CONTEMPORARY ISSUES IN COGNITIVE RADIO NETWORK

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ABSTRACT: The paper examines contemporary issues with cognitive radio networks as it relates to spectrum scarcity and the demand of users. With recent advancement in technology and increase in the need for wireless communication systems, this has given rise to search for desirable spectrum bands for transmission. Cognitive Radios renders an answer to the trouble by sensing the idle (licensed) bands and allowing (secondary) users to broadcast and transmit in these idle spaces. Spectrum sensing forms the main block of cognition cycle. However research has shown by previous researchers that radio spectrums are being under- utilized in most cases. This paper attempts to profound a solution to efficient and effective spectrum utilization has identified the current challenges and issues faced by spectrum sensing for cognitive networks. The principal issues with cognitive radios are that it should not interfere with the primary users and should vacate the band when it is required. For this sole reason, energy detector system model was used in this paper and performance evaluation was calculated. The performance evaluation is done for cooperative spectrum sensing schemes under non fading environment
This paper provides a clear understanding of cognitive radio technology, and its role in national development. Then several challenges and security issues are discussed.
KEYWORDS: Cognitive Radio; Spectrum Sensing; Primary Users; Secondary Users; Wireless Communication; Spectrum Hole; Cognitive Cycle; Cognitive Capabilities.

1. INTRODUCTION

The rapid growth of bandwidth demands for wireless technologies in our present day community has led to spectrum scarcity. In Nigeria, the Nigerian Communications Commission (NCC) is responsible for allocation of license. Licensed spectrum is allocated over relatively long period of time, and to be used by only users with license. These radio spectrums are splinted into bands and are strictly allocated to technology based services such as mobile telephony networks, radio and TV broadcasting stations.

However the NCC ensures through a management framework which guarantees that the radio frequency spectrum is exclusively licensed to an authorized party without interference. These authorized parties are referred to as the Primary Users (PU). They have access rights to licensed spectrum band, whereas, Secondary Users (SU), have cognitive radio capabilities. They have the ability to sense the surroundings for availability of unused band. They request the PU to make use of this unused spectrum for wireless communication. PU have higher priority over SU. SUs ensure that they do not cause interference to PUs.

A Cognitive Radio (CR) is a well-informed radio platform which has the ability to exploit its environment to increase spectral efficiency and capacity. CR's are regarded as transceivers that automatically sense the existence of available channels in a wireless spectrum and accordingly, change their transmission or reception parameters ([C+08]). The CR technology is imagined to enable identification, use and management of vacant spectrum, known as Spectrum Holes ([Hai05]). A spectrum hole is a region of space-time frequency, where a primary user is absent and a particular secondary use is possible ([TMS09]). However Cognitive radio networks (CRN) is IEEE 802.22 standards, also known as 5-G wireless technology. CRN carries primary users (PU) or licensed users and secondary users (SU) or un-licensed users.
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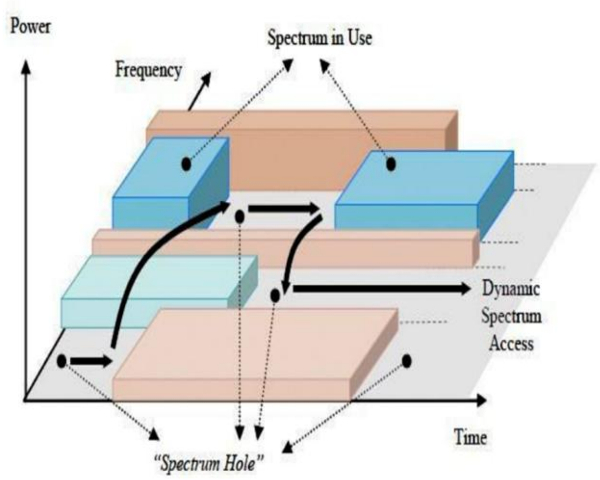


Figure 1; Spectrum Hole Illustration ([TMS09])

Cognition cycle involves the use of sensing the spectrum. After the initial phase of sensing, it is evident that reliable spectrum sensing is the most critical role of the cognitive radio process. However adapting as well as sensing the environment, a cognitive radio will possess the ability to fill in the spectrum holes and serve its users simultaneously without causing any form of interference to the primary user. A spectrum sensing scheme provides a general picture of the medium over the entire radio spectrum. In order to ascertain spectrum usage, the cognitive radio network is allowed to analyse all parameters (time, frequency and space). Figure 2 shows the process of the cognitive radio functions.

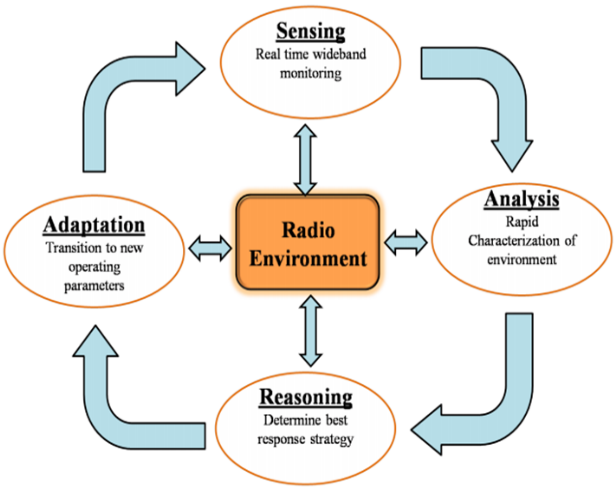


Figure 2. Cognitive Cycle ([Mit00])

The remainder of this paper is organized as follows: in section 2, the role of cognitive radio applications is discussed along with the contemporary issues and challenges of cognitive radio networks. Section 4 describes cooperative detection in spectrum sensing with the system model of an energy detector used for simulation has been discussed. Section 5 includes the simulation results from the ROC curves for OR, and AND majority fusion rules for m= 10 energy detectors, ROC curves over Rayleigh channel for M= 10 cooperating detectors and the Roc Curves over Nakagami Channel for M= 10 Cooperating Detectors. Section 6 we draw our conclusions. Finally the last section shows recommendation and future scope for continuation of research.

2. THE ROLE OF COGNITIVE RADIO APPLICATIONS.

It is of predominant importance to begin this part of the paper by making the leading words of the caption clear so that the message would be transparently depicted. Traditionally, wireless networks are faced with the challenge of security as well as scarcity of the wireless bandwidth required to meet the demand for high-speed applications. However cognitive networks are used to render broadband access to rural as well as under-resourced areas.

The cognitive radio networks can be applicable in different fields ranging from Public Safety Networks, Disaster Relief and Emergency Networks, Real Time Surveillance Applications to Health Care Application Systems as well as Security Applications both in the Public and Military domain among others.

Contemporary Issues and Challenges in Cognitive Radio Network.

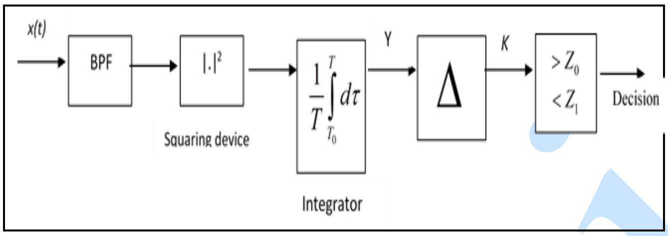
Firstly the word contemporary as defined means modern, current or present day. Therefore contemporary issues in cognitive radio network are various events and developments of the present day affect the efficiency and effectiveness of this network. Due to their coexistence with primary networks, cognitive networks are inherently impose unique challenges. Several research challenges are risen based on the advancement in technology as well as development in cognitive radio, some of these challenges are presented in the rest of this section:

- Spectrum Sensing Challenges: Generally a cognitive radio user cannot be aware of the precise locations of the primary receivers due to the lack of interactions between primary networks and cognitive radio networks. Therefore, there is need for new techniques to measure or estimate the interference temperature at nearby primary receivers. Spectrum sensing functions should be highly-developed considering the multi-user environment that consisting of multiple cognitive radio users and primary users, makes it more difficult to sense spectrum holes and estimate interference. ([GS08]; [L+11]).
- Spectrum Decision Disputes: A lot of open research challenges of cognitive radio on spectrum decision function such as strategy for selecting channel for sensing or access, design of application and spectrum adaptive spectrum decision models, where and how the decision on spectrum availability, optimization of radio performance among others ([JS09]). The choice of the decision algorithms is also a challenge.
- Spectrum Mobility Challenges: The users movement from one place to another gives rise to continuous allocation of spectrum and it's a challenge since the available bands also change as a user moves ([A+08]). Also cognitive radio networks adapt to the wireless spectrum based on the available bands and since these available channels change over time, enabling quality of service in this environment is challenging ([CH15]).

3. COOPERATIVE DETECTION

In this experiment we use the energy detection model with a single receiver for the spectrum sensing. However with cooperative spectrum sensing (CSS), information detected are collected at various locations of the SUs and are used together with ascertaining the spectrum availability. In implementing an energy detector, the received signal *x(t)* is filtered by a band pass filter (BPF) and by a square law device. The BPF is used to reduce the noise bandwidth. Therefore, noise at the input to the squaring device has a band-limited, at apparitional density. The output of the integrator is the energy of the input to the squaring device over the time interval T. The output signal from the integrator (the decision statistic), *Y*, is compared with a threshold, to decide whether a primary (licensed) user is present or not. Decision regarding the usage of the band is made by comparing the detection statistic to a threshold value *k*.

Table 1. Block Diagram Illustration of the Energy Detector used



Z_0 & Z_1 are presence and absence of signal respectively

$$x(t) = \begin{cases} n(t), & Z_0 \\ h * s(t) + n(t), & Z_1 \end{cases} \qquad (1)$$

From (1),
x(t) is the sample to be analysed at each instant t,
n(t) is additive noise; (with samples having zero-mean and variance σ^2)
h is the complex channel gain between the primary signal transmitter and the detector.
s(t) is the transmitted signal to be detected.
The sample signal is observed from this and then decide how correct Z_0 & Z_1 is based on the test statistic being either greater or less than the threshold.
The probability of detection (P_d), the probability of false alarm (P_f) and the probability of missed detection (P_m) are used to measure the performance of the energy detector, over fading and non-fading environment.
Previously the system model was illustrated using a block diagram as well as defining the mathematical deductions which were used theoretical for description of energy detector of signal in a spectrum particularly for cooperative sensing. Results of the analysis performed are presented and discussed here. All simulations in this paper work is executed using matlab[2] version r2012a.
The performance receiver is measured by depicting the receiver operating characteristics (ROC) curves, (p_d against p_{fa}). The ROC curves show plot of probability that the SU fails to detect the presence of the PU as against the probability that the SU decides the PU is in operation whereas it is a false-alarm. The ROC curves are plot with one of the parameters varied while the other is fixed. Networks of cooperative energy detectors in the various fading channels are considered. In fig. 3, using 10 energy detectors, the OR fusion rule depicts a better performance likened to the MAJORITY and AND fusion rules. This is attributed to the fact that OR decision fusion rule involves result of a minimum of a single user out of *k* energy detector nodes to declare the availability or presence of a PU. Though and Fusion rule indicates a slightly better performance at low P_f, as compared to the OR rule, as seen from the figure.

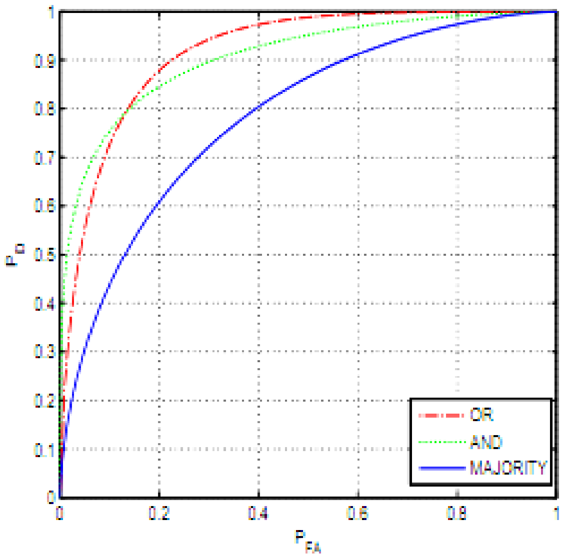


Figure 3: ROC curves for OR, and AND majority fusion rules for m= 10 energy detectors

Since the OR combining rule denigrates communication overhead - attributed to its property of sending a minimum of a single decision to the fc, this fusion rule will be adopted in the rest of the analysis for cooperative users in the various channel models under consideration. Figure 4 shows the complementary roc performance curves of the energy detector over Rayleigh fading. The number of cooperating nodes (m) are 10, with Average snr (γ) values of 0; 5; 10; 15db, and time bandwidth product, d= 5.

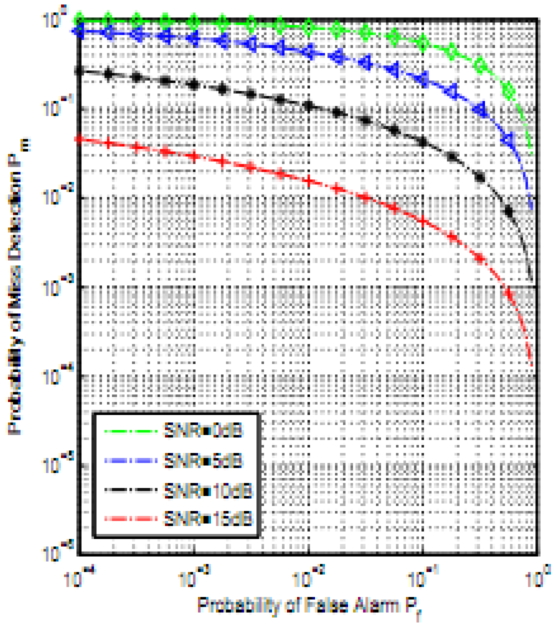


Figure 4: ROC curves over Rayleigh channel for M= 10 cooperating detectors

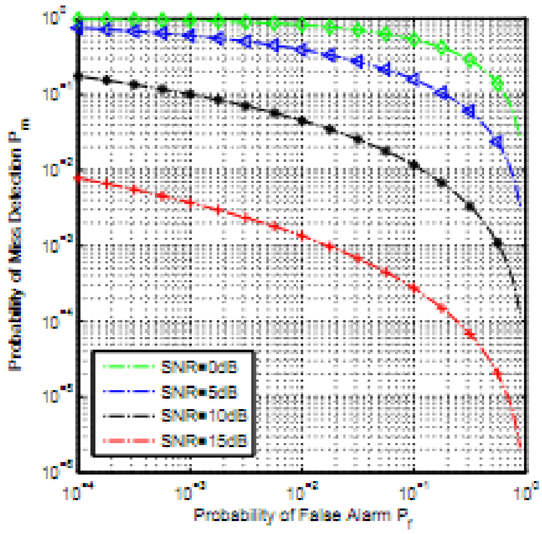


Figure 5: Roc Curves Over Nakagami Channel for M= 10 Cooperating Detectors

Evidently cooperative sensing is a promising technique of combating the underlying performance deterioration of the energy detector at different environments.

4. CONCLUSION

The scarcity in radio spectrum deepens by the day. Therefore there is urgent need to utilize it efficiently. This has given rise to cognitive radios employment of dynamic spectrum reuse concept. This technique intelligently identify the spectrum holes in licensed-bands which are used by primary users, and dynamically enables the secondary users to transmit in these spaces. Cognitive radio offers the ability to manage this situation more effectively by utilizing the ability to sense the actual propagation conditions that occur, and to adjust the radio dynamically to best fit these conditions.

In this paper, the fundamental concept about cognitive radio technology and cognitive radio capability functions are presented. Then, various contemporary challenges and security issues of cognitive radio networks are discussed. A simulation comparison of AND, OR and MAJORITY cooperative decision fusion rules was undertaken and results show that OR rule (corresponding to considering the decision of at least one detector out of *k* available detectors) outperforms the AND and MAJORITY combining rules. In future, study can be focused on security issues and efficient spectrum management challenges as well as trying to resolve these challenges.

5. RECOMMENDATION

The rapid proliferation of wireless technologies is unsurprisingly increasing the demand for radio spectrum by orders of magnitude over the next decade. This is an issue that must be addressed through technology and regulative improvements in spectrum efficiency. Hence, a significant hurdle to substantial progress in the field is the unfitness to conclusively test, evaluate, and establish cognitive networking technology, at scale and in real-world deployment scenarios. Test beds like the Universal Software Radio Peripheral (USRP) will assist in both experimental and qualitative analysis; to reduce as much as possible, simulation of novel techniques involved with identifying unused spectrum and the whole concept of opportunistic spectrum access.

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