



Quality of Service Control in Wireless Sensor Networks Based on Energy Management

By

Eman Mohamed Ahmed Saad Elshahed

**A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of M. Sc. in Computer
Physics**

to

**Physics Department
Faculty of Women for Art, Science and Education, Ain
Shams University**

2014



Faculty of Women for Art,
Science and Education, Ain
Shams University

Quality of Service Control in Wireless Sensor Networks Based on Energy Management

By

Eman Mohamed Ahmed Saad Elshahed

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of M. Sc. in Computer
Physics

To Physics Department

Faculty of Women for Art, Science and Education, Ain
Shams University

Supervisors

Prof. Dr. Hayam A. Elzahed

*Professor of Solid State,
Physics Department, Faculty of Women for
Arts, Science, and Education,
Ain Shams University.*

Dr. Shahinaz M. Al-Tabbakh

*Lecturer of Computer Applications in Physics
Physics Department, Faculty of Women for
Art, Science and Education,
Ain Shams University.*

Dr. Rabie A. Ramadan

*Lecturer of Computer Engineering
Computer Engineering Department, Faculty of
Engineering, Cairo University*

Supervision Committee Approval Sheet

Quality of Service Control in Wireless Sensor Networks Based on Energy Management

By

Eman Mohamed Ahmed Saad Elshahed

Submitted in Partial Fulfillment of the Requirements for the
Degree of M. Sc. in Computer Physics

Approved by:

Signature

Prof. Dr. Hayam A. Elzahed

*Professor of Solid State, Physics
Department, Faculty of Women for Art,
Science, and Education, Ain Shams University.*

Dr. Shahinaz M. Al-Tabbakh

*Lecturer of Computer Application
in Physics Department.
Faculty of Women for Art, Science
and Education Ain Shams University.*

Dr. Rabie A. Ramadan

*Lecturer of Computer Engineering
Computer Engineering Department,
Faculty of Engineering, Cairo University.*

Date of research: / /

Post Graduate Studies Department

Approval Stamp

Faculty Council Approval

Date: / /

Approval Date: / /

University Council Approval

Date: / /

Dedicated

To

*My Parents &
Husband Parents,
My Sisters & Brother,
My professors,
My Friends,
My HUSBAND*

And

My Sweet Daughter

Acknowledgement

*First and foremost I am kneeling obsequiousness to **ALLAH** thanking **HIM** for showing me the right way. Without **God** help and blessing I would not have been able to finish this work.*

*I would like to express my gratitude to **Prof. Dr. Hayam Elzahed** for encouraging me and giving me the guidance and unlimited support to me during my work.*

*Also, I wish to express all my deepest and sincerest gratitude to **Dr. Shahinaz Al-Tabbakh** and **Dr. Rabie Ramadan** for giving me an opportunity to work under their supervision. I am deeply indebted to them for their enormous patience, guidance, and support throughout the work program.*

*I'm grateful to the examiners **Prof. Dr. Mahmoud Marie** and **Prof. Dr. Fatthy Amer** for constructive suggestions and valuable comments, which improve the quality of the thesis.*

*I'm deepest grateful to my uncle **Dr. Mostafa Elshahed** for his fruitful and valuable assistance. He was very generous in his help and time.*

*Thanks to my dear **husband** for his patience and support. I would like to thank also all my family and my sisters and brother, whose hearts are always with me and whose light my way in this life.*

The image features a minimalist design on a white background. A central horizontal banner with rounded ends and a thin black border contains the word "Abstract" in a bold, black, italicized serif font. This banner is flanked by two large, light gray geometric shapes that resemble stylized chevrons or folded paper. Each shape has a pointed right side and a rounded bottom. The entire composition is enclosed within a double-lined black rectangular border.

Abstract

Abstract

The QoS control problem in Wireless Sensor Networks (WSN) is discussed in this study in centralized and distributed network with clustering. The problem takes into consideration many of the performance metrics. For instance, convergence, network lifetime, QoS ratio, average residual energy per node, power depleted nodes, average received messages, and average rejected sensors are taken into consideration. The contributions of this study are:

- (1) This work applies one of the game theory schemes which is Gur game. The Gur game is adapted to control the number of messages to be transferred to the sink node. However, it turns out that the Gur game convergence is taken too much time. Therefore, the study moved forward to the next contribution as follows.
- (2) Adaptive Gur game (AGur) is proposed to speed up the convergence of the Gur game in the network.
- (3) Periodic Gur game (PGur) is introduced to solve another problem noticed when applying Gur game in WSNs which is nodes' energy unbalance. The solution of this problem was inspired from Shuffle.
- (4) Introducing Adaptive Periodic Gur game (APGur) as a combination between AGur and PGur game is investigated in order to enhance the convergence time of PGur game.
- (5) Another game theory is utilized to solve the same problem which is Market Entry Game (MEG). The game seems beneficial and suitable to solve the QoS problem.

- (6) Another contribution in this thesis is the consideration of the Centralized and Distributed Networks. In the distributed networks, a clustering techniques is used to divide the network into clusters. Each cluster applies the games on its nodes and the cluster head along with the sink node do the same.

These contributions are implemented and evaluated; the results presented in this study show the efficiency of the proposed methods in enhancing the QoS of the overall WSNs. From results it is concluded that the MEG increases the centralized network lifetime with percentage between 50% and 150% than Gur game and the APGur improves the QoS level with percentage between 0.2 % and 9% than Gur game. In addition, the APGur increases the distributed network lifetime with percentage between 13% and 18% than Gur game and the AGur improves the QoS level with percentage between 3% and 10% than Gur game.



List of Contents

List of Contents

List of Figures.....	vii
List of Tables.....	x
List of Symbols and Abbreviations.....	xi
 CHAPTER 1. INTRODUCTION	 1
1.1 Introduction.....	1
1.2 Historical Survey of Sensor Networks.....	4
1.3 Hardware Components of Sensor Node.....	5
1.4 WSN Challenges.....	9
1.5 WSN Applications.....	11
1.5.1 Environmental Monitoring Applications.....	11
1.5.2 Health Care Monitoring.....	13
1.5.3 Military Applications.....	14
1.5.4 Smart Home Applications.....	15
1.5.5 Structural and Seismic Monitoring.....	16
1.5.1 Industrial Applications.....	16
1.6 Problem Statement.....	17
1.7 Scope of the Thesis.....	19
1.8 Thesis Outlines.....	20
 CHAPTER 2. LITERATURE REVIEW AND THEORETICAL ASPECTS.....	 25
2.1 Quality of Service for Sensor Networks.....	25
2.1.1 QoS in Traditional Wired and General Wireless Networks.....	27
2.1.2 QoS Requirements in WSNs.....	29
2.2 Radio Energy Dissipation Model.....	31
2.3 Energy-Efficient Computations and Communications Techniques in WSN.....	32

2.4	Theoretical Background of Game Theory.....	34
2.4.1	Game Theory	34
2.4.2	Learning Automata	36
2.4.3	Gur Game.....	38
2.4.4	Market Entry Game.....	40
2.5	Studies in Literature Addressing QoS in WSNs	41
2.6	Clustering Algorithms for WSNs.....	47
CHAPTER 3.	SOLUTION APPROACHES	56
3.1	Introduction	56
3.2	Centralized WSNs.....	57
3.2.1	Gur Game.....	57
3.2.2	Adaptive Gur Game (AGur)	58
3.2.3	Periodic Gur Game (PGur)	63
3.2.4	Adaptive Periodic Gur Game (APGur).....	66
3.3	Distributed WSNs with Clustering	68
3.3.1	LEACH Algorithm:	68
3.3.2	Applying Gur Game with LEACH Algorithm.....	72
3.3.3	Applying AGur with LEACH algorithm	73
3.3.4	Applying PGur Game with LEACH Algorithm	73
3.3.5	Applying APGur with LEACH algorithm	74
3.4	Market Entry Game (MEG) and QoS in WSN	75
3.4.1	MEG Solution Approach	76
CHAPTER 4.	SIMULATION RESULTS IN CENTRALIZED NETWORK.....	80
4.1	Gur Game and its Modifications Simulation Results.....	80
4.1.1	Gur Game and Adaptive Gur Game Convergence	82
4.1.2	Periodic Gur Game and Adaptive Periodic Gur Game Convergence	84

4.1.3	Network Lifetime Evaluation for Gur and AGur.....	86
4.1.4	Network Lifetime Evaluation for PGur and APGur	87
4.1.5	QoS Ratio Evaluation for Gur and AGur.....	89
4.1.6	QoS Ratio Evaluation for PGur and APGur	90
4.1.7	Power Depleted Nodes for Gur and AGur	92
4.1.8	Power Depleted Nodes for PGur and APGur	94
4.1.9	Average Residual Energy for Gur and AGur.....	95
4.1.10	Average Residual Energy for PGur and APGur	97
4.2	MEG Simulation Results	99
4.2.1	Network Lifetime Evaluation	100
4.2.2	Average Number of Rejected Sensors	101
4.2.3	Quality of Service Ratio Evaluation	102
4.2.4	Average Number of Received Messages	103
4.2.5	Average Number of Depleted Nodes	104
4.2.6	Average Residual Energy Evaluation	105
CHAPTER 5. SIMULATION RESULTS IN DISTRIBUTED NETWORK.....		109
5.1	Network Lifetime Evaluation for Gur_L and AGur_L	109
5.2	Network Lifetime Evaluation for PGur_L and APGur_L	111
5.3	QoS Ratio Evaluation for Gur_L and AGur_L	112
5.4	QoS ratio Evaluation for PGur_L and APGur_L	114
5.5	Power Depleted Nodes for Gur_L and AGur_L	115
5.6	Power Depleted Nodes for PGur_L and APGur_L	117
5.7	Average Residual Energy for Gur_L and AGur_L	118
5.8	Average Residual Energy for PGur_L and APGur_L	120
5.9	Gur Game and its Modifications Comparison	122
5.9.1	Comparison of Lifetime in Centralized Network	122
5.9.2	Comparison of QoS Ratio in Centralized Network	123

List of Contents

5.9.3 Comparison of Lifetime in Distributed Network.....	124
5.9.4 Comparison of QoS Ratio in Distributed Network.....	125
CHAPTER 6. CONCLUSION AND FUTURE WORK.....	128
6.1 Conclusion	128
6.2 Future Work	129
References.....	130
Published Article.....	137
الملخص العربي	أ

The page features a decorative border consisting of a double-line black frame. In the center, there is a white rectangular banner with rounded corners and a thin black outline. This banner is flanked by two white triangular shapes pointing towards it, and at the bottom, there are two gray, rounded rectangular shapes that look like folded corners or tabs. The text "List of Figures" is centered on the banner in a large, bold, black serif font.

List of Figures

List of Figures

<i>Figure</i>	<i>Title</i>	<i>Page</i>
Fig. (1.1):	Wireless sensor network architecture [3].	2
Fig. (1.2):	Basic structure of sensor node [7].	8
Fig. (1.3):	Smart agriculture [15].	12
Fig. (1.4):	Detect flooding [16].	13
Fig. (1.5):	Health care monitoring [17].	14
Fig. (1.6):	Military applications [18].	15
Fig. (1.7):	Smart home monitoring[20].	15
Fig. (1.8):	Monitoring bridges and roads [18].	17
Fig. (1.9):	Smart factory [16].	17
Fig. (2.1):	A simple QoS model [21].	27
Fig. (2.2):	Radio energy dissipation model [30].	31
Fig. (2.3):	An illustration of the relation between WSN and game theory[46].	36
Fig. (2.4):	The relation between learning automata and the environment [60].	37
Fig. (2.5):	Typical Gur Reward Function [14].	39
Fig. (2.6):	An example on the automaton with 6 states for the Gur game.	39
Fig. (2.7):	A finite state automaton associated with each sensor node in the Gureen Game control scheme[53].	42
Fig. (2.8):	An illustration of two numbers of yes votes $k < n$ and $k > n$ which would generate identical reward probability[53].	44
Fig. (2.9):	ACK feedback automaton.	45
Fig. (2.10):	Structure of clustered WSNs [70].	47
Fig. (2.11):	Hierarchy with grouping parameter $G = 4$ [77].	51
Fig. (3.1):	The proposed solutions tree.	56
Fig. (3.2):	Gur game flow chart.	60
Fig. (3.3):	AGur game flow chart.	62
Fig. (3.4):	Sensors States at different periods of time (a) 2ed trial, (b) 200th trial, (c) 500th trial [64].	63
Fig. (3.5):	PGur game flow chart.	65
Fig. (3.6):	APGur game flow chart.	67
Fig. (3.7):	MEG flow chart.	79
Fig. (4.1):	Number of active sensors versus time for (a) Gur and (b) AGur when $M = 1$ and $M = 3$ and (c) Network without game.	83
Fig. (4.2):	Number of active sensors versus time for (a) PGur and (b) APGur when $M = 1$ and $M = 3$.	85
Fig. (4.3):	Comparison of network lifetime for all algorithms (a) when $M = 1$ and (b) when $M = 3$.	87