



**AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING**

Electronics and communications engineering department

**Spectrum Sensing for Improved QoS of Cognitive Radio
Networks**

A Thesis submitted in partial fulfillment of the
requirements for the degree of Doctor of Science in
electronics and communications engineering

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STATEMENT

This Dissertation is submitted to Ain Shams University in partial fulfillment of the Degree of Doctor of Science in Electrical Engineering (Electronics and Communications Engineering).

The work include in this thesis was received by author at the Department of Electronics and Communications Engineering, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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Index

Chapter 1 Research Overview	2
1.1 Introduction	2
1.2 Research Objectives.....	5
1.3 Thesis Layout.....	7
Chapter 2 Cognitive Radio Networks.....	9
2.1 Introduction.....	9
2.1.1 Cognitive Cycle.....	10
2.1.2 Frequency Bands of Operation.....	11
2.1.3 Definition of Cognitive Radio.....	12
2.1.4 Functions of Cognitive Radio Framework.....	13
2.1.4.1 Transceiver Architecture.....	14
2.1.4.2 Functions of the Spectrum Management Process...	15
2.2 Paradigms of Cognitive Radio.....	16
2.2.1 Interweave Paradigm.....	16
2.2.2 Underlay Paradigm.....	16
2.2.3 Overlay Paradigm.....	17
Chapter 3 Spectrum Sensing	20
3.1 Introduction.....	20
3.2 Spectrum Sensing	20
3.2.1 Matched Filtering (Coherent Detector).....	21
3.2.2 Energy Detector.....	22
3.2.3 Feature Detection.....	23
3.2.3.1 Cyclostationarity-Based Sensing.....	23
3.2.3.2 Second-Order Moments Feature Detector.....	24
3.2.3.3 Covariance Matrix Detector.....	24
3.2.4 Design Challenges in CRNs.....	25
3.2.4.1 Hardware Requirements.....	25
3.2.4.2 Hidden Primary User Problem.....	25
3.2.4.3 Primary Users with Spread Spectrum.....	26
3.2.4.4 Sensing Duration and Frequency.....	26
3.2.4.5 Decision and Fusion Center.....	26
3.2.4.6 Security.....	26
3.3 Multiband Spectrum Sensing.....	27
3.3.1 Introduction.....	27
3.3.2 Serial Spectrum Sensing Techniques.....	28
3.3.2.1 Reconfigurable Bandpass Filter.....	28
3.3.2.2 Tunable Oscillator.....	29

3.3.2.3 Two-Stage Sensing.....	29
3.3.3 Parallel Spectrum Sensing	29
3.3.4 Wavelet Spectrum Sensing.....	30
3.3.5 Compressed Spectrum Sensing.....	31
3.3.6 Multi-Rate Sub-Nyquist Spectrum Sensing (SS).....	32
3.3.7 Angle-Based Spectrum Sensing.....	32
3.3.8 Blind Spectrum Sensing.....	33
3.4 Comparison.....	34
Chapter 4 Spectrum Sensing Performance Measures and Design Trade-Offs.....	36
4.1 Introduction	36
4.2 Receiver Operating Characteristics	36
4.2.1 Single Band.....	36
4.2.2 Cooperative Spectrum Sensing.....	38
4.2.3 Multiband Cognitive Radio.....	40
4.3 Throughput Performance Measures.....	41
4.4 Fundamental Limits and Trade-Offs in CRNs.....	44
4.4.1 Sensing Time Optimization.....	45
4.4.1.1 MAC Frame Structures.....	45
4.4.1.2 Dual Radio.....	48
4.4.1.3 Sequential Probability Ratio Tests.....	48
4.4.1.4 Number of Cooperating Users.....	48
4.4.2 Diversity and Sampling Trade-Offs.....	49
4.4.3 Power Control and Interference Limits Trade-Offs.....	50
4.4.3.1 Average and Peak Transmit Powers.....	50
4.4.3.2 Average and Peak Interferences.....	51
4.4.3.3 Beamforming.....	52
4.4.4 Resource Allocation Trade-Offs.....	52
4.4.4.1 Bandwidth Selection.....	52
4.4.4.2 Fairness.....	53
Chapter 5 Cooperative Wideband Spectrum Sensing Over Rician and Nakagami Fading Channels.....	55
5.1 Introduction.....	55
5.2 Cognitive Radio Networks.....	56
5.2.1 System Model.....	56
5.2.2 Preliminaries of Spectrum Sensing Setup.....	57
5.3 Multi-Rate Sub-Nyquist Spectrum Sensing (MS^3)....	59
5.4 MS^3 Over Rician and Nakagami-m Fading Channels	62
5.4.1 Rician fading channel.....	62

5.4.2 Nakagami-m fading channel.....	65
5.5 Simulation Results and Discussion.....	66
Chapter 6 Wide-Band Sensing and Optimization for Cognitive Radio Networks using multi-rate sub- Nyquist spectrum sensing (MS³)	71
6.1 Introduction.....	71
6.2 Generalized Energy Detection (GED).....	73
6.3 Multi-Rate Sub-Nyquist Technique (MS ³).....	75
6.4 Sensing Time Optimization.....	77
6.5 Simulation Results and Analysis.....	80
Chapter 7 Conclusions and Future Perspectives.....	85
References.....	86

List of table

Table 3.1:	Comparison between Spectrum Sensing Techniques	25
Table 3.2:	Comparison between Multiband Spectrum Sensing Algorithms	34

List of figure

Figure 1.1: Allocation of radio spectrum for different wireless communications	3
Figure 2.1: The CR cycle.	10
Figure 2.2: Overview of wireless technologies from short range to wide area.	12
Figure 2.3: Available technologies cognitive radio can adapt.	13
Figure 2.4: Block diagram of a typical cognitive radio (CR) transceiver.	14
Figure 2.5: Spectrum management framework.	16
Figure 2.6: In the interweave paradigm, the cognitive radio (CR) user cannot coexist with the primary user (PU).	17
Figure 2.7: In the underlay paradigm, the CR must transmit below the interference threshold	18
Figure 2.8: Figure 2.8: spectrum sharing paradigms. Primary transmitter, primary receiver, secondary transmitter, secondary receiver are denoted by PT, PR, ST, SR, respectively	18
Figure 3.1: Coherent detector.	21
Figure 3.2: Performance of the energy detector of different number of samples N and different SNR values.	23
Figure 3.3: First-order cyclostationarity detector.	24
Figure 3.4: Second-order cyclostationarity detector.	24
Figure 3.5: Illustration of multiband spectrum with M channels.	28
Figure 3.6: (a) A reconfigurable BPF; (b) a local oscillator; (c) a two-stage serial spectrum sensing scheme.	30
Figure 3.7: (a) Filter bank structure; (b) frequency-based parallel SB detectors.	31
Figure 3.8: Angle-based sensing.	33
Figure 4.1: ROC curves for different detectors in single-band framework (SNR = -10 dB).	38
Figure 4.2: ROC curves for different number of cooperating SUs (SNR = -10 dB).	39
Figure 4.3: Throughput performance with different number of channels and probabilities of false alarm and detection, $\rho_s^1 = 0.4\rho_s^0$, $\sigma^2 = 1$, $I = -20\text{dB}$, $p(H_0) = 1 - p(H_1) = 0.7$.	43
Figure 4.4: Impact of sensing time on throughput performance. (a) Throughput vs. SU transmitted power. (b) Probability of detection vs. transmitted power.	46
Figure 4.5: (a) A conventional MAC frame in CR; (b) the structure of a slotted frame; (c) a multiband slotted frame; (d) a multiband arbitrary-length slotted frame; (e) a novel frame where transmission and sensing occur at the same time; (f) an auction-based frame.	47
Figure 4.6: The relation between the sampling cost and the number of cooperating users.	50
Figure 4.7: Sampling cost-diversity trade-off.	51
Figure 5.1: System model for cooperative spectrum sensing.	57
Figure 5.2: Block diagram of multi-rate sub-Nyquist spectrum sensing system.	60
Figure 5.3: Values of Rice factor K varying from 0 to 1 compared with non-faded signal and Rayleigh faded signal.	67
Figure 5.4: Indicates performance of MS3 under Nakagami-m fading channel with different values of both m and SNR.	67
Figure 5.5: Receiver operating characteristic ROC curves at SNR=5dB.	68
Figure 5.6: Receiver operating characteristic (ROC) curves at SNR=10dB.	68
Figure 5.7: Receiver operating characteristic (ROC) curves at SNR=15dB.	69
Figure 6.1: The frame structure of a cognitive radio network.	72

- Figure 6.2: Block diagram of multi-rate sub-Nyquist spectrum sensing system. 75
- Figure 6.3: $f(T_0)$ of (24) for $\gamma_c = 20$ dB, $\gamma_k = -20$ dB and frame duration $T_f = 80$ 80
100, 500, 1000 ms . When $S_{sb} = 2$.
- Figure 6.4: $f(T_0)$ using equation (24) and setting $\gamma_c = 20$ dB, $\gamma_k = -20$ dB and frame 81
duration $T_f = 100, 500, 1000$ ms . When $S_{sb} = 10$.
- Figure 6.5: Comparison of the sensing time of the GED and GED combined with MS3 82
with $B_k = 6$ MHz, for $\gamma_c = 20$ dB, $\gamma_k = -20$ dB and frame duration $T_f =$
2000ms . When $S_{sb} = 10$.
- Figure 6.6: Comparison of the ROC for GED only and GED combined with MS3 with 83
SNR=-15dB

List of Abbreviations

3GPP	3rd Generation Partnership Project
ACF	Autocorrelation Function
ADC	Analog-to-Digital Converter
AWGN	Additive White Gaussian Noise
BPF	Bandpass Filters
BS	Blind Sensing
BS	Base Station
CDF	Complementary Distribution Function
CED	Conventional Energy Detector
CP	Cyclic Prefix
CR	Cognitive Radio
CRN	Cognitive Radio Network
CS	Compressive Sampling
CSI	Channel State Information
CSS	Cooperative Spectrum Sensing
CWT	Continuous Wavelet Transform
DCH	Detected Control Channels
DFT	Discrete Fourier Transform
DOA	Direction of Arrival
DSP	Digital Signal Processors
ED	Energy Detector
FC	Fusion Center
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Arrays
FSS	Fixed-Sample Size
GED	Generalized Energy Detector
i.i.d	Independent and Identically Distributed
IMT	International Mobile Telecommunications
ISM	Industrial, Scientific and Medical Bands
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radio Communications
LO	Local Oscillator
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
MAC	Medium Access Control
MB-CRN	Multiband Cognitive Radio Network
MB-SS	Multi Band Spectrum Sensing
MIMO	Multiple-Input Multiple-Output

MS ³	Wideband Multi-Rate Sub-Nyquist Spectrum Sensing Technique
MU-MIMO	Multi-User Multiple-Input Multiple-Output
OFDM	Orthogonal Frequency Division Multiple Access
PA	Power Amplifiers
PDF	Probability Density Function
PSD	Power Spectral Density
PU	Primary User
PUE	Primary User Emulation
QoS	Quality of Service
RF	Radio Frequency
ROC	Receiver Operating Characteristics
SB	Single Band
SB-CR	Single Band Cognitive Radio
SDR	Software Defined Radio
SNR	Signal-to-Noise Ratio
S/P	Serial-to-Parallel
SPRT	Sequential Probability Ratio Tests
SPTF	spectrum Policy task force
SS	Spectrum Sensing
SU	Secondary User
SU-MIMO	Single-User Multiple-Input Multiple-Output
UWB	Ultra Wide Band
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WRAN	Wireless Regional Area Network
ZMCSCG	Zero Mean Circularly Symmetric Complex Gaussian

Abstract

Cognitive radio network technology is an emerging wireless mobile technology that received much attention from researchers and research entities in the last few years. It is a very prominent candidate as a part of the fifth generation mobile technology.

Cognitive radio exploits the underutilization state of the already allocated frequency bands to different applications and services which will lead to a higher overall spectrum utilization efficiency.

In addition to this intelligent idea, cognitive radio offers many advantages including easy and soft establishment, it will cause no harm to the already working systems. It will be a solution for very difficult unmanageable situation like crisis relief, military actions at the international level; unknown battle fields also a new branch of satellite assisted communication system.

The cognition cycle consists of multitude of activities or functionalities, (each of them is a deep branch of research) like spectrum sensing, feature extraction, channel state estimation, decision making regarding the utilized and non-utilized frequency bands, awareness of the wireless transmission environment current state, for either primary or secondary users. A big entity which has a major function is the fusions centre, which collects sensing data from secondary devices and uses this data to decide which band is empty and broadcast this decision to all users. It also, coordinates the operation of the network transmission.

In this research cognitive radio network features are studied as a complete system, stress is made on two important functionalities. The first is the spectrum sensing, the second is the fusion centre control of the way of transmission of the secondary users. Our main objective is to enhance and improve the quality of service of these cognitive radio networks. To suggest the required solutions it was imperative to study the performance of cognitive radio networks under different operational situations and different types of channels.

Spectrum sensing is an important activity in the operation of cognitive radio network. It provides the data required for deciding whether certain band is busy or idle. There are many types spectrum sensing like energy, cyclostationary, compressive and cooperative spectrum sensing. The most recent type of spectrum sensing is the compressed type, specially the cooperative wide band multi rate sub-Nyquist spectrum sensing MS³.

For this type (MS³) the thesis presents its way of operation, its construction (block diagram), the effect of the state of the sensing channel and the type of

fading that it encounters. Stress is made on two types of fading namely; Rician fading and Nakagami-m fading.

Results for the performance of this system under these two types of fading are analyzed and results were found to be consistent with results of other researches published recently.

Also, the way of operation of the fusion centre and the share of time of the length of the frame allocated for sensing operation are studied with the main objective of improving the quality of service of the network. An optimization problem is designed with the objective of determining an optimum value of the sensing time (T_o) that will maximize the total throughput of the SUs. Consequently, it will provide maximum protection for the primary users.