

**UNIVERSITI TEKNOLOGI MARA**

**MULTIPLE ERROR CORRECTION  
(MEC) FOR LIFETIME  
OPTIMISATION IN WIRELESS  
SENSOR NETWORK**

**SAMIRAH NASUHA BINTI MOHD RAZALI**

Thesis submitted in fulfillment  
of the requirements for the degree of  
**Doctor of Philosophy**  
**(Computer Science)**

**Faculty of Computer and Mathematical Sciences**

**October 2019**

## ABSTRACT

Previous research had highlighted the methods to control energy consumption without taking other aspects into considerations such as error rates and latency that might significantly impact the network. The implementation of error correction schemes in Wireless Sensor Network (WSN) can help reduce the error rates and limit the number of flooded retransmissions in the network, which indirectly minimize energy consumption. However, the use of too high or too low error correcting capabilities and improper selection of error correcting codes can further degrade the lifetime of sensors and can promote an increase in latency during transmission between nodes. Thus, the problems of higher error rates in the WSN and the rise of high energy usage, as well as latency from the computation and decoding of error correction schemes, become the motivation of this study to design a new approach to optimise the lifetime of the WSN without compromising latency in the transmission and maintaining the error rates. This research aimed to propose an algorithm of multiple error correction that is adapted to the changes of SNR and congestion in the network to reduce higher usage of energy consumption when higher error correcting capabilities were not necessary. The algorithm corresponds to the classified SNR range that was estimated using Kalman Filter and the error correcting codes were carefully selected for every SNR classes to avoid excessive latency and unnecessary redundancy appended to the transmitted bits. From the result obtained, the energy consumption was seen to be significantly optimised alongside Bit Error Rates and latency in which the increment of 0.72 percent of remaining energy was observed with multi-coding MEC from single-coding BCH and increment of 0.68 percent of remaining energy observed with multi-coding MEC from single-coding RS.

## **ACKNOWLEDGEMENT**

In the name of Allah, the Most Gracious and the Most Merciful.

Alhamdulillah, all praise to Allah S.W.T the almighty for His protection, strength and blessing upon completing this thesis. First of all, I am heartily express my profound gratitude to my supervisor, Dr. Hj. Kamaruddin bin Mamat, and to my co-supervisor, Dr. Nor Shahniza Kamal Bashah for their guidance and supports from the beginning until the completion of this research.

Furthermore, I would like to sincerely thank all the lecturers and colloquium panels that had shown me and taught me a lot of valuable knowledge since my first semester. I would also like to acknowledge Research Management Institute (RMI), Universiti Teknologi MARA (UiTM) and for the Fundamental Research Grant Scheme (FRGS) #600-RMI/FRGS 5/3 (46/2015) and Malaysia Ministry Higher Education (MOHE) that financially support my PhD Degree through Mybrain15 scholarship.

Secondly, I would like to express my sincere thanks to my parent for their never-ending love, comfort encouragement, support and prayers. Lastly, I would like to thank all student bodies and my compassionate friends that help in contributing to the finest ideas for this dissertation and also for the completion of this research.

# TABLE OF CONTENTS

	<b>Page</b>
<b>CONFIRMATION BY PANEL OF EXAMINERS</b>	<b>ii</b>
<b>AUTHOR'S DECLARATION</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>iv</b>
<b>ACKNOWLEDGEMENT</b>	<b>v</b>
<b>TABLE OF CONTENTS</b>	<b>vi</b>
<b>LIST OF TABLES</b>	<b>xii</b>
<b>LIST OF FIGURES</b>	<b>xv</b>
<b>LIST OF SYMBOLS</b>	<b>xxi</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xxii</b>
<b>CHAPTER ONE: INTRODUCTION</b>	<b>1</b>
1.1 Research Background	1
1.2 Problem Statement	7
1.3 Research Questions	8
1.4 Objectives	8
1.5 Scopes	9
1.6 Significance of the Study	10
1.7 Organisation of Thesis	12
<b>CHAPTER TWO: LITERATURE REVIEW</b>	<b>14</b>
2.1 Introduction	14
2.2 Wireless Sensor Network (WSN)	15
2.2.1 Coded Division Multiple Access (CDMA)	17
2.2.2 Challenges of WSN	19
2.3 Error Detection and Correction Schemes	19
2.3.1 Cyclic Redundancy Check (CRC)	20
2.3.2 Automatic Repeat Request (ARQ)	21
2.3.3 Forward Error Correction (FEC)	22

2.3.4	Error Correcting Codes (ECC)	23
2.3.5	Block Codes	23
2.3.6	Convolutional Codes	25
2.4	Hybrid Automatic Repeat Request (HARQ)	26
2.5	Channel Estimation in the Tracking of Channel Conditions	28
2.5.1	Kalman Filter based Channel Estimation	30
2.6	Signal-to-Noise Ratio (SNR)	32
2.7	Bit Error Rate (BER)	33
2.8	Simulation Tools	34
2.8.1	MATLAB	34
2.8.2	The Purposes of Simulation Over Real-Time Test Beds	35
2.9	Analysis of the Related Works on the Error Correction Schemes	36
2.9.1	Analysis of the Related Works on Kalman Filter for Channel Estimation	40
2.9.2	Analysis of the Related Works on Power Control	41
2.9.3	Summarisation of related works.	43
 <b>CHAPTER THREE: RESEARCH METHODOLOGY</b>		<b>57</b>
3.1	Introduction	57
3.2	Problem Identification Phase	60
3.2.1	Simulation-based Preliminary Testing	62
3.2.2	Validation on the Previous Environment	62
3.2.3	Statement of Problem	66
3.3	Objectives of Solution	66
3.4	Design and Development Phase	68
3.5	Demonstration Phase	71
3.6	Evaluation Phase	71
3.7	Communication Phase	73
 <b>CHAPTER FOUR: THE DEVELOPMENT OF MULTIPLE ERROR CORRECTION (MEC)</b>		<b>75</b>
4.1	Introduction	75
4.2	The Overview of Preliminary Testing	77