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HEXAGONAL GRID-BASED DYNAMIC ROUTING ADJUSTMENT FOR OPTIMISING NETWORK LIFETIME IN WIRELESS SENSOR NETWORK

ZAID FAWAZ JARALLAH

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By

ZAID FAWAZ JARALLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Fulfilment for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to my beloved *parents*
For their endless love, encouragement and unconditional support in all my life
And
Especially to my beloved wife, Sarah
Anything good that has come to my life has been because of your example
And
My lovely Children (*Wisam and Tamarah*)
Love you always and forever
And
My Dear Sister (Luma) and her husband (Azher)
I will always be grateful to you

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in Fulfilment of the requirement for the degree of Master of Science

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Chairman : Abdullah Muhammed, PhD
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Over past few years we have seen a growing interest in the prospect use of wireless sensor networks (WSNs) in enormous domain of applications and it became an interesting research area. The formation of WSNs, which consist of small battery with limited power, make it has a huge shortage of energy.

Many researchers proposed various techniques to solve this problem, aiming to prolong the network lifetime. In the scientific literatures, some of the researchers proposed routing protocols to pass the data through the network. These include the division of sensing area into grids or cells as clusters, each cluster select one node as Cluster-Head (CH). CHs task inside the network is to connect with each other in order to receive the data from MNs and send it to S. The other suggested technique assumed that the sink has to be routable and moves around the network and collect data from MNs directly. By doing so, the mobile sink can reduce the energy depletion of the nodes subsequently, will enhance the network lifetime. The major issues while utilising this technique is how to detect the sink while moving and this is still a challenge. This research try to solve the problem that occur while utilizing the clustering technique, which are the CHs that close to the S node will deplete the energy faster than others, as well as, during the sink mobility technique, solving the detection of the mobile sink location process.

However, a new protocol has proposed called Hexagonal Grid based Dynamic Routes Adjustment (HGDRA) which divides the network cells into hexagonal clusters and used the mobile sink technique inside the network area in order to prolong the network lifetime. The proposed technique tries to reconstruct a data packet path that detects the mobile sink with less energy consumption, as well as improving the network lifetime.

The experimental result that gained via Ns2 simulator demonstrate that the proposed approach produce better quality solutions in terms of network reconstruction cost, number of hops, nodes residual energy and network lifetime when compared with the benchmark approach.

Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PELARASAN PENGHALAAN DINAMIK BERASASKAN GRID HEKSAGONAL(HGDRA) UNTUK MENGOPTIMUMKAN JANGKA HAYAT RANGKAIAN DALAM RANGKAIAN PENGESAN WAYARLES

Oleh

ZAID FAWAZ JARALLAH

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Sejak beberapa tahun kebelakangan ini kita telah melihat minat yang semakin meningkat dalam penggunaan prospek rangkaian sensor tanpa wayar (WSNs) dalam domain besar aplikasi dan ia menjadi kawasan penyelidikan yang menarik. Pembentukan WSNs, yang terdiri daripada bateri kecil dengan kuasa terhad, menjadikan ia mempunyai kekurangan besar tenaga. Ramai penyelidik mencadangkan pelbagai teknik untuk menyelesaikan masalah ini, yang bertujuan untuk memanjangkan jangka hayat rangkaian. Dalam kesusasteraan saintifik, beberapa penyelidik mencadangkan protokol routing untuk lulus data melalui rangkaian. Ini termasuk pembahagian kawasan ke dalam grid atau sel-sel sebagai kelompok penderiaan, setiap kelompok pilih satu nod sebagai Kluster-Kepala (CH). CHS tugas di dalam rangkaian ini adalah untuk menyambung antara satu sama lain untuk menerima data dari MNS dan hantar ke S. Teknik disyorkan lain diandaikan bahawa sinki telah menjadi routable dan bergerak di sekitar rangkaian dan mengumpul data dari MNS langsung. Dengan berbuat demikian, sinki mudah alih boleh mengurangkan kekurangan tenaga nod seterusnya, akan meningkatkan jangka hayat rangkaian. Isu-isu utama semasa menggunakan teknik ini adalah bagaimana untuk mengesan sink sambil bergerak dan ini masih satu cabaran. Kajian ini cuba untuk menyelesaikan masalah yang berlaku semasa menggunakan teknik pengelompokan, yang adalah CHS yang menutup kepada nod S akan dapat mengurangkan tenaga yang lebih cepat daripada yang lain, dan juga, semasa teknik sink mobiliti, menyelesaikan pengesanan sink mudah alih proses lokasi. Walau bagaimanapun, protokol baru telah dicadangkan dipanggil hexagon Grid berasaskan Laluan Dynamic Pelarasan (HGDRA) yang membahagikan sel-sel rangkaian ke dalam kelompok heksagon dan menggunakan teknik sinki mudah alih di dalam kawasan rangkaian untuk memanjangkan jangka hayat rangkaian. teknik yang dicadangkan cuba untuk membina semula jalan paket data yang mengesan sink mudah alih dengan penggunaan tenaga yang kurang, serta

memperbaiki hidup rangkaian. Hasil eksperimen yang mendapat melalui NS2 simulator menunjukkan bahawa pendekatan yang dicadangkan menghasilkan penyelesaian yang lebih berkualiti dari segi kos rangkaian pembinaan semula, bilangan hop, nod tenaga sisa dan jangka hayat rangkaian jika dibandingkan dengan pendekatan penanda aras. teknik yang dicadangkan cuba untuk membina semula jalan paket data yang mengesan sink mudah alih dengan penggunaan tenaga yang kurang, serta memperbaiki hidup rangkaian. Hasil eksperimen yang mendapat melalui NS2 simulator menunjukkan bahawa pendekatan yang dicadangkan menghasilkan penyelesaian yang lebih berkualiti dari segi kos rangkaian pembinaan semula, bilangan hop, nod tenaga sisa dan jangka hayat rangkaian jika dibandingkan dengan pendekatan penanda aras. teknik yang dicadangkan cuba untuk membina semula jalan paket data yang mengesan sink mudah alih dengan penggunaan tenaga yang kurang, serta memperbaiki hidup rangkaian. Hasil eksperimen yang mendapat melalui NS2 simulator menunjukkan bahawa pendekatan yang dicadangkan menghasilkan penyelesaian yang lebih berkualiti dari segi kos rangkaian pembinaan semula, bilangan hop, nod tenaga sisa dan jangka hayat rangkaian jika dibandingkan dengan pendekatan penanda aras.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVATIONS

AP	Access point
BS	Base Station
BVI	Backbone-based Virtual Infrastructure
CDS	Connected Domination Set-based backbone
CH	Cluster Head
DDB	Dynamic Directed Backbone
DN	Dominating Nodes
DWEHC	Distributed Weight-Based Energy-Efficient Hierarchical Clustering
EASR	Energy-Aware Sink Relocation
GMR	Geographic Multicast Routing
GPS	Global Positioning System
HCDD	Hierarchical Cluster-based Data Dissemination
HEED	Hybrid Energy-Efficient Distributed clustering
HexDD	Hexagonal Tiling-Based Data Dissemination
HGDRA	Hexagonal Grid-based Dynamic Routes Adjustment
HGDRA-S	Hexagonal Grid-based Dynamic Route Adjustment with Smart sink
HRPM	Hierarchical Rendezvous Point Multicasting
HTTDD	Hexagonal Two-Tier Data Dissemination
LEACH	Low Energy Adaptive Clustering Hierarchy
LEGOS	Low Energy self-Organisation Scheme
MCP	Maximum Capacity Protocol
MEME	Micro Electro Mechanical System
MMSR	Multiple Mobile Sink-based Routing
MN	Member Node
Ns2	Networks Simulator 2
RP	Rendezvous Point
S	Sink
SN	Sensor Node
TEEN	Threshold-sensitive Energy-Efficient sensor Network protocol
TTDD	Two-Tier Data Dissemination

VCCSR	Virtual Circle Combined Straight Routing
VGDRA	Virtual Grid based Dynamic Routes Adjustment
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

1.1 Research Background

Rapid evolution of Micro Electro Mechanical System (MEMS) technologies accelerates Wireless Sensor Networks (WSN) development, and it becomes growingly attractive for abundant application system in many fields, such as military exploration, security surveillance, disaster warning system, medical health, habitat monitoring, industrial automation, etc WSNs managed to create a relation between the human communities, physical world, and the computing world (Liu, 2012a).

WSN is a type of network that consists on number of nodes that connect with each other without a physical medium. The nodes are tiny size and containing a small battery with limited energy, and unplugged with power resources. The components of single sensor node in general: a controller module, memory module, communication module, sensing module, power supply module (Bal & Rath, 2014). Furthermore, in some types of networks it could contain a Global Positioning System (GPS) (Patwari et al., 2005).

WSN system architecture contains a base station or sink located in a specific place inside or around the network, this sink node does receive the data that collected by other nodes. The nodes inside the network works as data mining after exploring the area and give a pre-warning signals to the base station, then after collecting data they send it to the base station or the sink.

The data packet flow through the network using hop-by-hop communication, which makes the data flowing more effective in aspect of energy consumption. The sensor nodes in WSNs are highly restricted in terms of transmission energy, processing capacity storage, battery life-time and thus require careful energy managed (Singh et al., 2010a). Network lifetime is the most important factor in WSN, and the energy consumption remains the main critical issue that effect the network lifetime in general (Y. Wang, 2008).

The main goal of initiating a new technique is to prolong the sensor network life-time by presenting a protocol that will help the network consuming more energy for each single node in order to prolong the whole network life-time. The clustering technique has been applied on sensor network in many adjustment protocols to solve the fast energy depletion issues. A wide description on clustering technique are as follow (Kumarawadu et al., 2008).

1.1.1 Clustering Routing Protocols

Clustering routing protocols have many advantages such as scalability, energy consumption, and robustness.

I. High scalability: the sensor nodes separated around the clusters and it has different level of functions. The function of CHs is data forwarding and network management, and MNs function is to sense events and collect information within their signal range. The clustering topology is able to localise the routing setups inside the clusters and decrease the routing table size for each single sensor node. This type of network is easier to manage thus more scalable for responding in the environment.

II. Data aggregation: the processing of data gathering from many nodes to remove the redundant transmission and comprise data to the BS, the effective technique for saving energy in the WSNs. The most common data propagation technique is the clustering data aggregation. Each CH collects and forwards the compressed data to BS, and generally transmitted the data by using multi-hopping to other CHs with a tree structure which considered a high energy saving technique.

III. Energy consumption: Data aggregation in clustering routing protocols helps increasing data transmission and saving more energy. Moreover, clusters with intra-cluster data transmission help in reducing the number of nodes in performing long distance communication tasks. Thus providing more energy saving for the entire network.

IV. Robustness: In clustering routing protocols, it's easy for the network to control and respond to the network changes such as nodes numbers, nodes mobility and nodes failures. With the clustering protocol, these parameters can be controlled by a single cluster, thus the whole network more stable and robust and easy to manage.

V. Avoid collisions/latency: In WSNs, when it's divided into clusters, data transmission will be performed only on CHs outside the cluster. This mode of data transmission out of cluster is helping to avoid collisions between nodes. Accordingly, the latency will be decreased. The data transmission performed hop-by-hop flooding in flat routing protocols reducing the number of hops between source nodes and BS, and latency will be decreased accordingly.

VI. Network lifetime: the network lifetime is unavoidable factor in WSNs, because of low nodes energy supply, and with functions of sensing, processing data and bandwidth transmission. Apparently, it is essential to minimise the energy consumption for intra cluster communication via CHs which will be higher data resources than other nodes. Besides, nodes that are near to the most of nodes in the clusters should be apt to be selected as CHs. Additionally, energy-aware idea aiming to select routes that are expected to prolong the network lifetime in intra cluster communication, and the nodes with higher energy should be involved in these routes (Liu, 2012a; Y. Wang, 2008).

1.2 Problem Statement

In the WSNs, the most critical problem in the networks function is how to maintain the network lifetime. Utilising the clustering technique provide more energy fairness to the CHs by receiving the data flow for all other MNs and send it to the sink. Clustering technique help the sensor network avoiding energy hole problems (Thanigaivelu & Murugan, 2012).

The CHs will be suffered from the same energy problem, precisely, for CHs that close to the static sink will deplete their energy faster than others. Therefore, a new technique suggested that using the mobile sink in different patterns will help the CHs energy fairness, furthermore, enhance the whole network lifetime (Marta & Cardei, 2009).

Despite the enormous advantages of sink mobility, it caused difficulties in data collection during mobile sink tracking process. In order to maintain tracking the mobile sink in such networks, it has to take in consideration the route reconstruction mechanism that can ease the sink position detection process. In this research, the base work protocol will be Virtual Grid based Dynamic Routes Adjustment (VGDRA). The VGDRA protocol used a clustering technique for peripheral square shape network with mobile sink routing around the network perimeter (Khan et al., 2015a). There are some lacking in the scheme; firstly, CHs that had only four neighbouring clusters can communicate with, while there could be more than that number if we divided the network in a different shape, secondly, some of clusters that far from sink node in some of its position will have to send the data flow all over the network passing through large number of clusters in order to reach the sink and that will exhaust the whole network. The previous issue encourages us to suggest changing the sink movement path by letting it to go cross the network in orderly way to communicate with CHs by being closer to them, as well as, decreasing the data flow inside the network.

1.3 Research Questions

In line with the problem statements the following research questions are:

1. What is the best mechanism for improving the efficiency of the WSNs lifetime?
2. How an integrated routing protocol can conserve more energy and enhance the network energy depletion when utilising the clustering technique in WSNs?

1.4 Research Objectives

The main points of objectives for this research are as follows:

1. To improve the functionality of the mobile sink data collection mechanism by finding an ideal sink trajectory movement in WSN.
2. To propose a Hexagonal Grid-based Dynamic Route Adjustment (HGDRA) protocol that incorporate with smart sink technique to increase the number of data packets and the number of hops in order to improve the network lifetime.

1.5 Research Scope

Our research is scoping the energy dissipation that caused by data packet transmission for the nodes that are close to the base station (sink) in the WSNs. For the mobile sink cluster-heads that are close to the sink node, as well. We tried to solve the problem of the cluster-heads energy consumption, which are close to the sink, by improving the sink movement, as well as, enhancing the grid dividing technique for the sensor network.

1.6 Research Contributions

- The major contribution of this research is producing a clustering WSN approach that provides a better lifetime for all nodes inside the network. In order to achieve the main goal, a three movement scenarios for the mobile sink has been examined; hexagonal movement, peripheral movement and random movement. These scenarios have been compared and the result shows the hexagonal movement is outperforming the other two scenarios in terms of network lifetime.
- The best scenario has been used in our new proposed protocol called Hexagonal Grid-based Dynamic Routes Adjustment (HGDRA) that works in a new sink movement pattern which provides an ideal mechanism of sensor network data collection. The proposed protocol compared to a base work protocol Virtual Grid-based Dynamic Route Adjustment (VGDRA) using the same parameters and our proposed protocol outperforms the base work protocol with a magnificent percentage in all aspects.
- Another protocol has been proposed that uses a new technique called Hexagonal Grid-based Dynamic Route Adjustment with Smart sink (HGDRA-S), which used a new technique to detect the most active clusters in the network and move the sink near it, this protocol has been compared to the other two protocols (VGDRA) and (HGDRA) and the results demonstrate that the proposed protocol outperforms the other two with a good percentage.

1.7 Organisation of the Thesis

This thesis is generally divided into 6 chapters; the first chapter is the introduction of the research study that explains the research background. Next the problem statement, the questions of the research, the objectives of the research, the research contribution of this study, the scope of the research, and lastly, the organisation of the thesis, are depicted.

Chapter 2 of the study looks into the related works of the study, the related applications that utilises the WSNs, and the related clustering protocols that been implemented in order to solve the same issue that we refer to, and lastly, the approach of virtual backbone and the related protocols that used it.

In Chapter 3, the methodology of the research has been presented in steps, and each step has been illustrated clearly for our research and we give an explanation for each part of it in details.

In Chapter 4, we illustrate our proposed protocols in details and we explain the mechanism for each one of them and we explain the tools that we used to present the proposed protocols.

In Chapter 5, we demonstrate the result that we obtained from our experimental and we analyse the performance metrics for each protocol.

In Chapter 6, we discuss the conclusion of the research and the future work that could be done for the research method.

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