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PERFORMANCE ANALYSIS OF COGNITIVE RADIO OVERGAUSSIAN CHANNEL

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ABSTRACT

Cognitive radio is viewed as a novel approach for improving the utilization of a precious natural resource: the radio electromagnetic spectrum. The cognitive radio, built on a software-defined radio, is defined as an intelligent wireless communication system that is aware of its environment and uses the methodology of understanding- by-building to learn from the environment and adapt to statistical variations in theinput stimuli. Energy detection is the most widely used technique in cognitive radio networks to enable opportunistic spectrum access. In this paper, the problem of energy detection of an unknown deterministic signal over Gaussian Channel is revisited. Performance in terms of probability of detection, probability of false alarming is analyzed over Gaussian Channel.

Index Terms: Cognitive radio networks, Energy detection, Gaussian Channel, probability of detection, probability of false alarming

I. INTRODUCTION

REcent FCC measurements have indicated that 90 percent of the time, many licensed frequency bands remain unused [1]. As user demands for data services and data rates steadily increase, efficient spectrum usage is becominga critical issue. In order to better utilize the licensed spectrum, the FCC has recently launched a Secondary Markets Initiative [2], whose goal is to remove regulatory barriers and facilitate the development of secondary markets in spectrum usage rights among Wireless Radio Services. This proposalintroduces the concept of dynamic spectrum licensing, which implicitly requires the use of cognitive radios to improve spectral efficiency. Cognitive radio, a term first coined by Mitola [3], is a low-cost, highly flexible alternative to the classic single-frequency-band single-protocol wireless device. By sensing and adapting to its environment, a cognitive radio is able to cleverly avoid interference and fill voids in the wireless spectrum, dramatically increasing spectral efficiency. Although the gains to be made by the combination of cognitive radios and secondary spectrum licensing seem intuitive, the fundamental theoretical limits of the gains to be made by this coupling have only recently been explored [4], [5]. This motivates the writing of this article, where we review the basics of cognitive radio and the FCC initiatives they opportunistically exploit. Furthermore, the current state of the art on the theoretical limits of wireless channels employing cognitive radios are laid out, as well as a novel idea for an achievable rate region that more fully exploits the capabilities of cognitive radios. In short, the question of how much datacan be reliably transmitted over the newly defined cognitive radio channel is posed in information theoretic terms, in order to conclusively explore the limits of this new channel. This channel is modeled as a two-sender, two-receiver interference channel, with one twist: the genie. Suppose a (possibly non-cognitive) radio is transmitting. A cognitive radio that wishes to transmit may listen to the wireless channel, and can obtain the signal of the currently transmitting user. The genie idealizes message knowledge, and non-causally gives the incumbent cognitive radio full, non-causal knowledge of the existing transmitters messages. We argue why this is a viable model to explore and what conclusions may be drawn from these results. Approaching the problem from an information theoretic angle is novel, as the limited research on cognitive radios tends to come from a more practical protocol-oriented perspective. We finally explore some of the regulatory and engineering aspects that must be addressed in order to realize these gains.

II. COGNITIVE RADIO: THE SMART APPROACH

Over the past few years, the incorporation of software intoradio systems has become increasingly common. This has allowed for faster upgrades, and has given these wireless communication devices more flexibility, and the ability to transmit and receive using a variety of protocols and modula- tion schemes (enabled by reconfigurable software rather than hardware). Furthermore, as the name suggests, such radios can even become cognitive and, as dictated by the software, adapt their behavior to their wireless surroundings without user intervention. According to the FCC, software defined radio (SDR) encompasses any radio that includes a transmitter in which operating parameters such as frequency range, mod- ulation type or maximum output power can be altered by software without making any changes to hardware components that affect the radio frequency emissions. Mitola [3] took the definition of an SDR one step further, and envisioned a radio that could make decisions as to the network, modu- lation, and/or coding parameters based on its surroundings, and called such a smart radio a cognitive radio. Such radios could even make decisions based on the availability of nearby collaborative nodes, or on the regulations dictated by their cur- rent location and spectral conditions. One of the main players in the early development of software defined radios was the U.S. Department of Defense Joint Tactical Radio System.

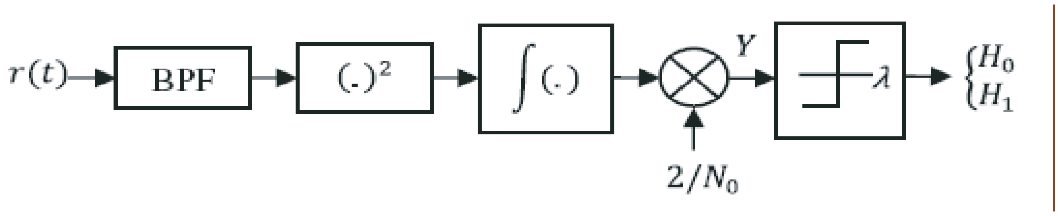

Fig. 1. Block diagram of the energy detector.

Fig. 2. Threshold based detection method.

(JTRS) Program. The JTRS developed a software architecture known as the Software Communications Architecture (SCA),into which different hardware components may be integrated. SCA was later adopted by commercial indus- try through a non-profit international organization aimed at promoting SDR technology, called the SDR Forum. In an alternative and parallel approach, the open source GNU radio project hopes to encourage research and development of SDRs, allowing anyone to contribute their own code to the already existing openly available software. In the EU, the End-to-End Reconfigurability (E2R) Project [6] aims at realizing the full benefits of the diversity within the radio eco-space, composed of a wide range of systems such as cellular, fixed, wireless local area,

and broadcast. The systems they intend to develop will provide common platforms and associated execution environments for multiple air interfaces, protocols, and applications, which will yield to scalable and reconfigurable infrastructure that optimize resource usage through the use of cognition based methods. Other SDR research efforts include the collaborationof Tektronix with Virginia Techs Mobile and Portable Radio Research Group, as well as a new National Science Foundation Research in Networking Technology and Systems (NeTS) program. Cognitive radio technology is perfectly suited to opportunistically employ the wireless spectrum. Their frequency agility, dynamic frequency selection, adaptive modulation, transmit power control, location awareness, and negotiated use meaning ability to incorporate agreements into their behavior all allow for very flexible spectrum use. In essence, cognitive radios could skillfully navigate their way through interference, and greatly improve spectral efficiency. The FCC, very enthusiastic about these possibilities, is now vigorously altering their regulations to allow for more flexible use of the licensed wireless spectrum.

III. SYSTEM MODEL

Fig. 1, Fig. 2 shows the block diagram of the energy detectorand threshold based detection method, respectively. Here, the existence or absence of a primary transmitter can be modelled as a problem of binary hypothesis which can be defined as:

$$x[n] = \begin{cases} w[n], & H_0 \\ hs[n] + w[n], & H_1 \end{cases} \quad (1)$$

here, $x[n]$ denotes the received signal at d, $s[n]$ is thesignal transmitted by the primary transmitter s, h is the Rayleigh distributedchannelcoefficientwhichisassumedtobeconstant during the period of N observations (i.e. $n = 1, 2, \cdots N$), $w[n]$ is the additive white gaussian noise with zero meanand σ^2variance. In (1), H_0 denotes the hypothesis when primary user signal is absent and H_1denotes the hypothesis when primary user signal is present. The energy detector used in this system model collects the N observations of the signal energy $x[n]$, so it can be represented as

$$Y = \sum_N |x[n]|^2 \quad (2)$$

In (2), $x[n]$ is a random process so Y is also random innature which is central chi-square distributed for hypothesis $H0$ and non-central chi-square distributed for hypothesis $H1$. Hence PDF of Y can be given as

$$f_Y(y)=\begin{cases} \frac{1}{\sigma^n 2^{N/2}\sigma(N/2)} y^{(N/2-1)} \exp\left(-\frac{y}{2\sigma^2}\right), & H_0 \\ \frac{1}{2\sigma^2}\left(\frac{y}{\zeta}\right)^{(N-2)/4} \exp\left[-\frac{1}{2\sigma^2}(y+\zeta)\right] * I_{(N/2)-1}\left(\frac{\sqrt{\zeta y}}{\sigma^2}\right), & H_1 \end{cases} \quad (3)$$

A. Probability of detection

Probability of correct detection of the primary signal by theenergy detector is called probability of detection. For Gaussian channel, Probability of detection can be modeled as follows

$$P_D = P_\tau(decision = H_1|H_1) \quad (4)$$

$$= P_\tau(y > \lambda\, |H_1) = \int_\lambda^\infty f_Y(y)dy,$$

here, λis the decision threshold.

B. Probability of Miss-detection

Probability of not detection condition of the primary signalby the energy detector is called probability of miss-detection. For Gaussian channel, Probability of miss-detection can be modeled as follows

$$P_{MD} = P_\tau(decision = H_0|\, H_1) \quad (5)$$

$$= P_\tau(y < \lambda|\, H_1) = \int_0^\lambda f_Y(y)dy,$$

here, λis the decision threshold.

C. Probability of false alarming

Probability of incorrect detection of the primary signal bythe energy detector is called probability of false alarming. For Gaussian channel, Probability of false alarming can be modeled as follows

$$P_{FA} = P_\tau(decision = H_1|\, H_0) \quad (6)$$

$$= P_\tau(y > \lambda|\, H_0) = \int_\lambda^\infty f_Y(y)dy,$$

here, $\lambda$is the decision threshold.

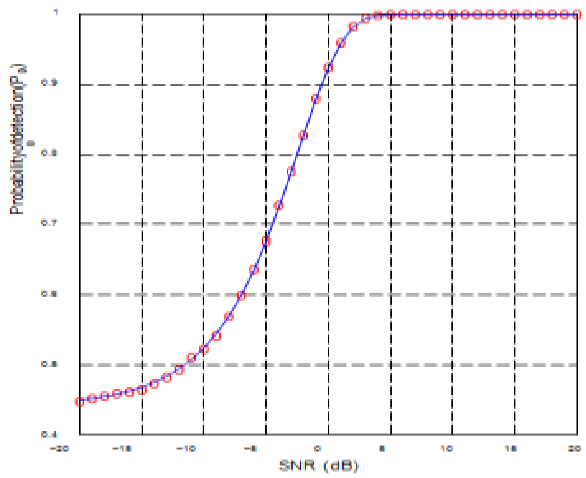

Fig. 3

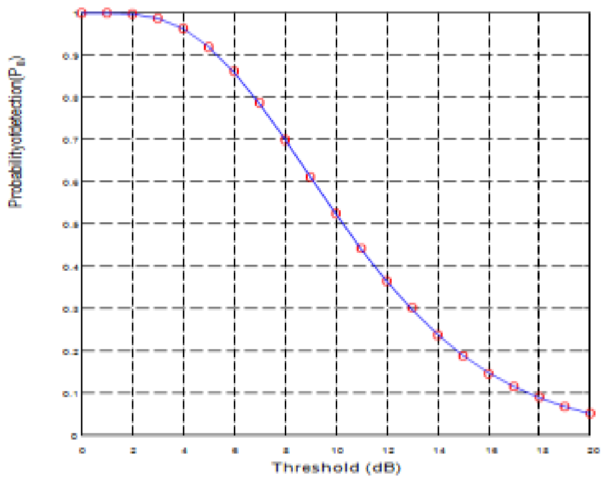

Fig. 5

Fig. 3.Detection probability of primary transmitter with respect to SNR

Fig. 5.Detection probability of primary transmitter with respect to threshold

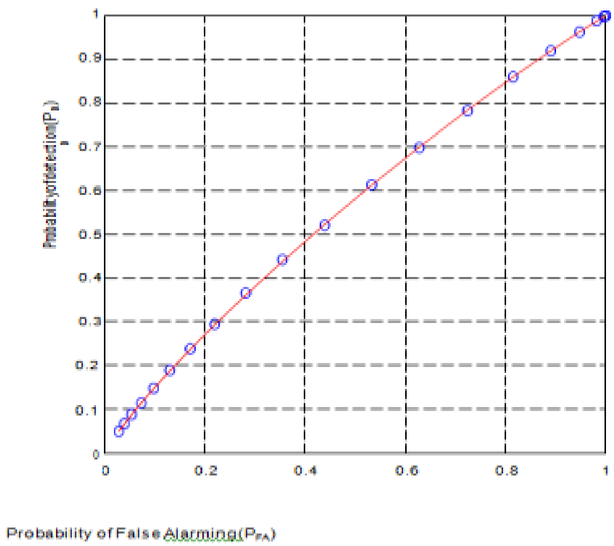

Fig. 4

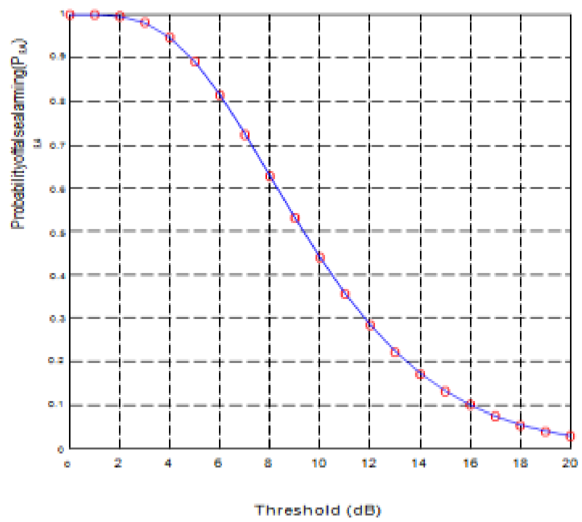

Fig. 6

Fig. 4. Detection probability of primary transmitter with respect to false alarming probability.

Fig. 6. Probability of false alarming for primary transmitter with respect to threshold

IV. NUMERICAL RESULTS

In this paper we have compared the results for SNR(dB)vs probability of detection over Gaussian channels. Also ROC curves (Probability of detection vs Probability of false alarm) are compared for both the cases.

A. SNR(dB) vs Probability of detection

In Fig. 3, probability of detection is plotted.

B. Probability of detection vs Probability of false alarm

The Fig. 4, shows the ROC (Receiver Operating Characteristics) curve which is the graph between the prob of false alarm and the prob of detection.

C. Probability of detection vs Threshold

In Fig. 5, probability of detection is plotted with respect to threshold.

D. Probability of false alarm vs Threshold

Probability of false alarm performance is analyzed in Fig.6.

V. CONCLUSION

Cognitive Radio has emerged as an intelligent networkthat fulfills the increasing demand of bandwidth for effective communication. In this paper energy detection based spectrumsensing in cognitive radio is analyzed over Gaussian channel. Detection performance and false alarming of energy detection is compared for different SNR and threshold values.

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