QUICKEST DETECTION SPECTRUM SENSING BY USING CUMULATIVE SUM

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Abstract : Quickest change detection (QCD) is a fundamental problem in many applications. Given a sequence of measurements that exhibits two different distributions around a certain flipping point, the goal is to detect the change in distribution around the flipping point as quickly as possible. The QCD problem appears in many practical applications, e.g., quality control, power system line outage detection, spectrum reuse, and resource allocation and scheduling. In this project, we focus on spectrum sensing as our application since it is a critical process for proper functionality of cognitive radio networks. Relying on the cumulative sum (CUSUM), we derive the probability of detection and the probability of false alarm of CUSUM based spectrum sensing. We show the correctness of our derivations using numerical simulations

IndexTerms - CUSUM detection, cognitive radio, quickest detection, spectrum sensing

I.INTRODUCTION

During the last decades, we have witnessed a great progress and an increasing need for wireless communications systems due to costumers demand of more flexible, wireless, smaller, more intelligent and practical devices explaining markets invaded by smartphones, personal digital assistant (PDAs), tablets and netbooks. All this need for flexibility and more ”mobile” devices lead to more and more needs to afford the spectral resources that shall be able to satisfy customers need for mobility. But, as wide as spectrum seems to be, all those needs and demands made it a scarce resource and highly misused. Trying to face this shortage of radio resources, telecommunication regulators and standardization organisms recommended sharing this valuable resource between the different actors in the wireless environment. The federal communications commission (FCC), for instance, defined a new policy of priorities in the wireless systems, giving some privileges to some users, called primary users (PU) and less to others, called secondary users (SU), who will use the spectrum in an opportunistic way with minimum interference to PU systems. Cognitive radio (CR) as introduced by Mitola [1], is one of those possible devices that could be deployed as SU equipment and systems in Wireless networks. As originally defined, a CR is a self aware and ”intelligent” device that can adapt itself to the Wireless environment changes. Such a device is able to detect the changes in Wireless network to which it is connected and adapt its radio parameters to the new opportunities that are detected. This constant track of the environment change is called the ”spectrum sensing” function of a cognitive radio device. Thus, spectrum sensing in CR aims in finding the holes in the PU transmission which are the best opportunities to be used by the SU. Many statistical approaches already exist. The easiest to implement and the reference detector in terms of complexity is still the energy detector (ED). Nevertheless, the ED is highly sensitive to noise and does not perform well in low signal to noise ratio (SNR). Other advanced techniques based on signals modulations and exploiting some of the transmitted signals inner properties were also developed. For instance, the detector that exploits the built-in cyclic properties on a given signal is the cyclostationary features detector (CFD). The CFD do have a great robustness to noise compared to ED but its high complexity is still a consequent draw back. Some other techniques, exploiting a wavelet approach to efficient spectrum sensing of wideband channels were also developed. Cognitive radios (CR) systems are a proposed solution to the spectrum scarcity problem found in radio frequency (RF) environment that aims to improve the overall spectrum utilization. Several studies showed (CHEN; OH, 2014) that licensed spectrum bands are often not occupied by the licensed users, thus creating the opportunity for other devices to access the unoccupied spectrum in an opportunistic way. These opportunistic devices, denoted as secondary users (SU) in the context of cognitive radios, need to be able to sense the spectrum to assess the presence or absence of licensed users, denoted as primary users (PU), either individually or cooperatively. The idea of cognitive radios was first introduced by Joseph Mitola III in 1999 but has been given a lot of attention recently due to the proposed heterogeneous nature of 5G networks .Spectrum sensing in cognitive radios still poses a challenge for high-performance.

And low-energy systems due to the fact that performance is often proportional to the spectrum sensing period which, in turn, is an energy consuming task that also degrades the spectral efficiency of the secondary users (since they need to spend time and energy on a task that does not effectively result in transmitted bits). Generally speaking, cooperative spectrum sensing schemes falls into two topologies: distributed (LI; YU; HUANG, 2009) or centralized (MA; ZHAO; LI, 2008). Centralized approaches require the SUs to transmit information regarding the local spectrum sensing (e.g., the SU binary decision on spectrum occupancy for hard combination schemes) to a fusion center, which in turn combines the received data according to a given method, decides on the spectrum occupancy and retransmits the decision back to the SUs. On the other hand, distributed approaches relies on information sharing among neighboring SUs and consensus methodologies, thus eliminating the need for a fusion center. through area under the curve (AuC) metrics and receiver operating characteristic(ROC) graphics, under additive white Gaussian noise (AWGN) and Rayleigh channel models. In addition, the computational performance of each model is evaluated through standard profiling tools in order to draw a complexity trade-off analysis. Furthermore, an analysis of training set size is conducted to reveal the effects on channel detection and training time. But, first and foremost, what do we mean by cognitive radio? Before responding to this question, it is in order that we address the meaning of the related term “cognition.” According to the Encyclopedia of Computer Science [7], we have a three-point computational view of cognition. 1) Mental states and processes intervene between input stimuli and output responses. 2) The mental states and processes are described by algorithms. 3) The mental states and processes lend themselves to scientific investigations. Moreover, we may infer from Pfeifer and Scheier [8] that the interdisciplinary study of cognition is concerned with exploring general principles of intelligence through a synthetic methodology termed learning by understanding. Putting these ideas together and bearing in mind that cognitive radio is aimed at improved utilization of the radio spectrum, we offer the following definition for cognitive radio. Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind: • highly reliable communications whenever and wherever needed; • efficient utilization of the radio spectrum. Six key words stand out in this definition: awareness,1 intelligence, learning, adaptivity, reliability, and efficiency. Implementation of this far-reaching combination of capabilities is indeed feasible today, thanks to the spectacular advances in digital signal processing, networking, machine learning, computer software, and computer hardware. In addition to the cognitive capabilities just mentioned, a cognitive radio is also endowed with reconfigurability.2 This latter capability is provided by a platform known as software-defined radio, upon which a cognitive radio is built. Software-defined radio (SDR) is a practical reality today, thanks to the convergence of two key technologies: digital radio, and computer software .

II. EXISTING SYSTEM:

Spectrum sensing can be achieved through different techniques including Matched filter detection and cyclostationary detection .On the other hand, signal detection based on probabilistic models, i.e general-likelihood-ratio test (GLRT) exploits the distributions of the received signal under the two hypotheses (occupied or vacant spectrum slot)

(i) Matched filter detection:

The first thing that would come to our mind when thinking of a technique for spectrum sensing is to detect active transmission channels between primary transmitters and receivers. Downlink channel detection is usually more efficient to detect, since the transmitter is most probably a base station hence, downlink signals are stronger and easier to detect. While uplink signals from primary users are usually weak due to the limited battery power capability.

(ii) Cyclostationary feature detection:

In cyclostationary feature detection ,modulated signals are in general coupled with sine wave carriers, pulse trains, repeating spreading, hopping sequences, or cyclic prefixes, which result in built-in periodicity. These modulated signals are characterized as cyclostationary since their mean and autocorrelation exhibit periodicity. These features are detected by analyzing a spectral correlation function .It differentiates the noise energy from modulated signal energy, since noise is wide sense stationary signal that does not exhibit periodicity signal and had no spectral correlation, while modulated signals are cyclostationary with spectral correlation due to the embedded redundancy of signal periodicity.

(iii) General Likelihood Ratio Test:

Spectrum sensing based on GLRT has been presented in which different tests are obtained under different parameter assumptions, i.e., unknown noise variance and/or signal covariance matrix. In the sequel, the GLRT is reviewed in its general form, and it will be employed for the detection of OFDM signals . If any of the two hypotheses describing a binary hypothesis testing problem involves some unknown parameters, the hypothesis is called a composite hypothesis . For a composite hypothesis, one approach is to perform the maximum likelihood estimation (MLE) of the unknown parameters. The estimated parameters are then used in the likelihood ratio test as if they are correct values.

(iv) DISADVANTAGES:

1.One critical problem in detection theory is the quickest change detection (QCD) problem. The objective of QCD is to detect the change point in a series of collected samples or measurements as quickly as possible, i.e., finding the point at which the distribution of the received samples changes.
2. In Cyclostationary Feature Detection, Computationally complex and requires significantly long observation time.

III. PROPOSED METHOD:

A framework for sequential detection for cognitive radio networks is presented as follows:
In the sequential change-point detection problem, one observes samples sequentially. Initially, the samples are drawn from a certain distribution. At an unknown time, the distribution changes. Once this occurs, one needs to raise an alarm as quickly as possible, hence to minimize the delay (rigorous definitions will be given in the sequel) between the time when the change occurs and the time when the alarm is raised. The sequential change point detection problem is different from but has a close relationship with the classic sequential testing problem. In the classic sequential testing problem developed by Wald [5], the objective is to distinguish between two hypotheses from a sequence of statistically homogeneous random samples. All the samples are drawn from the same distribution, it is only the identity of this distribution that is in question.Change detection is a fundamental problem arising in many fields of engineering, in finance, in the natural and social sciences, and even in the humanities. This book is concerned with the problem of change detection within a specific context. In particular, the framework considered here is one in which changes are manifested in the statistical behavior of quantitative observations, so that the problem treated is that of statistical change detection.

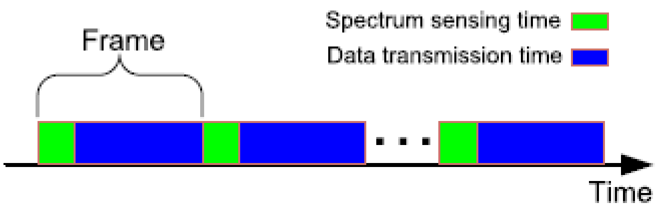

Figure.3.1: Periodic spectrum sensing.

The time is partitioned into frames of equal length. Each frame consists of a spectrum sensing phase and data transmission phase. In case the decision during the spectrum sensing phase is declared to be existence of the PU's signal, the SU remains silent during the data transmission phase since the frame belongs to the PU. Otherwise, the SU starts to exploit the data transmission phase to transmit and receive its own data.When spectrum sensing phase starts, the SU begins to collect samples, $y[\ell]$, where $\ell = 1, 2, \ldots, N$ with N denoting the maximum number of collected samples during the spectrum sensing phase. If the PU is not occupying this spectrum slot, $y[\ell] = w[\ell].w[\ell]$ where, $w[\ell]$ is a zero-mean white Gaussian noise with variance σ^2.

$$H_0^A : y[\ell] = w[\ell], \quad \ell = 1, \cdots, \tau - 1$$
$$H_1^A : y[\ell] = x[\ell] + w[\ell], \quad \ell = \tau, \cdots, N$$

(i) QCD BASED ON CUSUM:

The utilization of CUSUM for spectrum sensing under the assumption of full knowledge of distributions of the signal under the two hypotheses is a common practice in literature [7], [14]. This assumption provides a performance upper bound benchmark for the case when the variance of the signal under H1 is unknown. In this letter, we investigate in details the first case, i.e., when the spectrum status changes from vacant to occupied.

$$l(y[\ell]) = \ln \left\{ \frac{f_1(y[\ell])}{f_0(y[\ell])} \right\}, \\ = \frac{Py^2[\ell]}{2(P+\sigma^2)\sigma^2} + \frac{1}{2} \ln \left\{ \frac{\sigma^2}{P+\sigma^2} \right\}$$

where [$f_\nu(y[\ell]),\ \nu \in \{0, 1\}$, is the density function value at sample $y[\ell]$.The Kullback-Leibler divergence of f0 from f1exhibits a negative drift before the entrance of PU signal and positive drift otherwise [6] and the decision statistic for the CUSUM test can be applied recursively using [7]:

$$g_{\ell+1} = \max\{g_\ell + l(y[\ell+1]), 0\}, \\ g_0 = 0.$$

(ii) ADVANTAGES :

1.The QCD(Quickest Change Detection) problem is solved by using CUSUM Algorithm
2.The proposed QCD BASED ON CUSUM,requires less observation time and less in complexity .
3.No priori knowledge of the primary user signal such as the modulation type and order, the pulse shape, and the packet format is required .

(ii) Applications:

1.Spectrum-sensing ,

2.Resource allocation and scheduling .

3.Power-system line outage detection

4.Bio-informatics

5. Quality control.

IV. COMPONENTS REQUIREMENTS:

(i) HARDWARE COMPONENTS REQUIREMENTS:

Operating Systems:

1.Windows 10

2. Windows 7 Service Pack 1

3.Windows Server 2019

4.Windows Server 2016

Processors:

1.Minimum: Any Intel or AMD x86-64 processor

2.Recommended: Any Intel or AMD x86-64 processor with four logical cores and AVX2 instruction set support

Disk:

1.Minimum: 2.9 GB of HDD space for MATLAB only, 5-8 GB for a typical installation

2.Recommended: An SSD is recommended a full installation of all Math Works products may take up to 29 GB of disk space

RAM

1.Minimum: 4 GB

2.Recommended: 8

(ii) SOFTWARE COMPONENTS REQUIREMENTS:

MATLAB:

MATLAB is an intuitive framework whose important statistics aspect is an show off that does not require dimensioning. This allows you to tackle several specialized processing issues, particularly those with framework and vector info, in a small quantity of the time it'd take to compose a program in a scalar non intuitive dialect, as an instance, C or FORTRAN.The call MATLAB stays for grid studies facility. MATLAB changed into first of all composed to present easy access to framework programming created by way of the LINPACK and EISPACK ventures. Today, MATLAB motors fuse the LAPACK and BLAS libraries, inserting the cutting side in programming for network calculation.MATLAB has advanced over a time of years with contribution from several customers. In university situations, it's far the usual academic apparatus for early on and propelled guides in mathematics, designing, and science. In enterprise, MATLAB is the tool of choice for excessive-profitability studies, advancement, and exam.

V. COMMUNICATION:

Communications System Toolbox™ offers algorithms and gear for the layout, simulation, and analysis of communications systems. These capabilities are furnished as MATLAB ® features, MATLAB System gadgets™, and Simulink ® blocks. The machine toolbox includes algorithms for source coding, channel coding, interleaving, modulation, equalization, synchronization, and channel modeling. Tools are supplied for bit blunders charge evaluation, producing eye and constellation diagrams, and visualizing channel characteristics. The machine toolbox additionally provides adaptive algorithms that allow you to version dynamic communications structures that use OFDM, OFDMA, and MIMO techniques. Algorithms support fixed-point facts arithmetic and C or HDL code era.

(i) Implementing a Communications System:

Fixed-Point Modeling Many communications systems use hardware that requires a fixed-point representation of your design. Communications System Toolbox supports fixed-point modeling in all relevant blocks and System objects™ with tools that help you configure fixed-point attributes.

Fixed-point support in the system toolbox includes:

- Word sizes from 1 to 128 bits
- Arbitrary binary-point placement
- Overflow handling methods (wrap or saturation)
- Rounding methods: ceiling, convergent, floor, nearest, round, simplest, and zero

Fixed-Point Tool in Simulink Fixed Point™ facilitates the conversion of floating-point data types to fixed point. For configuration of fixed-point properties, the tool tracks overflows and maxima and minima.

(ii) Code Generation:

Once you've got advanced your set of rules or communications device, you can robotically generate C code from it for verification, rapid prototyping, and implementation. Most System gadgets, functions, and blocks in Communications System Toolbox can generate ANSI/ISO C code the use of MATLAB Coder™, Simulink Coder™, or Embedded Coder™. A subset of System gadgets and Simulink blocks also can generate HDL code. To leverage present highbrow belongings, you can choose optimizations for specific processor architectures and integrate legacy C code with the generated code.
You can also generate C code for both floating-point and fixed-point data types.
DSP Proto typing DSPs are used in communication system implementation for verification, rapid prototyping, or final hardware implementation. Using the processor-in-the-loop (PIL) simulation capability found in Embedded Coder, you can verify generated source code and compiled code by running your algorithm's implementation code on a target processor. FPGA Prototyping
FPGAs are used in communication systems for implementing high-speed signal processing algorithms. Using the FPGA-in-the-loop (FIL) capability found in HDL Verifier™, you can test RTL code in real hardware for any existing HDL code, either manually written or automatically generated HDL code.

VI. RESULT AND DISSCUSSION:

We provide simulation results for the detection of the entrance of the PU signal. We compare the numerical calculations for Pf and Pd with our derived analytical approximations presented in the above Equations. We plot total probability of detection at various samples after the entrance of the PU signal, i.e., Pd vs Pf for different signal to noise ratio (SNR) values.

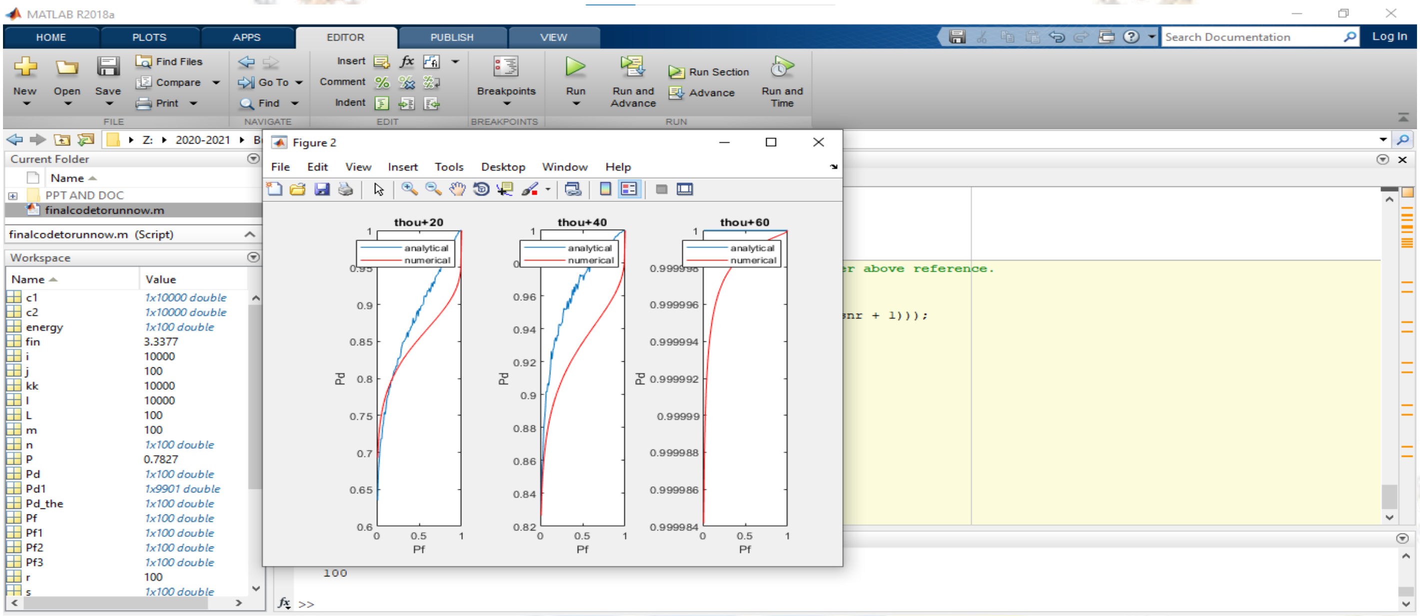

Figure. 6.1:ROC curves for numerical and analytical simulations for SNR = -10 dB.

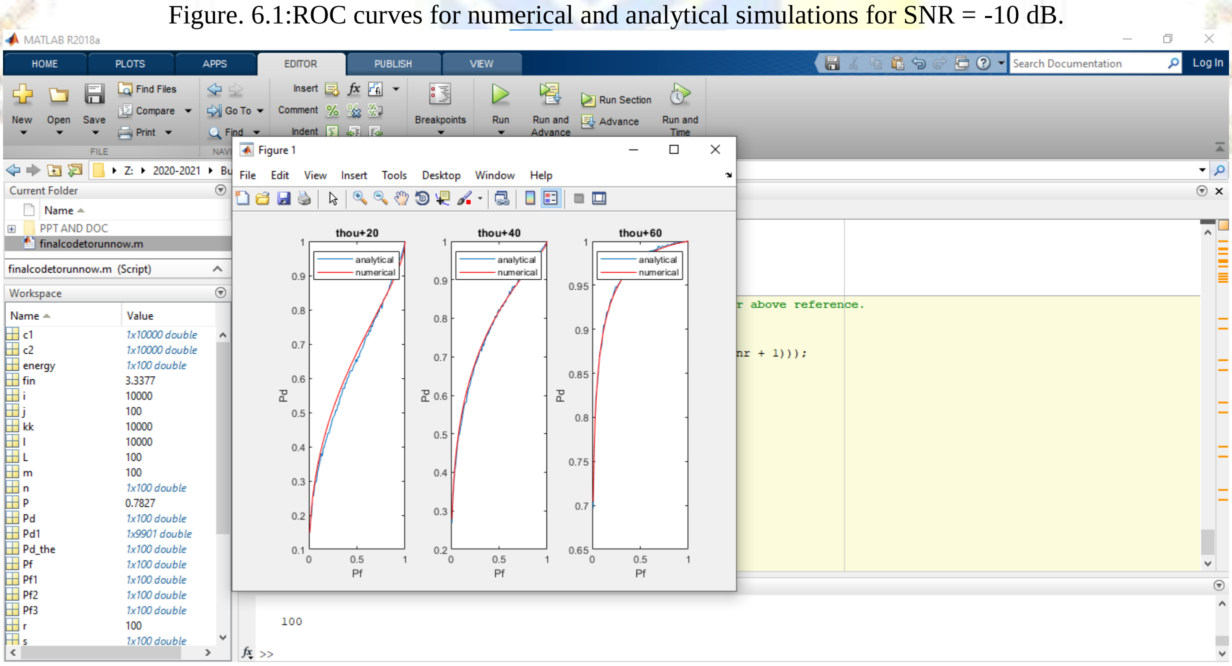

Figure. 6.2:ROC curves for numerical and analytical simulations for SNR = 3 dB.

VII. CONCLUSION:

We derived closed-form expressions for the probability of false alarm and probability of detection for QCD-CUSUM sequential test. Spectrum sensing is used as an application of CUSUM test with detecting the entrance of PU signal as the example. Through simulation comparison between analytical and numerical results, we showed that our derived expressions provide a very close approximation. The provided results can be used in all applications that require channel sensing and will simplify the optimization formulation procedures to achieve better performance for various applications.

VIII. REFERENCES:

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