UNIVERSITI TEKNOLOGI MALAYSIA

DECLARATION OF THESIS / ~~UNDERGRADUATE~~ PROJECT PAPER AND COPYRIGHT

Author's full name : **TAN JUI ANG**

Date of birth : **8TH JUNE 1976**

Title : **GENETIC ALGORITHM APPLICATION IN OPTIMIZING TRANSMISSION PARAMETERS ON ADAPTIVE MECHANISM OF COGNITIVE RADIO**

Academic Session: **2008 / 2009 - 2**

I declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the Organization where research was done)*
✓	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that Universiti Teknologi Malaysia reserves the right as follows:

1. The thesis is the property of Universiti Teknologi Malaysia.
2. The Library of Universiti Teknologi Malaysia has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

SIGNATURE	**SIGNATURE OF SUPERVISOR**
760608-01-6003	**DR. SHARIFAH KAMILAH BT SYED YUSOF**
(NEW IC NO. / PASSPORT NO.)	**NAME OF SUPERVISOR**
Date: 8TH May 2009	Date: 8 TH May 2009

NOTES: * If the thesis is CONFIDENTAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

GENETIC ALGORITHM APPLICATION IN OPTIMIZING TRANSMISSION PARAMETERS ON ADAPTIVE MECHANISM OF COGNITIVE RADIO

TAN JUI ANG

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical - Electronics and Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MAY 2009

ABSTRACT

Cognitive radio (CR) technology introduces a revolutionary in wireless communication network and it is capable to operate in a continuously varying radio frequency (RF) environment that depends on multiple parameters. CR has the capability to sense, learn the environment and adapt intelligently to the most appropriate way for providing the optimize service that suit to the user's requirements. Recent researches show that Genetic algorithms (GAs) that rooted in biological inspired are viable implementation technique for CR engine to optimize transmission parameters in a given wireless environment. In this work, GA is applied in adaptive mechanism of CR to perform optimization on transmitter parameters for physical (PHY) layer. The objective of optimization is to obtained optimum set of transmission parameters in order to meet quality of service (QoS) that defined by user in term of minimum transmit power, minimum bit error rate (BER) and maximum throughput. Fitness functions are developed to evaluate the performance of the GA in relation to transmission parameters that characterized. The characterization involves deriving chromosome structure that consists of transmission parameters gene. Finally, a MATLAB® code is developed for simulating the GA operations to achieve optimum set of transmission parameters for optimal radio communications. Simulation results show fitness score for minimum transmit power is 0.927174 with optimum transmit power 0.1768 mW and modulation 64 QAM. While the fitness score for minimum BER is 0.852842 with optimum transmit power 0.74 mW and modulation 8 QAM. Lastly, the fitness score for maximum throughput is 0.952603 with optimum transmit power 0.7144 mW and modulation 64 QAM.

ABSTRAK

Teknologi *Cognitive Radio (CR)* merupakan revolasi dalam wayerles radio komunikasi yang berupaya operasi dalam alam sekitar yang mengalami perubahan *RF* yang berterusan dengan melibatkan pelbagai *RF* parameter. *CR* mempunyai keupayaan untuk mengesan, mempelajari dari alam sekitar *RF* secara berterusan dan ia merupakan salah satu cara yang sesuai untuk mempertingkatkan *quality of service (QoS)* kepada kehendak pengguna. Kebelakangan ini penyelidik membuktikan *Genetic Algorithms (GAs)* yang berdasarkan biologi merupakan teknik yang sesuai dan diperkenalkan dalam enjin *CR* untuk mendapatkan parameter penghantaran yang optima dengan alam sekitar wayerles yang diberikan. Dalam kerja projek ini, *GA* digunakan untuk mencapai penghantar parameter yang optima pada *physical (PHY) layer* dengan tujuan untuk mencapai *QoS* yang ditentukan dan diperlukan oleh pengguna. Ini termasuk minimum penghantaran *power*, minimum *bit error rate (BER)* dan maximum *throughput. GA* digunakan dalam mekanismal *adaptive* pada *CR* untuk memperolehi penghantaran parameter yang optima. *Fitness function* diperkenalkan untuk menguji prestasi *GA*. Ini melibatkan kerja-kerja memperkenalkan struktur kromosom ynag mengandungi gen-gen dalam penghantaran parameter. Selain itu, kod-kod dalam MATLAB® diperkenalkan untuk menguji oprerasi dan prestasi *GA* dalam prosess mencapai penghantaran parameter yang optima untuk radio komunikasi. Keputusan simulasi menunjukkan *fitness score* untuk minimum penghantar kuasa adalah 0.927174 dengan optima penghantar kuasa 0.1768 mW dan modulation 64 QAM. Manakala *fitness score* untuk mimimum *BER* adalah 0.852842 mW dengan optima penghantar kuasa 0.74 mW dan modulation 64 QAM. Akhir sekali, *fitness score* untuk maximum throughput adalah 0.952603 dengan optima penghantar kuasa 0.7144 mW dan modulation 64 QAM.

.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AI	-	Artificial Intelligent
AWGN	-	Additive White Gaussian Noise
CE	-	Cognitive Engine
CR	-	Cognitive radio
CSM	-	Cognitive System Monitor
DARPA	-	Defense Advanced Research Projects Agency
GAs	-	Genetic Algorithms
GCC	-	Group Control Channels
ISM	-	Industrial, Scientific, and Medical
MAC	-	Medium Access Control
PHY	-	Physical
QAM	-	Quadratic Amplitude Modulation
QoS	-	Quality of Service
RF	-	Radio Frequency
SDR	-	Software Defined Radio
SINR	-	Signal to Interference Plus Noise Ratio
SNR	-	Signal to Noise Ratio
SSCR	-	Spectrum Sensing Cognitive Radio
UCC	-	Universal Control Channel
U-NII	-	Unlicensed National Information Infrastructure
UWB	-	Ultra Wideband Transmission
VT	-	Virginia Tech
WCGA	-	Wireless Channel Genetic Algorithm
WI-MAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless Local Network
WSGA	-	Wireless System Genetic Algorithm
XG	-	NeXt Generation

CHAPTER 1

INTRODUCTION

1.1 Introduction

The advances of wireless technology resulted demand of wireless connectivity continuously increase in the industrial, scientific, and medical (ISM) band. The demand keep increasing especially after the success of wireless local network (WLAN) like 802.11 and moving forward Worldwide Interoperability for Microwave Access (WI-MAX) like 802.16. Meanwhile, this has increased the interference problem and showing symptoms of spectrum scarcity.

Indirectly, efficiency of wireless communication system has degraded in term of quality of service (QoS). From the technical paper of David Maldonado *et al.* (2005), the current adaptive technique such as channel identification, dynamic frequency selection and adaptive modulation are implemented to obtain higher throughput. However, those techniques do not reach their full potential due to govern by a standard.

Cognitive radio (CR) technology introduces a revolutionary in wireless communication, as it is a promising technique for overcoming the apparent spectrum scarcity problem and improving the communication efficiency (Timothy R. Newman *et al.,* 2007). CR has the capability to sense, learn the environment and adapt intelligently to the most appropriate way for providing the optimize service that suit to the user's requirements. It is an extension of software defined radio (SDR) that provides an intelligent control over SDR. CR allows autonomous adaptation that can improve the radio performance, enhance spectrum usage, and further advance wireless ubiquity (T. W. Rondeau *et al.,* 2005).

In the adaptive mechanism of CR, it is required an optimization approach that continuously to evaluate and find out the suitable transmission parameters that closure or meet the QoS that defined by user for adapting to radio. GA is one of the optimization approach besides transitional approach such as rule based systems, expert systems, fuzzy logic, and neural networks for optimizing the transmission parameters.

The transmission parameters that focus in this work is at PHY layer which involve power transmit and type of modulation. While assuming AWGN channel is used with gray coded assignment. This chapter will explain the characterization of transmission parameters to GA following with developing fitness functions, developing the "concept" flowchart following with converting to "GA" flowchart.

Genetic algorithms (GAs) are optimization method that rooted in biological functions and viable implement for optimization problem that involving large search spaces. Recent researches show that GAs are viable implementation technique for CR engine to optimize transmission parameters in a given wireless environment that involve high number of parameters and many possible values for each parameter (Timothy R. Newman *et al.,* 2007).

1.2 Problem Statement

The apparent spectrum scarcity and efficiency degradation of wireless communication with the increasing of wireless connectivity and unlicensed spectrum have pushed the industrial and regulatory agencies to develop a more effective technique on spectrum utilization. This includes providing more system capacity with enable more users or higher data throughput.

The thesis of Danijela Branislav Cabric and Robert W. Brodersen (2007) stated the National Telecommunications and Information Administration's (NTIA) showed the overlapping frequency band for the overall static frequency allocated as shows in Figure 1.1. This reinforced the spectrum scarcity apparently at frequencies for wireless communications.

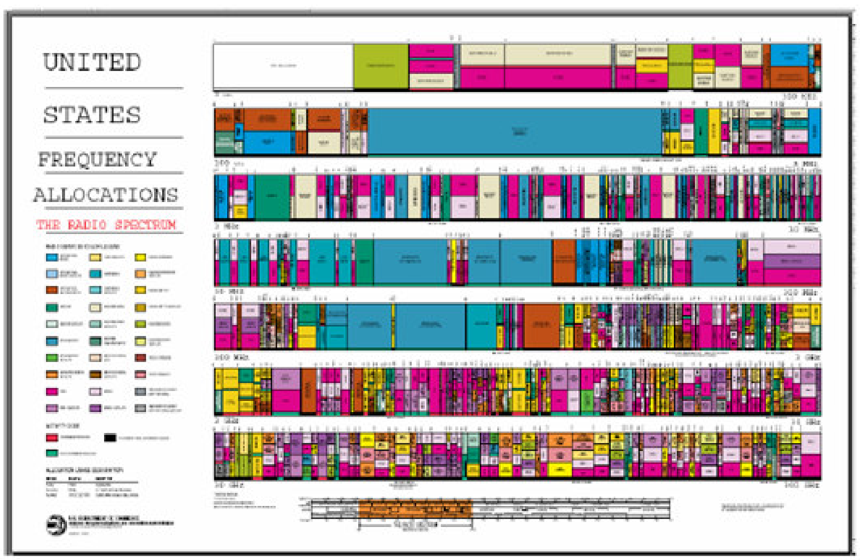
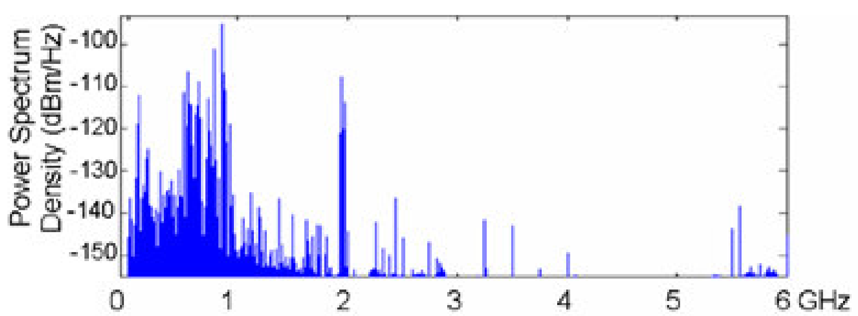


Figure 1.1 The NTIA's Frequency allocation chart.
(Adapted from Danijela Branislav Cabric and Robert W. Brodersen, 2007)

The static frequency allocation for wireless systems are regulated through fixed spectrum assignments, operating frequencies and bandwidths by limiting the transmit power and the operating range. To overcome the constraints of limiting transmit power and operating range, the current adaptive techniques such as channel identification, dynamic frequency selection, adaptive modulation, multiple antennas and other techniques are applied to achieve spectrum efficiency. Shannon Chanel Capacity is one of the techniques but it cannot provide the desired system capacity increase (Danijela Branislav Cabric and Robert W. Brodersen, 2007).

The static frequency allocation reflected spectrum scarcity apparently for available bandwidth in wireless communication. In fact, most of the assigned frequency bands are not effectively used. The survey (J. Yang, 2004) showed the measurements taken in downtown Berkeley indicated that the typical utilization is roughly 30% for frequency below 3 GHz, and 0.5% in the 3 to 6 GHz frequency band. Moreover, spectrum occupancy measurements reported in 2005 by Shared Spectrum Company (SSC) showed that the average spectrum occupancy for the radio bands between 30 MHz and 3,000 MHz was 5.2% as observed over multiple typical geographical locations (Bin Le *et al.*, 2007).



Freq (GHz)	0~1	1~2	2~3	3~4	4~5	5~6
Utilization(%)	54.4	35.1	7.6	0.25	0.128	4.6

Figure 1.2 Measurement of spectrum utilization (0-6) in downtown Berkeley. (Adapted from J. Yang, 2004)

1.3 Objective of Project

The objective of this project is applied biological rooted GA to perform optimization on transmitter parameters in adaptive mechanism of CR in order to achieve optimum quality of service (QoS) that defined by user. In general, CR has three basic mechanisms which are sensing, learning and adaptation mechanisms. Optimization of transmission parameters for adapting to radio is part of the adaptive mechanism in CR. In term of QoS, it relates to the user's requirements and for this work it focuses on minimum power transmit, minimum bit error rate (BER) and maximum throughput. Fitness functions are developed to evaluate the characterized parameters with considering the trade-off among each single objective of fitness function. A MATLAB® code is developed for simulating the GA operations to achieve optimum solution. A further explanation on CR, GA, work methodology, flow of project and simulation results will be elaborated more details in the following chapters.

1.4 Scope of Work

Project will begin with understand the current issue of spectrum utilization and improve the utilization by studying and applying the technology of CR. It will provide the history of CR that will go through CR concept developed by J. Mitola (1999), biologically inspired GA Vs Artificial Intelligent (AI) optimization approaches and overview of GA. The adaptive mechanism of CR will be focused in the work that involving develops MATLAB® code for simulating the GA operation that evolve the defined radio transmission parameters for optimum solution for adapting to radio.

The transmission parameters being considered in this work are power transmit and type of modulation, which are involved in the PHY layer. The power transmit are ranged from 0.1 mW to 2.4808 mW. The designed range of power transmit are based on maximum allowable power at U-NII band which at 2.5 mW. Assumption additive white Gaussian noise (AWGN) channel model is used with noise level at 0.1 mW. Meanwhile, four constellation of quadratic amplitude modulation (QAM) which are 8, 16, 32, are 64 level are applied with assumption maximum allowable BER at 0.5. This project is based on simulation work with developing MATLAB® code for simulating the optimum solution on evolve transmission parameters.

1.5 Thesis Outline

This thesis is organized into six chapters with the application of biological rooted GA to perform optimization on transmitter parameters in adaptive mechanism of CR to achieve optimum quality of service (QoS) defined by user.

Chapter 2 provides the literature reviews, which include evolution of cognitive radio, architecture and cognitive cycle of cognitive radio. Besides, cognitive radio technology and application are being reviewed and discussed.

Chapter 3 provides an overview of genetic algorithm, why genetic algorithm is chosen in comparison to other optimization method and application of genetic in wireless communication.

Chapter 4 discusses the methodology used in this project, which includes characterization of transmission parameters, defining fitness functions and simulation flow chart.

Chapter 5 presents and analyzes the results from the simulation work on the MATLAB® code that developed for characterizing and optimizing the transmission parameters.

Chapter 6 summarizes the project and provides recommendations for future work.

REFERENCES

3G AMERICAS (2004). *Technical Analysis and Position Paper on the Regulatory Issues between Licensed and Unlicensed Spectrum.* 3G AMERICAS.

Bin Le, Francisco A. G. Rodriguez, Qinqin Chen, Bin Philip Li, Feng Ge, Mustafa ElNainay, Thomas W. Rondeau, and Charles W. Bostian (2007). A Public Safety Cognitive Radio Node. *SDR Forum Technical Conference 2007.*

Christian James Rieser (2004). *Biologically Inspired Cognitive Radio Engine Model Utilizing Distributed Genetic Algorithms for Secure and Robust Wireless Communications and Networking.* Ph.D. Thesis. Virginia Polytechnic Institute and State University.

C. M. Fonseca and P. J. Fleming (1993). *Genetic Algorithms for Multiobjective Optimization: Formulation, Discussion, and Generalization.* Proc. Int. Conf. Genetic Algorithms. 416 – 423.

Danijela Branislav Cabric and Robert W. Brodersen (2007). *Cognitive Radios: System Design Perspective*. Ph.D. Thesis. University of California, Berkeley.

David Maldonado, Bin Le, Akilah Hugine, Thomas W. Rondeau, Charles W. Bostian (2005). Cognitive Radio Applications to Dynamic Spectrum Allocation. *First IEEE International Symposium.* 597 – 600.

D.E. Goldberg (1989). *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison-Wesley Pub Co.

Fed. Commun. Comm (2003). *Et docket-322*. Fed. Commun. Comm.

Feng Ge, Qinqin Chen, Ying Wang, Charles W. Bostian, Thomas W. Rondeau and Bin Le (2008). Cognitive Radio: From Spectrum Sharing to Adaptive. *Aerospace Conference, 2008 IEEE*. 1-8 March. 1 – 10.

J. G. Proakis (2000). *Digital Communications*. (4th ed.). McGraw-Hill.

J. Mitola and G. Q. Maguire (1999). Cognitive radio: Making software radios more personal. *IEEE Pers. Commun*, vol. 6. 13–18.

J. Mitola (2000). *Software Radio Architecture: Object Oriented Approaches to Wireless Systems Engineering*. John Wiley and Sons.

J. Yang (2004). Spatial channel characterization for cognitive radios. Master Thesis. University of California, Berkeley.

K. N. Steadman, A. D. Rose, and T. T. Nguyen (2007). Dynamic Spectrum Sharing Detectors. *New Frontiers in Dynamic Spectrum Access Networks (DySPAN)*. Dublin, Ireland.

Mubbashar and Sohaib (2008). *Decision Making Techniques For Cognitive Radio.* Master Thesis. Blekinge Institute of Technology.

Timothy R. Newman, Rakesh Rajbanshi, Alexander M. Wyglinski, Joseph B. Evans, and Gary J. Minden (2007). Population Adaptation for Genetic Algorithm-based Cognitive Radios. *CrownCom 2nd International Conference.* 1-3 August. 279 - 284

T. W. Rondeau, C. W. Bostian, D. Maldonado, A. Ferguson, S. Ball, S. F. Midkiff, B. Le (2005). Cognitive Radios in Public Safety and Spectrum Management. *33rd Research Conference on Communication, Information and Internet Policy.*