

In this case, primary user or licensed user is not present. So we can transmit.

Zone 2:

When E_1 is greater than D_1 but less than D_2

$D_1 < E_1 < D_2$

In this case, we are not sire because received signal energy is less than maximum primary user threshold but more than minimum threshold.

Zone 3:

When E_1 is greater than D_2

$D_2 < E_1$

In this case primary user is present, so we cannot transmit. Change the operating characteristics and try again

3. RESULTS:

In this chapter, results from different processes are presented here. Also a detailed analysis of the results is done.

Result 1: Power spectral density plot for a particular scenario

The below graph depicts a scenario after sensing the spectrum environment. We can observe that signal powers are quiet low around 5 MHz and 10MHz. So from the above observation we can transmit at these frequencies.

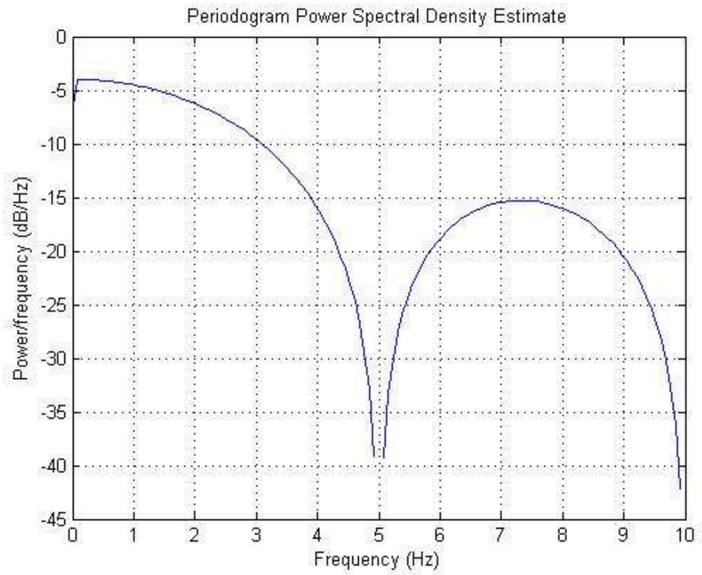

Figure 3 Pereiodogram power spectral density estimate

Result 2: Probability of detection versus Threshold

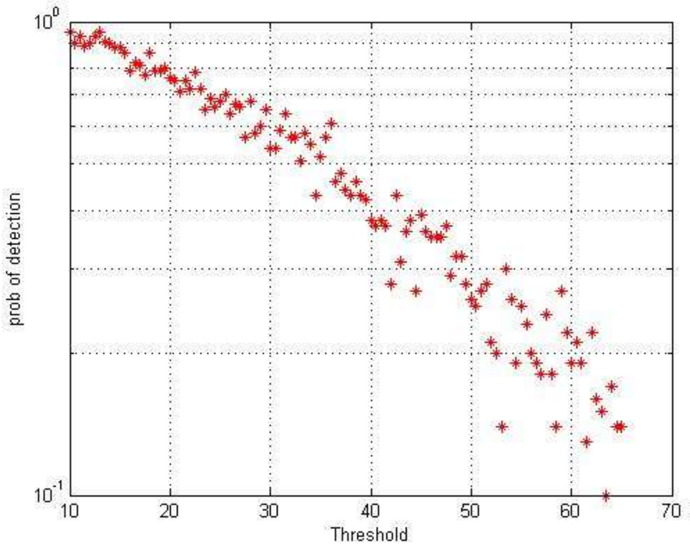

Figure 4 Probability of detection versus threshold plot

From the above figure, it is clear that upon increasing the threshold value of detection, the probability of detection decreases. Also the number of licensed user also decreases.

Result 3: Probability of false alarm versus Threshold

From the below graph, it is clear that the probability of false alarm also decreases upon increasing the threshold. This has both benefits and losses.

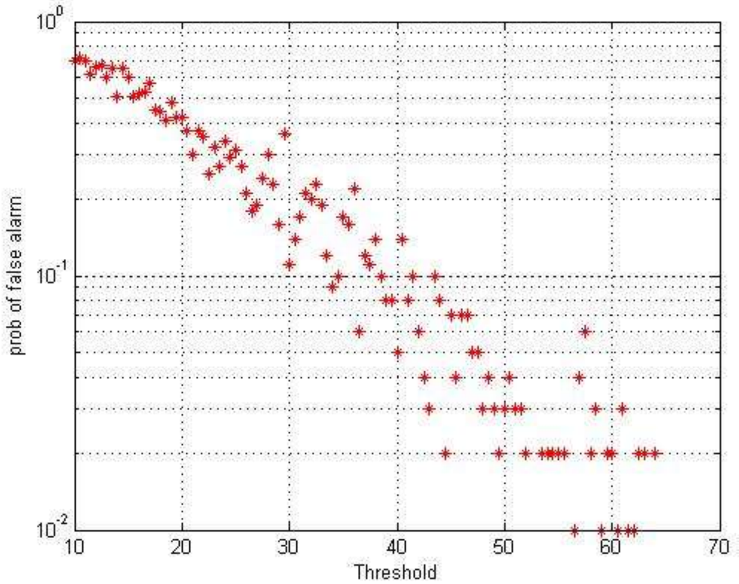

Figure 5 Probability of false alarm versus Threshold

CONCLUSION AND FUTURE SCOPE:

After building the method proposed, implementing it and obtaining satisfactory results, it can be concluded that the proposed methodology has proven efficient enough to detect a primary user in noisy environments. Results shown in this study reveal that upon selection of right values of thresholds, one can sense radio environments in short time and efficiently. The method of least jamming frequency search proved to be fruitful. The amount of shift in sensing frequency was a major challenge which was addressed well by the proposed method. Although, sensing time and power consumption during sensing can be reduced more.

Future aspects of this work are

- This methodology can be used in MIMO cognitive radio networks
- Calculation of new sensing frequency cab be worked on
- This method can be tested with other noise models of fading environments.

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