

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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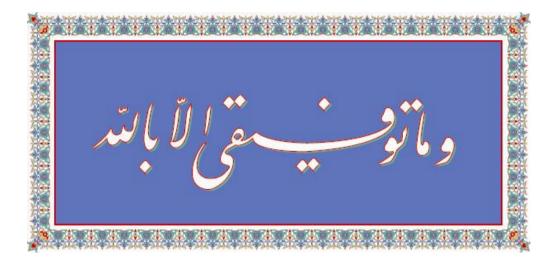


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List of Abbreviations

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

MS³ 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 (To) that will maximize the total throughput of the SUs. Consequently, it will provide maximum protection for the primary users.