

Vikram Kulkarni

Coexisting problems for wireless sensor networks working in 2.4 GHz frequency band

YOUR KNOWLEDGE HAS VALUE



- We will publish your bachelor's and master's thesis, essays and papers
- Your own eBook and book - sold worldwide in all relevant shops
- Earn money with each sale

Upload your text at www.GRIN.com
and publish for free



Bibliographic information published by the German National Library:

The German National Library lists this publication in the National Bibliography; detailed bibliographic data are available on the Internet at <http://dnb.dnb.de> .

This book is copyright material and must not be copied, reproduced, transferred, distributed, leased, licensed or publicly performed or used in any way except as specifically permitted in writing by the publishers, as allowed under the terms and conditions under which it was purchased or as strictly permitted by applicable copyright law. Any unauthorized distribution or use of this text may be a direct infringement of the author s and publisher s rights and those responsible may be liable in law accordingly.

Imprint:

Copyright © 2019 GRIN Verlag
ISBN: 9783346075338

This book at GRIN:

<https://www.grin.com/document/509404>

Vikram Kulkarni

**Coexisting problems for wireless sensor networks
working in 2.4 GHz frequency band**

GRIN - Your knowledge has value

Since its foundation in 1998, GRIN has specialized in publishing academic texts by students, college teachers and other academics as e-book and printed book. The website www.grin.com is an ideal platform for presenting term papers, final papers, scientific essays, dissertations and specialist books.

Visit us on the internet:

<http://www.grin.com/>

<http://www.facebook.com/grincom>

http://www.twitter.com/grin_com

A Book on

**AVOIDING INTERFERENCE FOR WIRELESS
SENSOR NETWORKS WORKING IN 2.4GHz
FREQUENCY BAND FOR SMART GRID
APPLICATIONS**

by

Dr. VIKRAM. K

Assistant Professor

Department of Information Technology

Mukesh Patel School of Technology Management Engineering

NMIMS University

Mumbai - India

ABSTRACT

With the introduction of Information and Data-Communication Technology (ICT) to the present electrical power systems, the traditional electrical-grid system is becoming more intelligent and adaptive. The ICT successfully establishes bi-directional communication between Utility companies and the consumer for improving the generation and utilization of power. Wireless Sensor Network (WSN) is efficiently utilized by wide-ranging Smart Grid (SG) applications. Despite many advantages, WSN faces a challenge of avoiding interference experiencing from other coexisting wireless technologies working in the 2.4GHz unlicensed frequency band. Providing support for WSN in terms of avoiding interference is a very challenging issue due to the dynamic wireless communication environment and extremely limited resources. In the present thesis, the problem of interference experienced by WSN in 2.4GHz has been investigated. The challenges, limitations and requirements for avoiding the interference for WSN working in the vicinity of other technologies like WiFi and Bluetooth have been identified. As a result of the literature survey carried out, it was identified that proper channel selection and channel prioritization for WSNs working in the coexisting environment had not been adequately developed till then. Hence, there was a requirement for addressing these issues. The contribution of this thesis consists of five novel schemes for improving the performance of WSNs working under the influence of WiFi.

Firstly, a Cross Layer Multi Channel Medium Access Control (CMCMAC) Algorithm is proposed. This algorithm estimates the initial channel parameters like Received Signal Strength Indicator (RSSI) and Channel Occupancy Rate (COR). Then, these parameters are applied to the Hidden Markov Model (HMM). Then, based on the estimation, the channel with less interference is identified and is selected for data communication. The CMCMAC performance was compared to the existing protocol, FDRX. CMCMAC outperforms 11% in terms of Packet Delivery Ratio (PDR) and 21% better in terms of Energy Consumed (EC) for different scenarios, based on the varying number of nodes and different data traffic scenarios.

Secondly, Forward Error Correction for CMCMAC (CMCMAC-FEC) is proposed with an aim of better data recovery of partially collided packets at the destination side. This algorithm further enhanced the performance of CMCMAC. Thus, with varying

number of nodes and constant WiFi data rate, CMCMAC-FEC outperformed by 7% in terms of PDR as compared to CMCMAC. CMCMAC-FEC performed 9% better in terms of PDR when number of nodes are constant and WiFi data rates are changing.

Thirdly, Particle Swarm Optimization Based Load Aware Channel Estimation and Channel Scheduling (PSOLACES) Algorithm is proposed. Development of PSOLACES recommends the channel shifting with a minimum frequency shift of 7MHz for the improved performance of WSN working under the influence of WiFi.

Fourthly, Collaborative Framework for Avoiding the Interference (CFAI) is proposed. CFAI Algorithm assures better channel utilization. The average number of packets generated by ZigBee network based on CFAI gets reduced in number. Also, CFAI assures better throughput compared to the existing works like CFMSS, PSOLACES, K.Hong et al., and RDBS.

Finally, Interference Aware Adaptive Transmission Power Control (IAATPC) is proposed for WSN. IAATPC analyzes the power level needed by a node in the network to ensure reliable data delivery. The data transmission is performed under different network conditions by adaptively controlling the transmission power; and in turn, ensuring network efficiency. From the results, it can be inferred that the average residual energy of a node based on IAATPC is 9.6% higher than AMTPC.

The proposed schemes in this thesis are based on simulation results obtained. All the presented schemes avoid interference by proper channel selection under diverse operational conditions by considering different Quality of Service (QoS) parameters; and assure better PDR, EC, reduced Frame Error Rate (FER) and proper channel utilization. The performance of WSN has been improved by strictly following the latency requirements of SG applications.

Keywords: *Home Area Networks, Interference Avoidance, Smart Grid Communications, The 2.4GHz Frequency Band, Wireless Sensor Networks.*

ACKNOWLEDGEMENT

With immense pleasure and deep sense of gratitude, I dedicate this book to **Lord Dharmapuri Lakshmi Narashimha Swamy**.

I could able to complete this book only with the blessings of **Mahaperiya Sri Sri Sri Chandrashekarendra Saraswathi Swami**

I wish to extend my profound sense of gratitude to my parents **Mr. Madhusudhan Rao and Mrs. Vijaya** for all the sacrifices they made during my research and also providing me with moral support and encouragement whenever required.

Last but not the least, I would like to thank my wife **Mrs. Ravali** and my daughter **Maithreyi** for their constant encouragement and moral support along with patience and understanding.

Dr. VIKRAM. K

TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGEMENT	iii
LIST OF FIGURES	viii
LIST OF TABLES	xi
LIST OF TERMS AND ABBREVIATIONS	xiii
1 Introduction	1
1.1 Introduction	1
1.2 The Introduction to Smart Grid Communication System Scenario	4
1.2.1 The Home Area Networks for SG Applications	5
1.2.2 The Neighbourhood Area Network (NAN) for SG Applications	8
1.2.3 The WAN for SG Applications	8
1.3 The WSN Protocol design goals for SG applications	9
1.3.1 Reliability of WSN	9
1.3.2 Quality of Service Requirements for WSN	10
1.3.3 Interference Avoidance	10
1.3.4 Energy Consumption	10
1.3.5 Interoperability	11
1.3.6 Memory Management	11
1.3.7 Security	11
1.3.8 Heterogeneous system conditions	11
1.4 Research Motivation	12
1.5 Research Objectives	12
2 A Review on Interference Avoiding Methods for WSN working in the 2.4GHz ISM Band	14

2.1	Review of Literature	14
2.2	Interference	18
2.2.1	Interference from other coexisting technologies working in same frequency band.	18
2.2.2	Interference from the nodes of same network	23
2.3	Evaluation and Modeling of Interference	24
2.3.1	Measurement of Interference	25
2.3.2	The Identification of Interferer	26
2.3.3	Modeling Interference	27
2.4	Observations	28
2.5	Open Research Issues	29
2.5.1	Reliability of data communication	29
2.5.2	Cross-layer dynamics	29
2.5.3	MAC layer	29
2.5.4	Channel Selection	30
2.6	Simulation Environment Utilized for the Research	30
2.6.1	The Network Simulator(ns) 2.34	30
2.6.2	Directories of ns-2	30
2.6.3	Basic Architecture	31
2.6.4	The Role of C++ and OTcl in ns-2	32
2.6.5	Main ns-2.34 Simulation Steps	33
2.6.6	Tracing of the Data Packets	34
3	Cross-layer based Interference Mitigation and Encoding for Multi- channel ZigBee Networks	36
3.1	Introduction	36
3.2	Related Works	38
3.3	Cross-Layer Multi Channel MAC Protocol	39
3.3.1	Overview	39
3.3.2	Estimation of Interference Level	40
3.3.3	Prediction of future of Hidden Markov Model	41
3.3.4	Data transmission through channel with least interference	42
3.4	Forward Error Correction based Encoding Technique for WSN	44

3.4.1	Transmission Scheme using (CMCMAC-FEC) Encoding.	44
3.5	Simulation Results of CMCMAC and CMCMAC-FEC	46
3.5.1	Analysis of network parameters based on varying number of nodes (ZigBee) and fixed data flows (WiFi)	46
3.5.2	Analysis of network parameters of CMCMAC-FEC based on vary- ing number of nodes and fixed data flows	49
3.5.3	Analysis of network parameters based on Varying number of flows (WiFi) to the fixed number of nodes(ZigBee)	49
3.5.4	Analysis of CMCMAC-FEC based network parameters by vary- ing number of flows	52
3.6	Conclusion	53
4	Load Aware Channel Estimation and Channel Scheduling for 2.4GHz Frequency Band Based Wireless Networks For Smart Grid Applications	55
4.1	Introduction	55
4.2	Related Works	57
4.3	Partile Swarm Optimization Based Load Aware Channel Estimation and Channel Scheduling for ZigBee Networks Working Under the Influence of WiFi	59
4.3.1	Pseudorandom-Based Interference Evading Scheme	60
4.3.2	Load Aware Channel Estimation	61
4.3.3	Traffic Weight Assignment	62
4.3.4	Particle Swarm Optimization (PSO) based Load Aware Channel Estimation	62
4.4	Simulation Results	64
4.4.1	Verification of various wireless technologies by changing the Num- ber of Nodes	67
4.4.2	Varying the Data Flows	68
4.5	Summary	70
5	A Collaborative Framework for Avoiding Interference between Zig- bee and WiFi for Effective Smart Metering Applications	71
5.1	Introduction	71

5.2	Related Works	73
5.3	Proposed Work	75
5.3.1	The Collaborative Framework for Avoiding Interference between ZigBee and WiFi networks	76
5.3.2	Realization of the Distance and RSSI	77
5.3.3	Realization of the Distance and RSSI	80
5.3.4	Throughput Estimation	81
5.4	Performance Evaluation	83
5.5	Conclusion	86
6	Interference Aware Adaptive Transmission Power Control Algorithm for ZigBee Wireless Networks	88
6.1	Introduction	88
6.2	Related Works	89
6.3	Interference aware Adaptive Transmission Power Control Algorithm . . .	90
6.3.1	Problem Identification and Objectives	90
6.3.2	Initialization stage	91
6.3.3	Operational stage	93
6.4	Simulation Results	95
6.4.1	Simulation Parameters	95
6.4.2	Performance Metrics	95
6.4.3	Results and Analysis	96
6.5	Conclusion	100
7	Conclusion	102
7.1	Future Scope	105
	REFERENCES	106
	LIST OF PUBLICATIONS	121

LIST OF FIGURES

Every figure was created by the author.

1.1	The Pictorial Representation of different Smart Grid functions	2
1.2	The representation of three important areas of different Smart Grid functions.	3
1.3	Network model with different networks for SG.	5
2.1	The modern wireless technology-based applications operating in 2.4GHz frequency band.	15
2.2	The modern smart home considering ZigBee for automation, WiFi for accessing Internet for SG Applications	17
2.3	Channel specifications of the wireless technologies operating in 2.4GHz frequency band	19
2.4	The directories in the ns-2.34	31
2.5	The basic architecture of ns-2	32
2.6	The internal structure ns-2	33
2.7	The simulation steps of ns-2	33
2.8	The Trace file format	35
3.1	The CMCMAC block diagram.	37
3.2	The comparison of packet delivery ratio to number of nodes.	47
3.3	The comparison of number of packets lost due to collision to the number of nodes.	47
3.4	The comparison of energy consumed (mJ) to the number of nodes.	48
3.5	The comparison of throughput to number of nodes.	48
3.6	The comparison of packet delivery ratio(CMCMAC-FEC) to number of nodes.	49
3.7	The comparison of throughput(CMCMAC-FEC) to number of nodes.	50
3.8	The comparison of packet delivery ratio to number of flows.	50

3.9	The comparison of number of packets lost due to collision to the number number of flows.	51
3.10	The comparison of energy consumed to number of flows.	51
3.11	The comparison of throughput to number of flows.	52
3.12	The comparison of packet delivery (CMCMAC-FEC) to number of flows.	52
3.13	The comparison of throughput (CMCMAC-FEC) to number of flows. . .	53
4.1	The Superframe architecture.	57
4.2	The Block diagram of PSOLACES	60
4.3	The Pseudorandom Order Generator (PROG).	61
4.4	The 2.4GHz ISM frequency based channels distribution for WLAN and WPAN technologies	65
4.5	Evaluation of FER for IEEE 802.15.4 under the coexistence of 802.11b transmission (when packet size is 20 bytes)	66
4.6	Evaluation of FER for IEEE 802.15.4 under the coexistence of 802.11b transmission (when packet size is 40 bytes)	66
4.7	Evaluation of FER for IEEE 802.15.4 under the coexistence of 802.11b transmission (when packet size is 127 bytes)	67
4.8	Comparison of packet delivery ratio (%) by varying number of nodes. . .	67
4.9	Comparison of Average Energy consumed (mJ) to by varying number of nodes	68
4.10	Comparison of packet delivery ratio (%) by varying number of flows . .	69
4.11	Comparison of AVG. Energy consumed to varying number of flows . .	69
5.1	Channel distribution of different technologies in 2.4GHz frequency band	73
5.2	The block diagram of the proposed CFAI	76
5.3	The architecture of smart home environment.	77
5.4	Transmission delay in Zigbee network.Delay D=10ms	83
5.5	Transmission delay in Zigbee network.Delay D=50ms	84
5.6	Average Number of Packets Generated per Second.	85
5.7	Average Number of Packets Generated per Second	86
6.1	Comparison of Number of Nodes to End-End Delay (ms)	96
6.2	Comparison of Number of Nodes to Packet delivery Ratio	96
6.3	Comparison of Number of Nodes to Overhead	97