IMPERIALIST COMPETITIVE ALGORITHM FOR ENERGY-EFFICIENT CLUSTERING IN WIRELESS SENSOR NETWORK

NURUL JANNAH ABDUL AZIZ

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

School of Electrical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2020

DEDICATION

This project report is dedicated to my beloved parents and family who have been my source of inspiration and continually provide their endless support, love and encouragement in all time.

ACKNOWLEDGEMENT

My profound gratitude goes to Almighty Allah (SWT) who has always given me health and infallible guide in all of my undertakings.

Special gratitude goes to my supervisor, Assoc. Prof Dr Nurul Mu'azzah Abdul Latiff for her valuable advices, as well as technical and insightful suggestions. Her immeasurable support and persistent help in all time guided me to complete the project and writing the project report seamlessly.

Gratitude equally goes to all the lecturers and staffs of School of Electrical Engineering for their countless assistance and understanding during my entire study. I would also like to thank my colleagues Hasan Nabeel Saleem and Abdelmoneim Mohamedosman for their support and help in all time during completing of this project.

Finally, I would like to express my deepest appreciation to my beloved parents for providing me with their endless encouragement throughout my years of study. This accomplishment has been possible because of them.

ABSTRACT

This project proposes an energy-efficient cluster head selection algorithm for the clustering of heterogeneous Wireless Sensor Network (WSN) inspired by imperialistic competition called Imperialist Competitive Algorithm (ICA). The main contribution of the work is the employment of the metaheuristic algorithm to solve NP-hard (non-deterministic polynomial) problem for the sake of reducing network energy consumption and subsequently extends the sensor network lifetime. This is achieved by first transforming the clustering problem into an optimization problem and then several cost functions are taken into consideration for the selection of optimal set of cluster heads such that the transmission distance between cluster heads to their respective cluster members as well as total network energy consumption in the network are minimized. In correspond for evaluating the effectiveness of the proposed algorithm, MATLAB simulations are carried out in different network scenarios. The performance of the ICA is evaluated against other widely-use evolutionary algorithm to demonstrate that the cluster-based protocol using ICA can significantly achieve improvement in terms of network lifetime, total data delivery and energy consumption of the network. The work can be considered significant due to the fact that the algorithm proposed in this project is therefore dynamic because it is able to adapt to the changes in various sensor network architectures and network growth. Besides that, the simulation results shown that the proposed algorithm can improve the lifetime of WSN up to 36 % compared to its comparative (which is LEACH-C protocol).

ABSTRAK

Projek ini mencadangkan satu algoritma cekap tenaga yang mencari kepala kluster untuk pengelompokan rangkaian sensor tanpa wayar yang heterogen, diilhamkan oleh persaingan imperialis yang dikenali sebagai Algoritma Kompetitif Imperialis. Sumbangan utama projek ini adalah penggunaan algoritma metaheuristik untuk menyelesaikan masalah berkaitan "NP-hard (non-deterministic polynomial)" dalam usaha untuk mengurangkan penggunaan tenaga rangkaian dan seterusnya memanjangkan jangka hayat rangkaian sensor. Telebih dahulu, untuk mencapai tujuan tersebut, permasalahan kelompok akan diubah kepada permasalahan pengoptimuman dan kemudiannya beberapa fungsi kos akan diambil kira bagi pemilihan kepala kelompok yang optima seperti jarak penghantaran antara kepala kelompok ke ahli kelompok serta jumlah penggunaan tenaga dalam sesebuah rangkaian. Untuk menguji keberkesanan Algoritma Kompetitif Imperialis, simulasi menggunakan perisian MATLAB dijalankan dalam beberapa senario yang berbeza. Prestasi Algoritma Kompetitif Imperialis dibandingkan dengan algoritma lain yang digunakan secara meluas untuk menunjukkan bahawa protokol kelompok yang menggunakan Algoritma Kompetitif Imperialis dapat mencapai peningkatan dari segi jangka hidup, jumlah penghantaran data dan penggunaan tenaga dalam rangkaian sensor tanpa wayar. Kerja ini dianggap penting berikutan kerana algoritma yang dicadangkan dalam projek ini adalah dinamik kerana algoritma ini mampu untuk menyesuaikan dengan perubahan dalam pelbagai jenis pembinaan dan pertumbuhan rangkaian sensor. Selain itu, keputusan simulasi menunjukkan bahawa algoritma yang dicadangkan ini mampu meningkatkan jangka hayat rangkaian sensor tanpa wayar sehingga 36 % berbanding dengan saingannya (iaitu protokol 'LEACH-C').

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CH	-	Cluster Head
CM	-	Cluster Member
BS	-	Base Station
OSI		Open System Interconnection
ICA	-	Imperialist Competitive Algorithm
WSN	-	Wireless Sensor Network
LEACH	-	Low Energy Adaptive Clustering Hierarchy
LEACH-C	-	Low Energy Adaptive Clustering Hierarchy-Centralized
GA	-	Genetic Algorithm
BSA	-	Backtracking Search Optimization
PSO	-	Particle Swarm Optimization

CHAPTER 1

INTRODUCTION

1.1 Wireless Sensor Network

Wireless sensor network (WSN) refers to a group of fixed or randomly distributed of tiny devices called sensors that are capable of sensing, monitoring, computing and recording of the physical environment in which usually deployed in the specific area for specific purpose usually in the areas which are difficult or impossible to reach by human. These sensors have the ability to measure environmental conditions such as sound, vibration, pressure, temperature, heat, humidity etc. Although the sensor nodes typically have a very small size, they are fully equipped with memory, power source, processor and radio for transmitting and receiving the sensing signals.

Today, WSNs are immensely and diversely used in numerous of applications especially in agriculture for monitoring of plant, military for controlling and monitoring the borders, environmental control for the detection of wildfire or pollution, disaster relief, traffic control, home automation and many other areas.

1.2 Architecture of Wireless Sensor Network

The architecture of the WSN is generally based on the architecture of Open System Interconnection (OSI) Model. This architecture consists of five layers and additional three cross layers. The distinct five layers are namely physical layer, data link layer, network layer, transport layer and application layer. For the seamless operation of WSN, three additional cross layers are introduced comprises the power management plane, mobility management plane and task management plane.

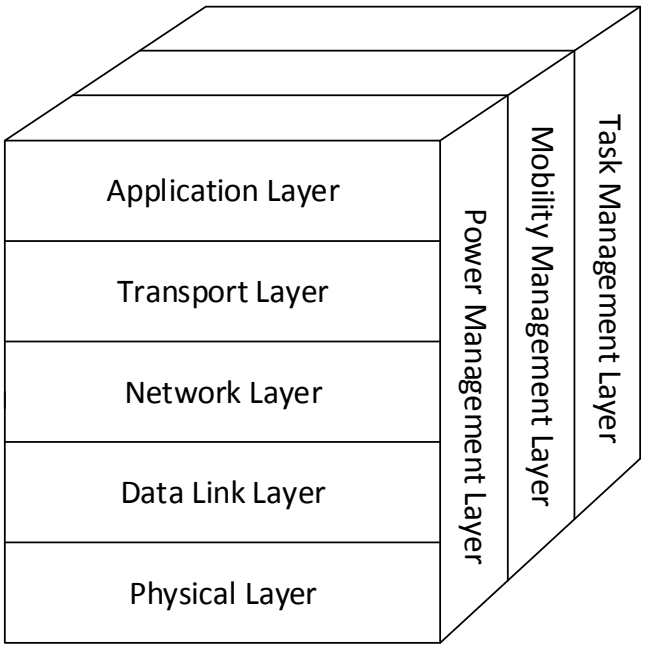

Figure 1.1 Wireless sensor network architecture

Each of the layers in the WSN architecture has its own function. The role of each layer can be briefly explained as follows:

(a) Application layer is used to control the traffic and provides software for innumerable applications for obtaining the information.

(b) Transport layer provides reliability and congestion avoidance.

(c) The main function of network layer is routing. However, this layer also responsible for power reservation.

(d) Data link layer controls the error and multiplexing of data streams and additionally responsible for the reliability of point-to-point or point-to multi point routing.

(e) Physical layer provides a mechanism for the transmission of streams of data through a physical medium. In this layer, there are several operations are being conducted such as frequency selection, generation of signal frequency, detection of the signal, modulation process as well as data encryption.

1.3 Clustering in Wireless Sensor Network

The amount of energy dissipates in the WSN is greatly consumed during the process of data transmission. For this reason, a mechanism that is capable of minimizing the energy consumption and therefore able to preserve the network lifetime are significantly important in the network design. Sensor network require certain protocol for efficient performance [1]. Grouping sensor nodes into several clusters have been one of the efficient approaches to support scalability and network growth in WSN. In comparison to the direct transmission from each node, clustering not only remarkably helps in maximizing the transmitted data, but because of load balancing between nodes, conserve the energy of the network as well.

Clustering has a significant role in information retrieval methods for organizing large collections inside a few significant clusters [2]. Clustering divides the nodes of the WSN into several groups or clusters in which for every cluster, there is one node appointed as a leader known as a Cluster Head (CH) and the rest of the nodes in the cluster becomes Cluster Member (CM) in which they can directly communicate with their respective CH. Base Station (BS) which acts as a gateway, receive the transmitted data from the CH(s) through single or multi hop and forward the data to the remote user. Figure 1.2 illustrates the clustering in the wireless sensor network.

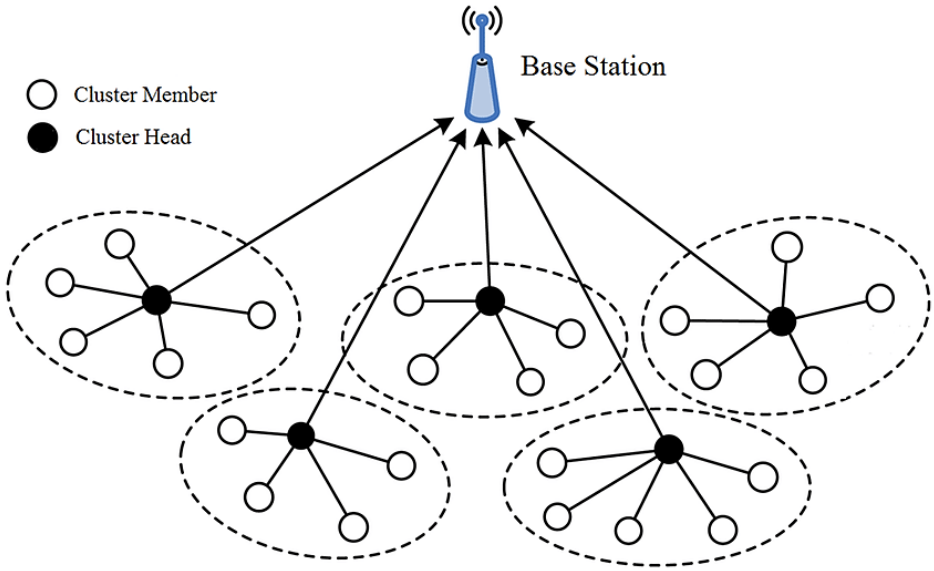

Figure 1.2 Clustering in wireless sensor network [3]

1.4 Cluster Head Selection

Cluster head (CH) has several important roles in the cluster. It has the ability to collect all the sensed data from its group member, may or may not aggregate the data for reducing the overhead and finally compress the information data prior forwarding it to the BS. However, all of this responsibility added a huge burden to the CH and resulted in significantly greater energy consumption at the CH node.

This is why the most important phase of the cluster-based routing protocols is the cluster head selection procedure that ensures uniform distribution of energy among the sensors, and consequently increasing the lifespan of a sensor network [4]. The selection of the best CH is not only for conserving the energy of the network, but also need to make the cluster balanced, achieve maximum number of transferred packets as well as lessen the amount of the energy exchange during data transmission. Therefore, the CH selection process is a very challenging task in the network design.

As the selection of CH in each cluster greatly affected the network lifetime of the WSN, there are numerous approaches that can be considerably taken in order to choose the optimum CH, for example the CH can be randomly chosen or the CH can be selected based on which node has the highest remaining energy in the cluster. Other than that, the other way is to appoint CH which is reachable and accessible by all the nodes in the cluster with the smallest consumed energy. However, in order to avoid the rapid depletion of the energy of the CH, it is essential to alternate the role of CH between all nodes to lessen the overloading of few nodes with more responsibilities compared to others.

1.5 Problem Statement

There are a few challenges in the selection for the best CH in each cluster such that, the selection for the best CH is referred as NP-hard problem particularly that it is challenging and timely as well as computationally consuming to reach the deterministic solution due to the massive growth of the search space.

Besides, wireless sensor network has a limited power resource, hence energy efficiency algorithm is needed to find the optimal set of CHs at each round so that the network energy consumption is minimized and at the same time the total data delivery is maximized and prolonged the sensor network lifetime.

1.6 Objectives

There are several objectives of this project which can be described as follows:

(a) To develop an energy-efficient CH selection algorithm for the clustering of the heterogeneous wireless sensor network based on Imperialist Competitive Algorithm (ICA).

(b) To evaluate the performance of the cluster-based algorithm in terms of energy efficiency, network lifetime and data delivery in various network scenarios.

1.7 Scope of Study

This study is limited to centralized-based routing protocols, with particularly emphasis on energy efficiency, data throughput and network lifetime. The sensor nodes are assumed to be randomly deployed and have heterogeneous properties in terms of initial energy as well as each of them has information about their own location. Moreover, the base station is assumed to be fixed and has high energy resource and computational power.

For the evaluation purpose, MATLAB 2017a will be used as the simulation platform. The analysis will be carried on the comparison of proposed algorithm with other widely-use routing protocol in order to determine their performance in terms of energy consumption, data received and network lifetime in various network scenarios. The work does not take into account other routing protocol, but the others are only used for comparison purposes.

1.8 Significance of Study

In this project, an energy-efficient CHs selection algorithm for WSN based on ICA is studies with the aim of enhancing the CH selection process to improve performance, energy reduction and network lifetime of the WSN.

The proposed algorithm is therefore dynamic because it is efficient and adaptive to multiple network architecture and network growth. Moreover, excessive number of simulations were performed and we compared the proposed method with fundamental routing protocol. The result of the analysis showed how large amounts of energy is saved by implementing the proposed algorithm, ultimately reducing energy consumption, increasing the total data delivery to the base station and prolonging the network lifetime.

1.9 Thesis Structure and Organization

Chapter 1 introduces the general description of wireless sensor network, the role of CH in the clustering of WSN, objectives, scope and significance of the project.

Chapter 2 describes the previous works of other researchers. The work on WSN specifically the cluster-based routing protocol and energy-efficient CHs selection algorithms are discussed in this chapter.

Chapter 3 describes a research method which is implemented in this project. The proposed algorithm is introduced and is briefly discussed.

Chapter 4 discusses the design, implementation and development of the proposed algorithm in the clustering of WSN for selection of the best CH.

Chapter 5 shows the validation of the proposed technique and how it is being implemented in the MATLAB environment as well as the analysis of the simulation results in details.

Chapter 6 concludes the achieved results and the overall work and emphasized the recommendation for future works.

1.10 Summary

A brief background of this project has been discussed, providing the background of the project, problem statements, objectives, scope and significance of this project. The next chapter will cover the literature review related to the various CH selection algorithms based on clustering of the WSN.

REFERENCES

1. Shankar, A. and N.J.P.C.S. Jaisankar, *A novel energy efficient clustering mechanism in wireless sensor network.* 2016. **89**: p. 134-141.
2. Salehpour, S. and H. Parvin, *Converting Ensemble Clustering Problem to a Mathematical Optimization Problem and Providing an Approach to Solve Based on Optimization Toolbox.* 2018.
3. Gui, T., et al., *A novel cluster-based routing protocol for wireless sensor networks using Spider Monkey Optimization*. 2016.
4. Kang, S.H. and T.J.I.C.L. Nguyen, *Distance based thresholds for cluster head selection in wireless sensor networks.* 2012. **16**(9): p. 1396-1399.
5. Shi, S., X. Liu, and X. Gu. *An energy-efficiency Optimized LEACH-C for wireless sensor networks*. in *7th International Conference on Communications and Networking in China*. 2012. IEEE.
6. Brisha, A.M.J.I.J.o.O. and B. Engineering, *A Comparison Between Methods of Selecting Cluster Head.* 2010. **6**(4): p. 7-13.
7. Jin, S., M. Zhou, and A.S. Wu. *Sensor network optimization using a genetic algorithm*. in *Proceedings of the 7th world multiconference on systemics, cybernetics and informatics*. 2003.
8. Latiff, N.A., N.N.A. Malik, and L. Idoumghar. *Hybrid backtracking search optimization algorithm and K-means for clustering in wireless sensor networks*. in *2016 IEEE 14th Intl Conf on Dependable, Autonomic and Secure Computing, 14th Intl Conf on Pervasive Intelligence and Computing, 2nd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress (DASC/PiCom/DataCom/CyberSciTech)*. 2016. IEEE.
9. Latiff, N.A., C.C. Tsimenidis, and B.S. Sharif. *Energy-aware clustering for wireless sensor networks using particle swarm optimization*. in *2007 IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications*. 2007. IEEE.
10. Janakiraman, S., *A Hybrid Ant Colony and Artificial Bee Colony Optimization Algorithm-based Cluster Head Selection for IoT.* Procedia computer science, 2018. **143**: p. 360-366.

11. Jia, D., et al., *Dynamic cluster head selection method for wireless sensor network.* IEEE Sensors Journal, 2016. **16**(8): p. 2746-2754.
12. Atashpaz-Gargari, E. and C. Lucas. *Imperialist competitive algorithm: an algorithm for optimization inspired by imperialistic competition*. in *2007 IEEE congress on evolutionary computation*. 2007. IEEE.
13. Correia, L.H., et al., *Radio channel model of wireless sensor networks operating in 2.4 ghz ism band.* INFOCOMP, 2010. **9**(1): p. 98-106.
14. Heinzelman, W.R., A. Chandrakasan, and H. Balakrishnan. *Energy-efficient communication protocol for wireless microsensor networks*. in *Proceedings of the 33rd annual Hawaii international conference on system sciences*. 2000. IEEE.
15. Marler, R. and J. Arora, *The weighted sum method for multi-objective optimization: New insights*. Vol. 41. 2010. 853-862.
16. Rostami, A.S., et al. *Imperialist Competition based Clustering Algorithm to Improve the Lifetime of Wireless Sensor Network*. in *International Workshop Soft Computing Applications*. 2016. Springer.
17. Peiravi, A., H.R. Mashhadi, and S.J.I.J.o.C.S. Hamed Javadi, *An optimal energy-efficient clustering method in wireless sensor networks using multi-objective genetic algorithm.* 2013. **26**(1): p. 114-126.
18. Vidya, T., k. vanisree, and N. Kolla, *Maximum Throughput in Wireless Sensor Network Using Modified Leach Protocol Using Matlab.* IOSR Journal of Electronics and Communication Engineering, 2017. **12**: p. 01-08.
19. Mortazavi, S.M., M. Malekzadeh, and R.A. Moghaddam, *Reducing Energy Consumption in Wireless Sensor Networks by CICA Algorithm.*
20. Perez, A.J., M.A. Labrador, and P.M. Wightman. *A multiobjective approach to the relay placement problem in wsns*. in *2011 IEEE Wireless Communications and Networking Conference*. 2011. IEEE.
21. Hosseinirad, S.M.J.J.o.A. and D. Mining, *Multi-layer Clustering Topology Design in Densely Deployed Wireless Sensor Network using Evolutionary Algorithms.* 2018. **6**(2): p. 297-311.
22. Kumar, H., P.K.J.J.o.T. Singh, Electronic, and C. Engineering, *Node energy based approach to improve network lifetime and throughput in wireless sensor networks.* 2017. **9**(3-6): p. 79-88.