UNIVERSITI PUTRA MALAYSIA

ENERGY-EFFICIENT TWO-STAGE CHAIN PROTOCOL ROUTING ALGORITHM FOR WIRELESS SENSOR NETWORKS

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ENERGY-EFFICIENT TWO-STAGE CHAIN PROTOCOL ROUTING ALGORITHM FOR WIRELESS SENSOR NETWORKS

By

HUSAM KAREEM FARHAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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DEDICATION

I would like to dedicate my thesis to my beloved parents and siblings because of all the wonderful things they have done to me and supporting me all the way

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

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May 2014

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Wireless sensor nodes are mostly used in extreme environments, especially at remote and hostile areas including battlefield, volcanoes and underwater. Thus, it is difficult to replenish the energy source of the sensor node once it is installed. One of the factors that plays very important role in extending the wireless sensor networks lifetime is routing algorithm. In order to extend the lifetime of the nodes, we propose a new routing algorithm that can achieve significant energy conservation in WSNs, known as Two Stage Chain Routing Protocol (TSCP). The main objective of TSCP is to increase the network lifetime of wireless sensor networks. The new TSCP routing algorithm is compared with other similar grid-based routing algorithms namely Chain-Cluster based Mixed routing (CCM) and Chain-Chain Based Routing Protocol (CCBRP).

TSCP algorithm divides the sensor network into multiple chains and work within two stages. The first stage is dividing the nodes to horizontal chains that include all sensor nodes within the same row and one of the nodes in the chain will act as a head for other members. The second stage is involving the formation of vertical chain that includes all chain heads, one of the nodes in the vertical chain that includes all chain heads and selecting one of the nodes to act as a main head for the entire network.

Simulation results show that TSCP algorithm outperforms CCM and CCBRP algorithms in terms of four performance metrics namely Network lifetime, FND and LND (First Node and Last Node Died), network stability period, and energy consumption. The main concern for TSCP algorithm is to extend the lifetime of wireless sensor network. As a result, TSCP could achieve an

improvement over CCM and CCBRP algorithms in about 25% and 8% respectively for small network size (3 X 3) sensor nodes configuration. At the same time, TSCP could achieve about 29% and 9% improvement in comparison with CCM and CCBRP respectively using medium network size, (9 X 9) sensor nodes configuration. When we carried on the comparison using large network size, which is (15 X 15) sensor nodes configuration, TSCP shows an improvement about 25% and 18% over CCM and CCBRP algorithms respectively.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

ALGORITMA PROTOKOL PENGHALAAN RANTAIAN CEKAP TENAGA DWI-PERINGKAT UNTUK RANGKAIAN PENDERIA TANPA WAYAR

Oleh

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Nod penderia tanpa wayar (WSN) kebanyakannya digunakan di persekitaran yang melampau, terutama di kawasan pendalaman termasuk lapangan perang, gunung berapi dan di dalam air. Justeru itu ianya amat sukar untuk menambah semula sumber tenaga nod penderia apabila ianya telah dipasang. Salah satu faktor utama yang memainkan peranan penting di dalam melanjutkan jangka hayat nod penderia tanpa wayar ialah algoritma penghalaan. Demi melanjutkan jangka hayat nod tersebut, kami mencadangkan algoritma penghalaan baharu yang boleh mencapai penjimatan tenaga yang ketara di dalam WSN yang dikenali sebagai algoritma Penghalaan Protokol Rantaian Dua Peringkat (TSCP). Objektif utama TSCP adalah untuk menambah jangka hayat rangkaian nod penderia tanpa wayar. Algoritma penghalaan TSCP yang baharu dibandingkan dengan algoritma penghalaan berdasarkan grid lain yang serupa iaitu Rantaian-Kluster Campuran (CCM) dan Protokol Penghalaan Rantaian-Rantaian (CBRP).

Algoritma TSCP membahagikan rangkaian penderia kepada beberapa rantaian dan berfungsi di dalam dua peringkat. Peringkat yang pertama adalah membahagikan nod kepada rantaian melintang yang merangkumi semua nod penderia di dalam barisan yang sama dengan salah satu daripada nod di setiap rantai akan dipilih untuk menjadi ketua untuk ahli nod yang lain. Peringkat yang ke dua adalah melibatkan penubuhan rantaian menegak dan memilih salah satu daripada nod sebagai ketua utama untuk keseluruhan rangkaian.

Hasil simulasi menunjukkan algoritma TSCP menewaskan algoritma CCM dan CCBRP di dalam empat metrik prestasi iaitu jangka hayat rangkaian,

FND dan LND (Kematian Nod Pertama dan Terakhir), jangka masa rangkaian stabil dan penggunaan tenaga. Keprihatinan yang utama untuk algoritma TSCP adalah untuk melanjutkan jangka hayat rangkaian penderia tanpa wayar. Sebagai hasilnya, TSCP boleh mencapai peningkatan berbanding algoritma CCM dan CCBRP, masing-masing sebanyak 25% dan 8% untuk saiz rangkaian kecil dengan nod penderia berkonfigurasi (3 X 3). Pada masa yang sama, TSCP boleh mencapai peningkatan, masing-masing sebanyak 29% dan 9% berbanding CCM dan CCBRP dengan menggunakan saiz rangkaian nod penderia sederhana berkonfigurasi (9 X 9). Apabila kami menjalankan perbandingan dengan menggunakan saiz rangkaian yang besar, iaitu nod penderia berkonfigurasi (15 X 15), TSCP menunjukkan peningkatan masing-masing sebanyak 25% dan 18% berbanding algoritma CCM dan CCBRP.

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I certify that a Thesis Examination Committee has met on (**DATE OF VIVIA**) to conduct the final examination of Husam Kareem Farhan on his thesis entitles "ENERGY EFFICIENT TWO STAGE CHAIN ROUTING PROTOCOL (TSCP) FOR WIRELESS SENSOR NETWORKS" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

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LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
BS	Base Station
QoS	Quality of Service
SPIN	Sensor Protocols for Information via Negotiation
IP	Internet Protocol
GPS	Global Positioning System
MECN	Minimum Energy Communication Network
GAF	Geographic Adaptive Fidelity
LEACH	Low-Energy Adaptive Clustering Hierarchy
PEGASIS	Power-Efficient GAthering in Sensor Information Systems
TEEN	Threshold sensitive Energy Efficient sensor Network protocol
SAR	Sequential Assignment Routing
CCBRP	Chain –Chain Based Routing Protocol
CCM	Chain –Cluster based Mixed routing
TSCP	Two Stage Chain Routing Protocol
EBSCR	Energy-Based selective Cluster-Head Rotation
SPER	Safe and Power –Efficient Routing Algorithm
EECB	Energy Efficient Chain Based Routing Protocol
IEEPB	Improved Energy Efficient Based Protocol
ID	Identification
ECBSN	Energy Efficient Chain Based Network
EBRT	Energy-Based Re-transmission Algorithm
MIEEPB	Mobile sink Improved Energy-Efficient PEGASIS-Based routing protocol
IECBSN	Improved Energy Efficient Chain Based Sensor Network
ACK	Acknowledgement
BEC	Based Energy Clustering
MCHRP	Multiple Cluster-Heads Routing Protocol
CFDASC	Chain-based Fast Data Aggregation Algorithm Based on Suppositional Cells
CBERP	Cluster Based Energy Efficient Routing Protocol for Wireless Sensor Network
ECCP	Energy Efficient Cluster-Chain based Protocol
REC+	Reliable and Energy-efficient Chain-cluster Based Routing Protocol
CCCP	Chain-Clustered Communication Protocol
MATLAB	Matrix Laboratory
pJ	Pico-Joule
M	Meter
FND	First Node died
LND	Last Node Died

CHAPTER 1

INTRODUCTION

1.1 Wireless Sensor Networks

Generally, any device that has the ability to sense the surrounding environment can be considered as a sensor node. A wireless sensor network (WSN) is a group of sensor nodes that cooperate with each other, it may contain few numbers of sensors or it can consists of thousands of sensors, these nodes are capable of doing many tasks such as data processing and environmental sensing. WSNs can be used in wide range of applications such as measuring the temperature, the humidity, the pressure, noise level, monitoring the vehicular movement, military applications and health applications [1].

The typical node in a WSN contains four main parts, which are sensing unit, computing unit, communication unit, and power unit. Figure 1.1 shows the basic sensor node architecture. These nodes mostly deployed in areas that have the least direct human interaction. The typical WSN consists of hundred to thousand nodes, those nodes have the ability to connect with each other, and it can directly be connected to the base station (BS) [2].

The number of the nodes in a WSN depends on the application and the geographical area that represents the field of interest. In other words, a greater number of sensor nodes are needed for larger area considering the level of accuracy that demanded from that area. One of the main crucial issues can face the operation and the surveillance of WSNs is energy consumption. Energy in WSNs mostly powered by battery and the greatest share of this energy is consumed during Data transmission [3]. Many researches have been done to solve this problem or at least find a solution to decrease this consumption. One of those solutions is using efficient routing algorithm. Figure 1.1 demonstrates the main components in a typical sensor node.

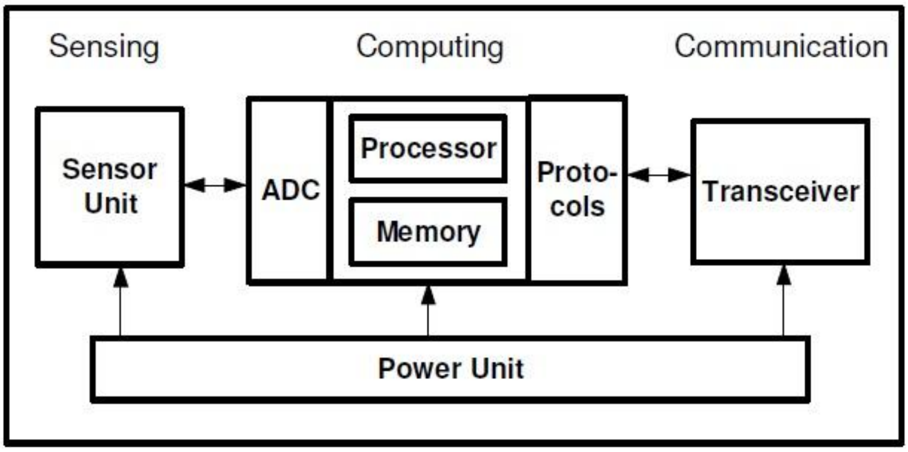

Figure 1.1: The components of typical sensor node [4].

1.2 Classification of Routing Algorithms of WSNs

Since there are numerous applications for WSNs, this leads to propose many new algorithms to be compatible with different applications and different network structure. These routing algorithms have considered in their design WSNs characteristics, we summarized some of them earlier. All types of routing algorithms can be classified within four categories, which are data centric protocols, location based protocols, hierarchical protocols, and network flow and QoS-aware protocols [5].

1.2.1 Data Centric Protocols

In most applications of WSNs, it is unfeasible to use global identifiers for the deployed sensor nodes. If we consider the random deployment of sensor nodes along with the lack of global identifiers, it will be difficult to choose a specific group of sensor nodes to be queried. So that, when data transmitted from sensor nodes within specific field would have significant redundancy then it will consume more energy. Because of this problem, they come up with data centric protocols. In this type of routing algorithms, the base station send query to specific area and wait for receiving data from the sensor nodes located in that area. The base station specifies the properties of data using attribute-based naming. The first proposed data centric protocol is Sensor protocols for information via negotiation (SPIN)[5].

1.2.2 Location Based Protocols

Generally, in many applications for WSNs, the position of sensor node is required. The reason that in some cases it is necessary to know the location of sensor nodes is to estimate the energy dissipation between nodes in the sensing area. Moreover, sensor nodes location information can be used efficiently for energy conservation. For example, if the region needed to be sensed were known, by using the location information for the nodes, the query would be sent only to the demanded region, this would lead to significant reduction in the number of transmissions.

They mostly use GPS to updates their location information, so that they are also applicable for mobile sensor nodes. There are many location based routing algorithms but some of them are not applicable for WSNs because they are not energy aware. In order to stay with the theme of WSNs we will mention some examples which can be used as routing algorithms for WSNs like Minimum energy communication network (MECN) and Geographic adaptive fidelity (GAF) [5].

1.2.3 Hierarchical Protocols

In hierarchical algorithms sensor nodes are grouped within clusters or chains and one of those nodes act as the cluster head or chain head then all other nodes send their sensed data to their own head. The head will act as a gateway between sensor nodes and base station. The main aim that motivates researchers to come up with this kind of routing technique is scalability and robustness. Since hierarchical algorithms using multi-hop technique to transmit their data from sensor nodes to the head then to the base station it will reduce the energy consumed by data transmission in long distance and as a result for this reduction, it will increase the network lifetime. The main hierarchical routing algorithms for WSNs are Low-Energy Adaptive Clustering Hierarchy (LEACH), Power-Efficient GAthering in Sensor Information Systems (PEGASIS) and Threshold Sensitive Energy Efficient Sensor Network protocol (TEEN) [6-8].

1.2.4 Network Flow and QoS-aware Protocols

In this category of routing algorithms, there must be a balance between energy consumption and one or more other factors such as (end-to-end delay, bandwidth, throughput, etc.) when they send the data to base station. The first algorithm that consider as a QoS approach is Sequential Assignment Routing (SAR) [2]. SAR introduced as a routing algorithm that can obtain fault tolerance and energy efficiency together. Many other algorithms proposed to provide a specific QoS and network flow for instance SPEED algorithm provides soft real-time end-to-end guarantees [2].

1.3 Routing Difficulties and Design Challenges in WSNs

Although the numerous applications of WSNs, these networks have many limitations, such as limited computing abilities, limited energy resources and limited bandwidth [2]. One of the main important goals to design a routing algorithm for WSNs is to carry out data communication while trying to extend the network lifetime and prevent connectivity degradation by employing aggressive energy management techniques. Many factors can act as challenges in design a routing algorithm for WSN and in order to achieve an efficient communication in WSNs, these challenges must be overcome. We summarize some of the challenges that can affect the design of routing algorithm in WSNs.

1.3.1 Nodes Deployment

Deployment of nodes in WSNs depends on the application of the network under consideration, it can be randomized or deterministic. In random deployment, the nodes are randomly scattered in the target area. Random deployment, in practice, is faster than deterministic method and more feasible. On the other hand, it costs more sensor nodes to get more data accuracy [9]. In deterministic deployment, the nodes are manually installed according to predetermined distance. Although, it is time consuming to deploy the sensor nodes manually but it can use fewer nodes in comparison with random deployment with same accuracy level. An example of deterministic deployment is grid deployment.

1.3.2 Energy Consumption

During planning for the nodes' distribution, the process of designing the routing protocol is greatly affected by energy constraint. The energy consumption in wireless radio transmission is proportional to the square of the distance of transmission and sometimes higher than this in the presence of obstacles. To decrease the consequences of this issue, we have to choose one of two options, multi-hop routing or single-hop routing. Multi-hop routing is more energy conservation but it can cause more overhead for topology management [9]. On the other hand, single-hop routing has less overhead but it consumes much more energy than multi-hop because of the direct transmission to the sink especially, when the sensor nodes are relatively far from the sink. So that, using multi-hop routing, in most applications, become unavoidable.

1.3.3 Scalability

The number of nodes deployed, in any sensing area, can reach hundreds or even thousands of sensors. Therefore, the routing scheme for such area should consider this amount of nodes and must be able to handle all nodes in the sensing field [2]. In addition, routing protocol should have the ability to handle any probable scaling for the network.

1.3.4 Data Aggregation

Since sensors might generate redundant data, they implement a data aggregation to eliminate the duplicated data and consequently decrease the number of transmissions. The aggregated data is a combination of data collected from different sources and combined together in order to decrease the data packet size [5]. There are some functions can be used to aggregate the data such as minima, maxima, duplicate suppression and average. This technique is very efficient to improve the WSN lifetime, especially when multi-hop routing is applied in that network, because data aggregation can be very applicable technique when it is used along with multi-hop routing technique at the same algorithm.

1.3.5 Nodes Heterogeneity

According to the assumption of many studies, sensors were assumed to be homogenous (they have the same ability in terms of energy, communication and computation) [2]. Sensor node can have different abilities depending on the required function and application. The reason that motivates most of the researchers to use homogenous nodes is that the usage of heterogeneous nodes could come up with many issues related to data routing. For example, some clustering algorithms use the nodes with more capabilities in energy and bandwidth to act as cluster heads during the network lifetime while some other protocols use homogeneous nodes and periodically select new cluster head to distribute the load more evenly among all nodes.

1.4 Problem Statement

Energy consumption in WSNs represents a key issue in the lifetime of such networks. Due to the limitation in power source in WSNs, that is mostly small battery, many researchers have been trying to minimize the energy consumption in such networks. Especially in those networks that used for hostile areas such as volcanoes, battlefields and underwater, because once they scattered the nodes, it would be impossible to replenish them again.

One of the main techniques that can be very effective to minimize the energy consumption in such networks is the routing algorithm. In the recent years, a wide variety of routing algorithms have been proposed to solve the high-energy consumption and to extend the network lifetime of WSNs. Although there are many routing algorithms for WSNs, but until now there is no algorithm can be consider as a perfect and optimal algorithm that can be suitable for all WSNs. Each algorithm is proposed to be applicable for specific applications. The type of application will be used can decide which issues (i.e. energy consumption, delay, load balancing and etc.) will be taken in consideration during the design of routing algorithm. In this study, we proposed a routing algorithm that can work perfectly with grid-based WSNs and compare its performance with two existing algorithms that proposed to work with same network structure. The performance comparison will be based on four metrics, energy consumption, network lifetime, network stability and first node and last node died.

1.5 Scope of the Thesis and limitations

In this part, we clarify the scope of our study by explaining the type of routing algorithm, the network structure and the layer that we work on.

- The concern of the thesis will be within the network layer.
- The type of routing algorithms would be limited to hierarchical routing algorithms for WSNs.
- The structure of the network oriented on grid-based topology (2-Dimentional array).
- We cannot use this algorithm in a random distributed sensor nodes because our algorithm is using the (x, y) coordinates in order to achieve horizontal-vertical approach.

1.6 Research Objectives

1) To design, simulate, and analyze a new energy efficient routing algorithm for grid-based WSNs.
2) To investigate the impact of our proposed algorithm on horizontal-vertical approach using different networks size (small, medium, and large) networks.

3) To investigate the impact of utilizing the distance between the node and the base station along with the residual energy of corresponding node to decide upon the chain head nodes and main head node.

1.7 Thesis Organization

The rest of the thesis is divided as follows.

Chapter 2 – The literature review of hierarchical routing protocols for WSNs.

Chapter 3 – The description of materials and methods utilized for performing the study including working precepts of CCBRP, CCM and the proposed algorithm TSCP.

Chapter 4 – The explanation of simulation results and their discussion.

Chapter 5 – The conclusion.

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