



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكرو فيلم

بسم الله الرحمن الرحيم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم



شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



MONA MAGHRABY



Q-LEARNING BASED RESOURCE MANAGEMENT IN 5G NETWORKS WITH CO-EXISTENCE OF HUMAN AND MACHINE TYPE COMMUNICATIONS

By

Amaal Samir Abd El-Hameed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY
in
Electronics and Communications Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2021

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Amaal Samir Abd El-Hameed

Date: / /2021

Signature:

Dedication

To my father, mother, brother.

To my beloved husband and sons.

Acknowledgments

I wish to thank my supervisor: Prof. Khaled Fouad, for his continuous encouragement and kind support.

I would like to thank my whole family specially my parents for supporting and encouraging me during my life.

Finally, thanks to everyone who helps me to make this work comes to reality.

Table of Contents

DISCLAIMER	I
DEDICATION	II
ACKNOWLEDGMENTS	III
LIST OF TABLES	VIII
LIST OF FIGURES	X
NOMENCLATURE	XII
SYMBOLS TABLE	XIV
ABSTRACT	XVII
CHAPTER 1 : INTRODUCTION	1
1.1. HETEROGENEOUS ARCHITECTURE	1
1.2. LTE OVERVIEW	2
1.3. LTE-M	4
1.4. MOTIVATION.....	6
1.5. ORGANIZATION OF THE THESIS.....	7
CHAPTER 2 : M2M IN LTE.....	8
CHAPTER 3 : BASICS OF Q-LEARNING ALGORITHM	10
3.1. REINFORCEMENT LEARNING	10
3.2. ELEMENTS OF REINFORCEMENT LEARNING	10
3.3. TYPES OF REINFORCEMENT LEARNING	11
3.3.1. THE Q-LEARNING ALGORITHM.....	11
3.3.2. STATE-ACTION-REWARD-STATE-ACTION (SARSA).....	13
3.3.3. DEEP Q-NETWORK (DQN).....	15
3.3.3.1. EXPERIENCE REPLAY	15
3.3.3.2. UPDATING THE Q NETWORK	15
3.3.4. DEEP DETERMINISTIC POLICY GRADIENT (DDPG)	17
CHAPTER 4 : THE PROPOSED Q-LEARNING METHOD FOR RANDOM ACCESS IN LTE-ADVANCED.....	18
4.1. RANDOM ACCESS CHANNEL (RACH) PROCEDURE	18
4.2. LITERAL REVIEW OF RACH	20
4.3. THE PROPOSED Q-LEARNING BASED RACH PREAMBLES ALLOCATION SCHEME	22

4.4. THE EXECUTION OF THE Q-LEARNING SCHEME	25
4.4.1. COPING WITH DYNAMIC TRAFFIC: RE-LEARNING.....	27
4.5. PERFORMANCE EVALUATION RESULTS.....	30
4.5.1. BASIC PERFORMANCE	33
4.5.2. COMPARISONS WITH OTHER SCHEMES.....	34
4.5.2.1. ACCESS SUCCESS PROBABILITY	35
4.5.2.1.1. EFFECT OF INCREASING THE H2H ARRIVALS	35
4.5.2.1.2. EFFECT OF INCREASING THE M2M ARRIVALS.....	37
4.5.2.2. AVERAGE NUMBER OF RE-TRANSMISSIONS.....	39
4.5.2.3. TOTAL SERVICE TIME.....	40
4.5.3. CONVERGENCE OF THE PROPOSED Q-LEARNING SCHEME	42
4.6. CONCLUSION.....	43
CHAPTER 5 : THE PROPOSED Q-LEARNING ALGORITHM FOR CELL ASSOCIATION AND LOAD BALANCING	45
5.1. INTRODUCTION	45
5.2. RELATED WORK	48
5.2.1. Q-LEARNING BASED CELL ASSOCIATION AND LOAD BALANCING.....	49
5.3. SYSTEM MODEL.....	50
5.4. THE PROPOSED Q-LEARNING BASED CELL ASSOCIATION	52
5.4.1. CELL ASSOCIATION FOR H2H UES.....	53
5.4.2. CELL ASSOCIATION FOR M2M DEVICES USING Q-LEARNING (CAM-QL).....	53
5.4.3. THE Q-LEARNING BASED LOAD BALANCING SCHEME AT THE PICO-ENB (LB-QL)	59
5.4.4. THE GREEDY SCHEME FOR DYNAMIC ADJUSTMENT OF BIAS VALUE IN THE LOAD BALANCING SCHEME.....	63
5.5. THE OVERALL SCHEME DESCRIPTION.....	65
5.5.1. THE INTERPLAY BETWEEN THE LB-QL AT THE PENB AND THE QL SCHEME AT THE M2M DEVICES.....	66
5.6. PERFORMANCE EVALUATION RESULTS.....	66
5.6.1. BASIC PERFORMANCE	69
5.6.2. COMPARISONS WITH OTHER SCHEMES.....	70
5.6.2.1. ACCESS BLOCKING PROBABILITY	70
5.6.2.1.1. H2H BLOCKING PROBABILITY.....	70

5.6.2.1.2.	M2M BLOCKING PROBABILITY	71
5.6.2.2.	AVERAGE RESOURCE UTILIZATION FOR MENB AND PENB.	72
5.6.2.3.	AVERAGE UPLINK TRANSMISSION POWER	74
5.6.1.	ADAPTIVE BEHAVIOR OF THE BIAS VALUE	76
5.7.	CONCLUSIONS	77
	DISCUSSION AND CONCLUSIONS	79
	REFERENCES	81

List of Tables

Table 1.1: LTE Cat. M Network Parameters.....	6
Table 4.1: The Reward ranges and corresponding actions.	24
Table 4.2: An Example of the Q-table.....	26
Table 4.3: An Example of the Q-matrix Evolution	27
Table 4.4: Simulation Parameters.....	32
Table 5.1: An Example of the Q-table.....	55
Table 5.2: The Reward ranges and corresponding actions.....	63
Table 5.3: Simulation Parameters.....	66

List of Figures

Figure 1.1: Heterogeneous Network Example	1
Figure 1.2: LTE/LTE-M Network Architecture	5
Figure 3.1: The Q-learning Process	11
Figure 3.2: The Q-learning Algorithm	13
Figure 3.3: SARSA Learning Code	14
Figure 3.4: DQN Algorithm	16
Figure 3.5: DDPQ Algorithm	17
Figure 4.1: Contention based random access in LTE	19
Figure 4.2: Random Access in LTE	20
Figure 4.3: The Demand Arrival Traffic Model	22
Figure 4.4: The Q-learning Markov Decision Process	25
Figure 4.5: The Proposed Q-learning Algorithm	29
Figure 4.6: The Heterogeneous Network Architecture with the coexistence of both H2H and M2M devices	30
Figure 4.7: The H2H RA success probability with the number of H2H arrivals for different number of M2M arrivals M at each frame	33
Figure 4.8: The M2M RA success probability with the number of M2M arrivals for different number of H2H arrivals N at each frame	33
Figure 4.9: H2H RA success probability using Q-learning, DACB and PRA with the number of H2H arrivals N at each frame	35
Figure 4.10: M2M RA success probability using Q-learning, DACB and PRA 15 with the number of H2H arrivals N at each frame	36
Figure 4.11: H2H RA success probability using Q-learning, DACB and PRA 25 with the number of M2M arrivals M at each frame	37
Figure 4.12: M2M RA success probability using Q-learning, DACB and PRA 15 with the number of M2M arrivals M in each frame	38
Figure 4.13: Comparison between Q-learning, DACB and PRA for the average number of access re-transmissions with the number of M2M arrivals M in each frame	39
Figure 4.14: Comparison between Q-learning, DACB and PRA 15 for M2M total service time against the number of preambles	40

Figure 4.15: Comparison between Q-learning, DACB and PRA for M2M total service time for number of preambles $P = 15$, $N = 50$, and M varies from 1 to 3000 devices arrived in each frame.....	41
Figure 4.16: RMS for the Q-matrices for a sudden burst load arrives at time $t=1400$..	42
Figure 5.1: The heterogeneous network architecture with the coexistence of H2H and M2M devices.....	44
Figure 5.2.a: Network with Macro-cell and two Pico-cells without CRE.....	46
Figure 5.2.b: Network with Macro-cell and two Pico-cells. With CRE the Pico-cell size is increased using an offset. Thus, more users are served by Pico-cell and they will have better UL power transmission.....	46
Figure 5.3: The M2M based Q-learning Markov Decision Process.....	54
Figure 5.4.a: The learning phase of the M2M cell association using the Q-learning algorithm.....	56
Figure 5.4.b: The M2M cell association using the Q-learning algorithm	57
Figure. 5.5: The load balancing based Q-learning Markov decision process in case if we move up or down with 2dBm step.....	59
Figure 5.6.a: The learning phase of PeNB load balancing using the Q-learning algorithm	60
Figure 5.6.b: PeNB load balancing algorithm	61
Figure 5.7: The load balancing based Q-learning Markov decision process for dynamic adjustment of bias value.....	63
Figure 5.8: The H2H blocking probability with the change of system utilization.....	68
Figure 5.9: The M2M blocking probability with the change of system utilization.....	68
Figure 5.10: Comparison between the H2H Blocking Probability for different schemes with the change of system utilization.....	70
Figure 5.11: Comparison between the M2M Blocking Probability for different schemes with the change of system utilization.....	71
Figure 5.12: Comparison between the average resource utilization in the MeNB for different schemes with the change of system utilization.....	72
Figure 5.13: Comparison between the average resource utilization for all PeNB for different schemes with the change of system utilization.....	73
Figure 5.14: Comparison between the M2M average Uplink transmission power for different schemes with the change of system utilization.....	74
Figure 5.15: Adaptation of the bias values as traffic rate changes.....	75