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A PATH FOR HORIZING YOUR INNOVATIVE WORK

GLRT BASED SPECTRUM SENSING IN COGNITIVE RADIO

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Abstract: There are new system implementation challenges involved in the design of cognitive radios, which have both the ability to sense the spectral environment and the flexibility to adapt transmission parameters to maximize system capacity while co-existing with legacy wireless networks. The critical design problem is the need to process multi-frequency wide bandwidth and reliably detect presence of primary users. This places severe requirements on sensitivity, linearity, and dynamic range of the circuitry in the RF front-end. To improve radio sensitivity of the sensing function through processing gain we investigated energy detection and spectrum sensing for cognitive radio. Our technique shows generalized likelihood ratio test (GLRT) with that reduces probability of false alarm versus the probability of detection for different input energy levels.

Keywords: Cognitive Radio, **GLRT**, Probability of Detection, Spectrum Sensing

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INTRODUCTION

A driving feature of future network architectures will be the mobile user. Users increasingly will access information resources while on the move, whether when in a vehicle, attending a business meeting, or working in remote locations. Wireless technology is necessary to support the mobile user and adaptive and efficient use of radio spectrum is an important aspect of enveloping future network architectures. Cognitive Radios (CRs) integrate radio technology and networking technology to provide efficient use of radio spectrum, a natural resource, and advanced user services. The cognitive radio wireless network is intended as an advanced technology integration environment with focus on building adaptive, spectrum-efficient systems with emerging programmable radios. The emerging cognitive radio scenario is of current interest to both policy makers and technologists because of the potential for order-of-magnitude gains in spectral efficiency and network performance. Protocol research to be supported with the planned experimental system includes discovery and self-organization, cross layer protocols for PHY adaptation, cooperation and competition mechanisms, spectrum etiquette procedures, and cognitive radio hardware/software performance optimization.

Cognitive Radio Features [1]

The idea of a cognitive radio extends the concepts of a hardware radio and a software defined radio (SDR) from a simple, single function device to a radio that senses and reacts to its operating environment. A Cognitive Radio incorporates multiple sources of information, determines its current operating settings, and collaborates with other cognitive radios in a wireless network. The promise of cognitive radios is improved use of spectrum resources, reduced engineering and planning time, and adaptation to current operating conditions. Some features of cognitive radios include:

Sensing the current radio frequency spectrum environment:

This includes measuring which frequencies are being used, when they are used, estimating the location of transmitters and receivers, and determining signal modulation. Results from sensing the environment would be used to determine radio settings.

Policy and configuration databases:

Policies specifying how the radio can be operated and physical limitations of radio operation can be included in the radio or accessed over the network. Policies might specify which frequencies can be used in which locations. Configuration databases would describe the

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operating characteristics of the physical radio. These databases would normally be used to constrain the operation of the radio to stay within regulatory or physical limits.

Self-configuration:

Radios may be assembled from several modules. For example, a radio frequency front-end, a digital signal processor, and a control processor. Each module should be self-describing and the radio should automatically configure itself for operation from the available modules. Some might call this “plug-and-play.”

Mission-oriented configuration:

Software defined radios can meet a wide set of operational requirements. Configuring a SDR to meet a given set of mission requirements is called mission oriented configuration. Typical mission requirements might include operation within buildings, substantial capacity, operation over long distances, and operation while moving at high speed. Mission-oriented configuration involves selecting a set of radio software modules from a library of modules and connecting them into an operational radio.

Adaptive algorithms:

During radio operation, the cognitive radio is sensing its environment, adhering to policy and configuration constraints, and negotiating with peers to best utilize the radio spectrum and meet user demands.

Distributed collaboration:

Cognitive radios will exchange current information on their local environment, user demand, and radio performance between themselves on regular bases. Radios will use their local information and peer information to determine their operating settings.

Security:

Radios will join and leave wireless networks.

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MATERIALS AND METHODS

Spectrum Sensing

A "Cognitive Radio" is a radio that is able to sense the spectral environment over a wide frequency band and exploit this information to opportunistically provide wireless links that best meet the user communications requirements [2].

While many other characteristics have also been discussed as possible additional capabilities, we will use this more restricted definition and consider

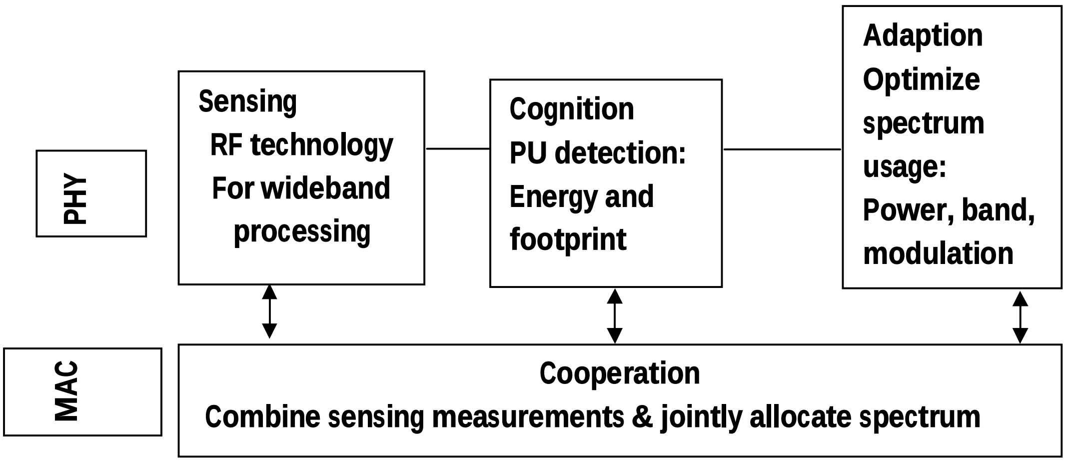

Figure1: Cross layer functionalities related to spectrum sensing

Physical (PHY) and medium access control (MAC) functions that are linked to spectrum sensing as illustrated in Figure 1. Since cognitive radios are considered lower priority or secondary users of spectrum allocated to a primary user, a fundamental requirement is to avoid interference to potential primary users in their vicinity [3], [4], [5]. On the other hand, primary user networks have no requirement to change their infrastructure for spectrum sharing with cognitive networks. Therefore, cognitive radios should be able to independently detect primary user presence through continuous spectrum sensing. Different classes of primary users would require different sensitivity and rate of sensing for the detection. For example, TV broadcast signals are much easier to detect than GPS signals, since the TV receivers' sensitivity is tens of dBs worse than GPS receiver. In general, cognitive radio sensitivity should outperform primary user receiver by a large margin in order to prevent what is essentially a *hidden terminal problem*. This is the key issue that makes spectrum sensing very challenging research problem. Meeting the sensitivity requirement of each primary receiver with a wideband radio would be difficult enough, but the problem becomes even more challenging if the sensitivity requirement

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is raised by additional 30-40 dB. This margin is required because cognitive radio does not have a direct measurement of a channel between primary user receiver and transmitter and must base its decision on its local channel measurement to a primary user transmitter[6]. This type of detection is referred to as *local spectrum sensing* and the worst case hidden terminal problem would occur when the cognitive radio is shadowed, in severe multipath fading, or inside buildings with high penetration loss while in a close neighborhood there is a primary user whose is at the marginal reception, due to its more favorable channel conditions. Even though the probability of this scenario is low, cognitive radio should not cause interference to such primary user. The implementation of the spectrum sensing function also requires a high degree of flexibility since the radio environment is highly variable, both because of different types of primary user systems, propagation losses, and interference. The main design challenge is to define RF and analog architecture with right trade-offs between linearity, sampling rate, accuracy and power, so that digital signal processing techniques can be utilized for spectrum sensing, cognition, and adaptation. This also motivates research of signal processing techniques that can relax challenging requirements for analog, specifically wideband amplification, mixing and A/D conversion of over a GHz or more of bandwidth, and enhance overall radio sensitivity [7], [10], and [11].

Energy Detection

A. Theoretical Analysis

In some cases, an optimal detector based on matched filter is not an option since it would require the knowledge of the pilot data and perfect synchronization for coherent processing. Instead a suboptimal and simple energy detector is adopted, which can be applied to any signal type. Conventional energy detector consists of a low pass filter to reject out of band noise and adjacent signals, Nyquist sampling A/D converter, square law device and integrator (Figure 2 a). Without loss of generality, we can consider a complex baseband equivalent of the energy detector [9]. The detection is the test of the following two hypotheses:

H0: $Y[n] = W[n]$ signal absent

H1: $Y[n] = X[n] + W[n]$ signal present

$n = 1,\ldots,N$; where N is observation interval The noise samples $W[n]$ are assumed to be additive, white and Gaussian (AWGN) with zero mean and variance σw^2. In the absence of coherent detection, the signal samples $X[n]$ can also be modeled as Gaussian random process with

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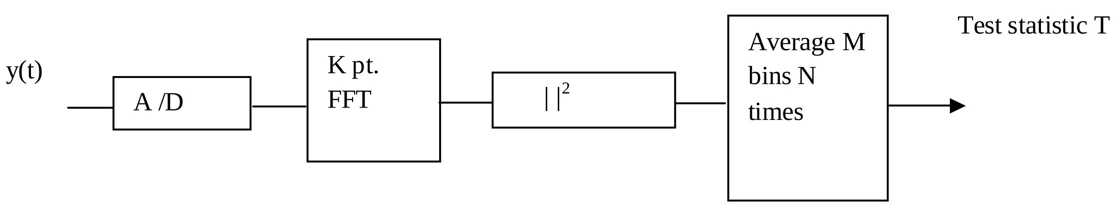
variance σx^2. Note that over-sampling would correlate noise samples and, in principle, the model could be always reduced. A decision statistic for energy detector is:

$$T = \sum_{N} (Y [n])^2$$

Note that for a given signal bandwidth *B*, a pre-filter matched to the bandwidth of the signal needs to be applied. This implementation is quite inflexible, particularly in the case of narrowband signals and sine waves. An alternative approach could be devised by using a periodogram to estimate the spectrum via squared magnitude of the FFT, as depicted in Figure 2 b). This architecture also provides the flexibility to process wider bandwidths and sense multiple signals simultaneously. As a consequence, an arbitrary bandwidth of the modulated signal could be processed by selecting corresponding frequency bins in the periodogram. In this architecture, we have two degrees of freedom to improve the signal detection. The frequency resolution of the FFT increases with the number of points *K* (equivalent to changing the analog pre-filter), which effectively increases the sensing time.



RESULT AND DISCUSSION

The complete system along with various parameters is modeled using MatLab code to detect the probability of false alarm versus the probability of detection that is depicted in figure 3. In addition, increasing the number of averages *N* also improves the estimate of the signal energy. In practice, it is common to choose a fixed FFT size to meet the desired resolution with a moderate complexity and low latency. Then, the number of spectral averages becomes the parameter used to meet the detector performance goal. We consider this approach in our experiments. If the number of samples used in sensing is not limited, an energy detector can meet any desired *Pd* and *Pfa* simultaneously[12],[13]. The minimum number of samples is a function of the signal to noise ratio $SNR= \sigma x^2/ \sigma w^2$:

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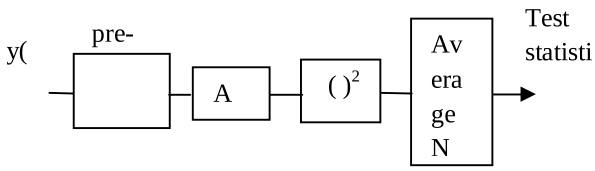
$N = 2[(Q^{-1}(P_{fa}) - Q^{-1}(P_d))SNR^{-1} - Q^{-1}(P_d)]^2$

In the low *SNR << 1* regime, number of samples required



(a)

Figure.2: a) Implementation with analog pre-filter and square-law device b) implementation using periodogram: FFT magnitude squared and averaging

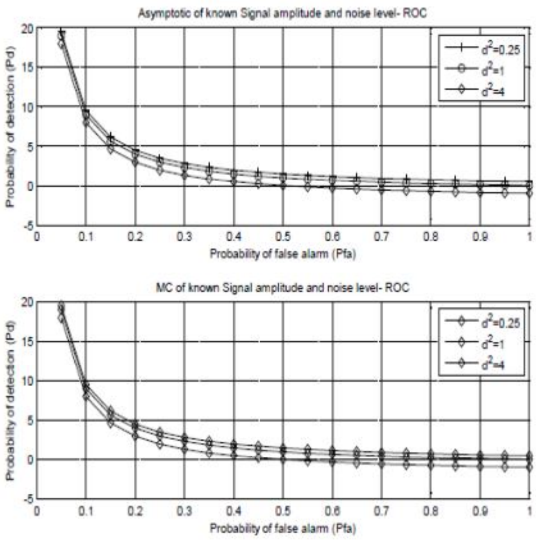


Figure.3: Probability of Detection Vs Probability of False Alarm

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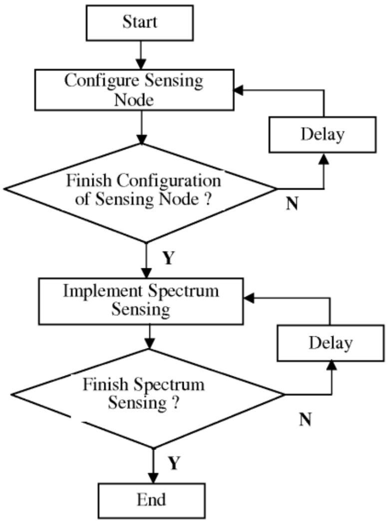

Figure.4:Implementation steps for Spectrum Sensing

IV. CONCLUSION

In the paper, we explore the new field of cognitive radios with a special emphasis on one unique aspect of these radios - spectrum sensing. We motivate the strong need for sophisticated sensing techniques and established sensing to be a cross-layer function. We identify two key issues related to the cognitive radio frontend - dynamic range reduction and wideband frequency agility. Firstly, the energy detection is applied to detect possible sub-bands, while in the second step GLRT detection is used to decide either primary signal is present or not. The detection performance is improved by using GLRT over Energy detection.

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