ENERGY EFFICIENT CLUSTER HEAD DISTRIBUTION IN WIRELESS SENSOR NETWORKS

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ABSTRACT

ENERGY EFFICIENT CLUSTER HEAD DISTRIBUTION IN WIRELESS SENSOR NETWORKS

The main objective of this research is to improve the cluster based wireless sensor networks lifetime by selecting appropriate cluster head (CH) via improved swarm intelligence. In general, low energy adaptive cluster hierarchy (LEACH) is one of the most common clustering protocols used to elect the cluster head. The probability model will possibly lead to a reduction in network lifetime due to the election of CH with a least desired location in the network. For network clustering, the distribution of CH selection directly influences the networks lifetime. In order to maximize the network lifetime, fuzzy logic CH selection (FLCH) and particle swarm optimisation (PSO) are embedded in LEACH protocol for better CHs distribution and hence prolong the network lifetime. PSO is lightweight heuristic optimization algorithm with each CH will move towards the best solutions by individual interaction with one another while learning from their own experience. Thus, the best selected CHs location with network global information using FLCH and PSO will be announced by the base station (BS) to the sensor nodes. Therefore it can significantly increase the networks lifetime. Evaluation and assessments have been carried out through simulation under different network topologies and it shows that FLCH selection improved first node dies (FND) round by 26.88 % as compared to LEACH. The proposed of fuzzy logic based PSO (FPSO) to automatically tuning the inertia and velocity value for each particle has further improved the FND round over the LEACH by 61.41 %. Therefore, it can be concluded that the developed FLCH and FPSO can increase the network lifetime by proper CHs selection.

ABSTRAK

Objektif utama kajian ini adalah untuk meningkatkan jangka hayat rangkaian sensor tanpa wayar berasaskan sistem kluster dengan memilih ketua kluster (CH) yang berpatutan. Secara umum, pengugusan mudah suai hierarki kuasa rendah (LEACH) merupakan salah satu protokol pengklusteran yang akan melantik ketua kluster berdasarkan model kebarangkalian yang mungkin akan mengakibatkan pengurangan dalam jangka hayat rangkaian disebabkan oleh pemilihan ketua kluster dengan lokasi rangkaian yang kurang memuaskan. Bagi protokol pengklusteran rangkaian, lokasi ketua kluster akan mempengaruhi jangka hayat rangkaian secara langsung. Untuk memaksimumkan jangka hayat rangkaian, particle swarm optimisation (PSO) bersepadu dalam LEACH protokol untuk menghasilkan lokasi ketua kluster yang lebih baik untuk memanjangkan jangka hayat rangkaian. PSO adalah pengoptimuman algoritma heuristik ringan di mana setiap ketua kluster akan bergerak menuju ke arah penyelesaian yang terbaik dengan berinteraksi dengan satu sama lain sambil belajar dari pengalaman sendiri. Oleh itu, lokasi ketua kluster yang terbaik akan dipilih dan diumumkan oleh stesen pangkalan (BS) kepada nod sensor yang lain. Dengan cara ini, jangka hayat rangkaian akan di panjangkan dengan lokasi ketua kluster yang sesuai. Penilaian telah dijalankan melalui simulasi dengan topologi rangkaian yang berbeza dan ia menunjukkan bahawa pemilihan ketua kluster dengan fuzzy logic (FL) dapat meningkatkan pusingan bagi nod pertama tidak berfungsi (FND) sebanyak 26.88% berbanding dengan LEACH. Kajian ini mengenalkan FL berasas PSO (FPSO) secara automatik untuk menala inersia dan halaju bagi setiap particle dan telah mempertingkatkan pusingan FND berbanding dengan LEACH sebanyak 61.41%. Oleh itu, kesimpulan boleh dibuat bahawa pemilihan ketua kluster dengan fuzzy logic (FLCH) dan FPSO dapat meningkatkan jangka hayat rangkaian dengan pemilihan CHs yang lebih berpatutan.

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LIST OF ABBREVIATIONS

ABC	Artificial Bee Colony
ADC	Analog to Digital Converter
AI	Artificial Intelligence
ALEACH	Adaptive Low Energy Adaptive Clustering Hierarchy
APTEEN	Adaptive Periodic Threshold Sensitive Energy Sensor Network
BS	Base Station
CH	Cluster Head
CHEF	Cluster Head Election with Fuzzy Logic
CPU	Central Processing Unit
DWEHC	Distribution Weight-Based Energy Efficient Hierarchical Clustering
EA	Evolutionary Algorithm
EECF	Energy-Efficient Clustering
Eu	Euclidean Distance
E-LEACH	Energy-Low Energy Adaptive Clustering Hierarchy
FIS	Fuzzy Inference Engine
FL	Fuzzy Logic
FLCH	Fuzzy Logic Cluster Heads Selection
FND	First Node Dies
FPSO	Fuzzy based Particle Swarm Optimisation
GA	Genetic Algorithm
GA-ABC	Genetic Algorithm Artificial Bee Colony
GSM	Global System for Mobile Communications
GUI	Graphic User Interface
HEED	Hybrid Energy Efficient Distribution Clustering

H-PEGASIS	Hierarchical-Power-Efficient Gathering in Sensor Information System
ID	Identification
I/O	Input and Output
LEACH	Low Energy Adaptive Clustering Hierarchy
LEACH-C	Low Energy Adaptive Clustering Hierarchy-Centralized
LEACH-D	Low Energy Adaptive Clustering Hierarchy-Distribution
LEACH-F	Low Energy Adaptive Clustering Hierarchy-Fixed
LEACH-FL	Low Energy Adaptive Clustering Hierarchy-Fuzzy Logic
LEACH-TM	Low Energy Adaptive Clustering Hierarchy-Thrust Multi-Path
LND	Last Node Dies
MC	Momentum Factor
M-LEACH	Multihop-Low Energy Adaptive Clustering Hierarchy
MTE	Minimum Transmission Energy
NP-Hard	Non-Deterministic Polynomial-Time Hard
PSO	Particle Swarm Optimisation
PSO-DH	Particle Swarm Optimisation-Double Cluster Heads
PSO-SSM	Particle Swarm Optimisation-Supervisor Student Model
PSO-TVAC	Particle Swarm Optimisation-Time Varying Acceleration Coefficients
PSO-TVIW	Particle Swarm Optimisation-Time Varying Inertia Weight
PEGASIS	Power-Efficient Gathering in Sensor Information System
RF	Radio Frequency
ROF	Radio Over Fiber
RSS	Radio Signal Strength
SI	Swarm Intelligence

SNR	Signal-to-Noise Ratio
TDMA	Time Division Medium Access
TEEN	Threshold Sensitive Energy Sensor Network
TPC	Transmission Power Control
UMTS	Universal Mobile Telecommunications System
WSN	Wireless Sensor Network

LIST OF SYMBOLS

γ	Weight of Fitness Function
c_1	Acceleration Coefficient of Cognitive Component
c_2	Acceleration Coefficient of Social Component
Co	Fitness Cost
D	Dimension
de	Transmit Distance
$dist$	Average radius of the preferred cluster
E	Sensor Node Energy
E_0	Initial Sensor Node Energy
E_{DA}	Data Aggregation Model
Eu	Euclidean Distance
f_1	Fitness Value of Energy Consideration
f_2	Fitness Value of Cluster Size Consideration
G	Set of Non-Cluster Heads
$iter$	Current Iteration
i	Particle Number
I	Total Number of Particles
k	Cluster
K	Total Number of Clusters
ke	Data Packet Size
$\max\_iter$	Maximum Number of Iteration
n	Number of Sensor Node
N	Total Available Sensor Nodes
p	Desire Percent of Cluster Heads

P_G	Global Best Position
P_i	Previous Best Position for particle i
r	Current Round
r_1	Random Number Generator 1
r_2	Random Number Generator 2
t	Time (second)
T	Cluster Head Selection Threshold
v	Particle Velocity
x	Particle Position
w	Inertia Weight

CHAPTER 1

INTRODUCTION

1.1 Wireless Sensor Networks

Wireless sensor network (WSN) has been announced as one of the technologies that will change the world (Technology Review, 2003). A sensor node equipped with processing unit, communication unit, sensing unit and power unit is capable to monitor the environmental parameters and further deliver to the end users. In addition, hundreds and thousands of tiny smart sensors nodes deployed in a sensing area can form a powerful WSN. The advance in WSNs technology will change the way we live and interact with the physical world (Zheng and Jamalipour, 2009). Like the internet that linked the world together, billion of sensor nodes all over the world have the ability to link the physical environment to the digital world together. For example, the WSN application allows the end user from one side of the globe to access into weather station located at the opposite site for real-time climate monitoring purpose.

At 1900s, Defense Advanced Research Project Agency (DARPA) had carried out a series of WSN researches (Chong and Kumar, 2003). Due to the technologies limitation at that time, the development of a small size sensor node is a challenging task. Recent advance in microelectromechanical systems (MEMS) has lead to the emergence of WSNs. The advanced in MEMS technology, has significantly reduce the size and development cost of a sensor node. WSN shown wide range of potential applications therefore various studies have been carried out to improve the constraints of WSN.

Sensor nodes have to deploy over the interest area to continuously monitor the physical phenomenon for a few months or even a year. The monitoring operation requires sensor nodes to have a big capacity of power storage for operating at a longer period. But most of the time, a sensor node only equipped with limited power capacity due to its small size (Hu and Cao, 2009). The problem becomes significant when the sensor nodes are deployed in hazardous area which replacing the battery become impossible and impractical. Therefore, it is important to design an energy efficient WSN.

1.2 Energy Efficient Wireless Sensor Network Design

Many researchers are investigating the ways to improve the energy efficiency and power awareness in WSN design. To achieve low-power consumption at the sensor node, it is important to have intelligent power management and low-power circuit design (Zhu *et al.*, 2009; Chen *et al.*, 2009). Moreover, apart from the main power source, the integration of charging system provides the sensor node a secondary power source. Secondary power source can be harvested from solar, vibration, wind and so on.

Although it can achieve low power consumption at the node level by designing a low-power circuit, there is another way to improve the energy efficiency in WSN. The energy efficiency in WSN can be improved via proper network layer design. Network layer is responsible for data routing in the network. In WSN, the energy consumed for communication is much higher than other tasks such as sensing and computing (Feng *et al.*, 2002). For example, the energy needed to transmit one bit of data for 100 m is equal to the energy consumed to execute 3000 instructions (Zheng and Jampolipour, 2009; Pottie and Kaiser, 2000). Therefore, by focusing on the communication activity can optimise the energy utilization in WSN.

Hierarchical clustering based routing protocol has been introduced to enhance the network performance while reducing the energy consumption (Akkaya and Younis, 2005). Basically, in clustering based routing protocol, sensor nodes are grouped into few clusters. By only allowing the clusters leaders and cluster heads (CHs) to directly transmit aggregated data to the base station (BS), it reduces the overall energy consumption of the network. Conventional fixed clusters protocol experienced faster energy draining in CHs due to uneven heavy workload distribution.

Heinzelman *et al.* (2000) proposed low energy adaptive clustering hierarchy (LEACH) protocol to randomly select the CHs and evenly distribute the workload by rotating the CHs. Since LECAH protocol select CHs based on probability model, therefore the selected CHs may not be in the desire location. The selected CHs may locate near to one another, or vice versa. At the same time, there could be none or too many CHs being selected. This phenomenon is mainly due to the lack of global information used to select the CHs.

To improve the LEACH protocol, lightweight heuristic optimisation algorithm like particle swarm optimisation (PSO) is selected as the CHs selection algorithm. PSO algorithm can search iteratively for better CHs formation that has lowest energy consumption in current situation. The consideration of sensor node remaining energy and cluster size in CHs selection can result in longer network lifetime. It is challenging to define the proper parameter (inertia weight and acceleration coefficients) values for PSO algorithm and the solution may easily trapped in local maxima.

It is time consuming and troublesome to set optimum parameter values for different network topologies. Therefore, in this work fuzzy logic (FL) based PSO (FPSO) is introduced as CHs selection algorithm. The uses of FL can control the trade-off balance of exploration and exploitation of PSO algorithm to seek for better CHs formation. In addition, the introduction of particle reselection mechanism can reduce the chances of PSO algorithm for being trapped at local maxima.

1.3 Scope of Work

This research focuses on the control and computation of PSO parameters to enhance the performance of PSO based CHs selection in prolonging the network lifetime. The work is initiated with the review of the optimization in WSN energy utilization. The review provides information about the present and past researches plus the trend of energy efficient WSN. The hierarchical clustering based routing protocol is modelled and simulated in MATLAB m-file. The developed model is mainly focused on the energy consumption of the network operations. Swarm intelligence (SI) will be chosen as CHs selection algorithm that is being conducted at the base station (BS). Adaptive SI approach is designed to improve the original SI adaptability for better of CHs formation searching.

1.4 Research Objectives

The objective of this research is to optimise the energy utilisation in the hierarchical network to prolong the first node dies (FND) round. Optimisation of energy utilisation can be achieved through proper selection of CHs formation. LEACH protocol is constructed as simulation model of hierarchical clustering based protocol. PSO based clustering algorithm is developed to select suitable CHs formation for each round. FL is adapted into the PSO algorithm for better control of the trade-off balance in search space exploration and exploitation. The developed fuzzy PSO (FPSO) CHs selection algorithm is tested in various simulations to investigate the improvement of the network lifetime. The research objectives can be achieved through the following efforts:

1.4.1 To Model and Simulate the Energy Efficient Adaptive Clustering Network

LEACH protocol is selected as the study model in this research. Using the algorithm provided by Heinzelman *et al.* (2000), LEACH protocol energy model is constructed and written in MATLAB m-file coding. LEACH protocol simulation model has been developed to illustrate the similar characteristics of real LEACH protocol. The developed model is further enhanced with the additional of data aggregation model and path loss model. The used of these models in the simulation model can increase the similarity to the real application. This is important since the lack of these models considerations in the development cannot accurately calculate and represent the energy consumption during data aggregation process in the CH and long distance transmission losses for all the sensor nodes. Lastly, the performances of the developed LEACH protocol are observed and compared to the conventional direct transmission and random CHs selection methods.