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.

No part of this thesis was submitted for a degree or qualification at any other university or institution.

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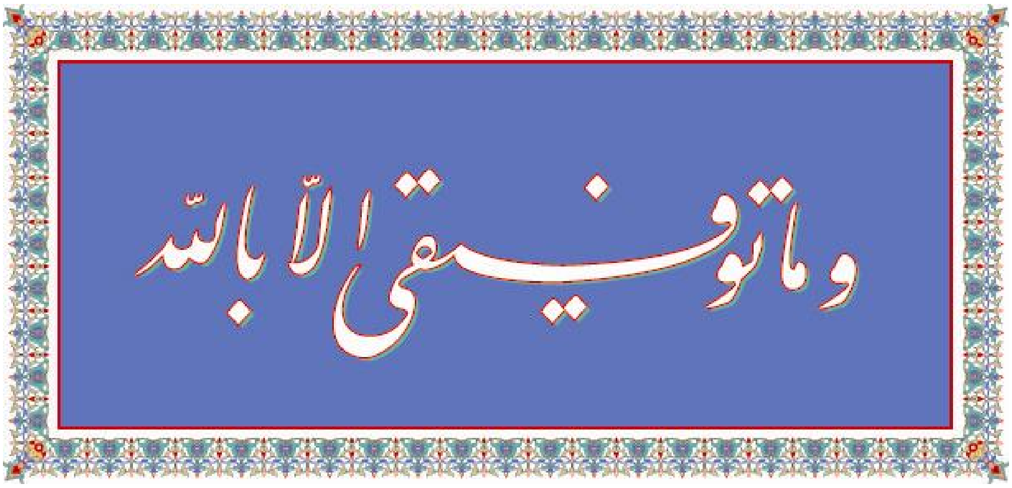

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List of Abbreviations

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 MS^3.

For this type (MS^3) 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 (*To*) that will maximize the total throughput of the SUs. Consequently, it will provide maximum protection for the primary users.