A NEW WIRLESS SENSOR NETWORKS DEPLOYMENT STRATEGY USING HYBRID PARTICLE SWARM OPTIMIZATION

by

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LIST OF ABBREVIATIONS

SN	*Sensor network*
PDR	*Packet delivery ratio*
LMOJPSO	*Lag multi-objective jumping particle swarm optimization*
ELM	*Extreme learning Machina*
ROI	*Region of interesting*
WSND	*Wireless sensor network deployment*
MOO	*Multi objective optimization*
2D	*Two dimensional*
QOS	*Quality of service*
RSSI	*Received signal strength indictor*
TOA	*Time of arrival*
TDOA	*Time different of arrival*
LVQ	*Learning vector quantization*
BPSO	*Binary particle swarm optimization*
DE	*Differential evolution*
HS	*Harmony search*
NSAG-II	*Non-dominated Sorting Genetic Algorithm II*
GA	*Genetic algorithm*
PSO	particle swarm optimization
ABC	*artificial bee colony*
DSC	*Dynamic Stability Control*
MCSDP	*Maximum coverage sensor deployment*
LA	*Learning automation*
LT	*Life time*
GPS	Global Positioning System
NDS	*Non-dominated solutions*
H. V	*Hyper volume*
ZDT	*Zitzler-Deb-Thiele)*
SN	*Sensor network*
PDR	*Packet delivery ratio*
LMOJPSO	*Lag multi-objective jumping particle swarm optimization*
ELM	*Extreme learning Machina*
ROI	*Region of interesting*

LIST OF SYMBOLS

$\boldsymbol{N_{si}}$	*Number of sensing intersections*
$\boldsymbol{A_{si}}$	*Area of sensing intersection*
$\boldsymbol{avg_{dn}}$	*Average of distances between nodes*
$\boldsymbol{avg_{ds}}$	*Average of distances between nodes and sink*
$\boldsymbol{N}$	*Number of nodes*
$\boldsymbol{N_c}$	*Number of connections to the sink*
$\boldsymbol{Avg_{pns}}$	*Average of paths node number to the sink.*
$\boldsymbol{max_{pns}}$	*Maximum path node number to the sink*
$\boldsymbol{min_{pns}}$	*Minimum path node number to the sink*
$\boldsymbol{Avg_{pls}}$	*Average of paths length to the sink*
$\boldsymbol{max_{pls}}$	*maximum path length to the sink*
$\boldsymbol{min_{pls}}$	*Minimum path length to the sink*
$\boldsymbol{stdR_s}$	*Standard deviation of connectivity radius over distance to the sink*
$\boldsymbol{Avg_{rds}}$	*Average of connectivity radius over the distance to the sink*
$\boldsymbol{Avg_x}$	*Average of X coordinate*
$\boldsymbol{Avg_y}$	*Average of Y coordinate*
$\boldsymbol{Avg_{sr}}$	*Average of sensing radius*
$\boldsymbol{Avg_{cr}}$	*Average of connectivity radius*
$\boldsymbol{\alpha}$	*Alpha*
$\boldsymbol{\beta}$	*Beta*

A New Wireless Sensor Network Deployment Strategy Using Hybrid Particle Swarm Optimization

ABSTRAK

Penempatan Sensor (SN) merupakan salah satu cabaran utama dalam seni bina rangkaian sensor tanpa wayar. Salah satu isu asas dalam penempatan sensor tanpa wayar ialah mencari keseimbangan antara dua objektif rangkaian yang bercanggah; Nisbah Penghantaran Paket (PDR) dan jangka hayat rangkaian, di bawah liputan tertentu dan kekangan penyambungan. Walaupun pendekatan pengoptimuman pencarian meta-heuristik telah digunakan secara umum, ia telah gagal menangani beberapa isu yang berkaitan dengan multi-objektif dan permukaan pengoptimuman rumit. Bagaimanapun, sifat multi-objektif masalah ini dan permukaan pengoptimuman yang rumit memerlukan pengoptimalan carian meta-heuristik multi-objektif yang disesuaikan. Tesis ini mencadangkan pendekatan "Lagged Multi-Objective Jumping Particle Swarm Optimization (LMOJPSO)" yang bertujuan untuk mencari bahagian depan Pareto yang memaksimumkan nisbah penghantaran paket dan meminimumkan penggunaan tenaga sensor untuk memanjangkan jangka hayat rangkaian. Rangka kerja LMOJPSO yang dicadangkan untuk meningkatkan prestasi proses pengoptimalan carian meta-heuristik, dilakukan dengan menggabungkan dua teknik pencarian yang berbeza. Teknik pengoptimuman pertama dijalankan dengan bantuan Mesin Pembelajaran Melampau (ELM), dan pengoptimuman carian kedua menggunakan kaedah simulasi rangkaian sensor tanpa wayar. Dalam tesis ini, kaedah yang dicadangkan diperiksa dalam contoh ujian rangkaian sensor tanpa wayar dan penilaian prestasinya dilakukan dengan menggunakan metrik prestasi rangkaian sensor tanpa wayar. Keputusan menunjukkan bahawa model yang dicadangkan lebih unggul daripada Algoritma Genetik Penyusunan yang Tidak Dikuasai (NSGA-II).

A New Wireless Sensor Network Deployment Strategy Using Hybrid Particle Swarm Optimization

ABSTRACT

Sensor Deployment (SN) is one of the major challenges in wireless sensor network architectural. One of the most fundamental issues in wireless sensor deployment is to find a trade-off between two conflicting network objectives; Packet Delivery Ratio (PDR) and lifetime, under certain coverage and connectivity constraint. Although the approach of meta-heuristic searching optimization has been commonly applied, it has failed in addressing several issues related to multiple objectives and intricate optimization surface. However, the multi-objective nature of this problem and the complicated optimization surface requires developing customizable multi-objective meta-heuristic searching optimization. This thesis proposes a Lagged Multi-Objective Jumping Particle Swarm Optimization (LMOJPSO) approach that aims to find the Pareto front that maximizes the packet delivery ratio and minimizes the sensor energy consumption for prolonging network lifetime. The proposed LMOJPSO framework for improving the performance of the meta-heuristic search optimization process, is done by combining two different searching techniques. The first optimization technique carries out its searches with the help of Extreme Learning Machine (ELM), whereas the second search optimization uses a wireless sensor network simulator. In this thesis, the proposed method is examined in a given wireless sensor network test instances and the evaluation of its performance is carried out by using a wireless sensor networks performance metric. The results indicated that the proposed model is superior to the Non-dominated Sorting Genetic Algorithm (NSGA-II).

CHAPTER 1 : INTRODUCTION

Wireless sensor networks (WSNs) are composed of a large number of small, multifunctional electronic devices named sensors. The geometrical distribution of these sensors inside a region of interest (ROI) is called deployment. Each sensor is responsible for collecting data from surrounding areas and transmitting both its data and that of its neighbours to other sensors that can then send the data to gateways. WSNs have two types of data transmission to a gateway: direct and multi-hop. If the network collaborates to assist in reliable data transmission between any node and the sink, then its performance metrics are improved.

Wireless sensor networks are involved in several areas of research such as network coverage, communication and security, etc. This thesis specifically concentrates on lifetime problem and the packet delivery ratio (PDR). however, in many applications like target detection, monitoring of battlefield, home safety, personal protection or animal habit monitoring, the system performance is closely linked to lifetime and PDR problems. The most important factor is the positioning of the sensors in the wireless sensor network. For maximum lifetime and a good packet delivery ratio, sensors are deployed planned. Sensors cannot be deployed planned under certain conditions such as, in applications involving areas suffering from natural disasters or harsh environments. In addition, sensors may not be deployable one-by-one in precise locations if the sensing field is very large or has only limited entry. Instead, they may need to be deployed all at once from an aircraft. When sensors are deployed randomly, as in planned deployment, the area coverage initially provided by the sensor network cannot be guaranteed to be optimal.

The networks are very useful for accessing harsh or remote areas and cost-effectively observing situations in such locations. The coverage of wireless sensor network deployment (WSND) depends on the number of sensors used, along with their positions in the area that must be monitored. Therefore, to maximize the spatial coverage of these networks, various optimization algorithms have to be applied to determine the best location for every sensor within the network. Sensor coverage is a huge problem in WSNs, which must be considered when improving the connectivity and coverage of the network configuration, as well as for energy conservation.

Researchers have used optimization algorithms to address issues related to sensor deployment and improve coverage. They have ensured that every region is monitored by at least one sensor node. Good coverage is important for an effective WSN (Chehreghan et al., 2016). According to many researchers, the major issues of WSND include the placement of a minimal number of sensors to achieve maximal coverage, maintenance of the best network connectivity, and low energy consumption. Some also stated that energy consumption costs, implementation, and maintenance costs have to be considered, since the manner in which sensors are deployed could significantly affect the cost and flexibility of a WSN. The balance between coverage quality and implementation costs must be optimized before all sensors are deployed. Furthermore, energy consumption has to be effectively optimized for increasing the life of a network. Metaheuristic algorithms offer alternative processes for quickly determining the optimal solutions, in comparison to other algorithms which require a long time to converge effectively (Tsai et al., 2015). Every metaheuristic algorithm displays its characteristic features; no single metaheuristic algorithm can solve all optimization problems and always provide the best result with regards to outcome quality and computation time.

However, applied a machine learning model for predicting the fitness values of random solutions this will increase the number of solutions for each iteration. After a fixed number of iterations, metaheuristic optimization was considered as an initial population comprised of a different metaheuristic optimization, which used two simulators model to training the dataset based on extreme learning machine (ELM), to accurately estimate the fitness values of all solutions for a longer time period. In this framework, extreme learning machine optimization could rapidly predict the single-hidden-layer neural network. This improved the metaheuristic algorithm and elevated it to an advanced search level in the whole solution space.

1.1 Research Background

A typical sensor network consists of a large number of sensor nodes deployed in or near the phenomenon of interest. These sensor nodes are devices with sensing, computing and wireless communication capabilities. However, the sensors take measurements and transmit their observation data to single or multiple sink, via wireless interfaces. Sensor tasks include sensing temperature, light, humidity, vibration, sound, etc. WSN applications typically include monitoring, tracking, and controlling. Specific applications included environmental monitoring, health systems, structural monitoring, management of supply chains, surveillance of disaster and military support. (Z. Zhang et al. 2018). However, if an earthquake or an outbreak occurs, sensor nodes detect it and send data through a multi-hop network to a base station. Data from several base stations can be collected and analyzed to produce accurate volcano mappings. The WSNs were recognized as one of the 21st century's most important technologies. The main areas of WSN application are presented in the following section.

1.1.1 Military applications

The military was an initial engine for the development of sensor networks. The various advantages these networks offer include, among others, rapid deployment, reduced equipment costs, self-organization, and fault tolerance, which make this type of network highly appreciated in the military field. A network of sensors deployed in a battlefield in a strategic or difficult-to-access area allows, for example, the monitoring of enemy movements or an analysis of the terrain (detection of mines, chemical or biological agents, radiation, etc.) before deploying troops.

1.1.2 Monitoring applications

The application of WSNs in the field of security can significantly decrease the money spent on securing places and people. Thus, with intelligent and autonomous networks, the structures of planes, ships, automobiles, subways, and public places can be followed in real time. Similarly, energy circulation or distribution networks can be monitored and controlled in real time by a WSN. In addition, the integration of sensors into large structures such as bridges, roads, platforms, railways, or buildings can help detect any cracks or alterations in the structures in the event of earthquakes or aging.

1.1.3 Environmental applications

The control of environmental parameters by WSNs gives rise to several potential applications (Duncan et al., 2014). For example, the deployment of thermo-sensors in a forest can help detect the possible start of a fire and can subsequently facilitate a means of control in real time. The deployment of chemical sensors in urban settings can help to detect pollution and analyze air quality. Similarly, the deployment of sensors at industrial sites can prevent certain industrial risks, such as the leakage of toxic products (gases, radioactive chemicals, etc.). Sensor nodes can also be deployed in space or at the bottom of the ocean by aircraft, balloons, or ships to measure environmental parameters on these catchment fields and report potential environmental problems (e.g., pollution, weather hazards, etc.).

1.1.4 Medical applications

The implementation of sensor nodes in living organisms can help physicians collect measurements on certain physiological parameters and monitor, in real time, the vital functions of these organisms. Furthermore, multi sensor capsules or micro cameras can be swallowed without the need for surgery and allow the transmission of images of the interior of a human body. Other biomedical applications based on the WSN also exist today, such as blood glucose monitoring and early detection of cancers. With such applications, classical medicine is entering an age of "wireless medicine" (Lounis et al. 2016) that allows a doctor to consult his patients remotely in order to either collect medical data or follow up.

1.1.5 Commercial applications

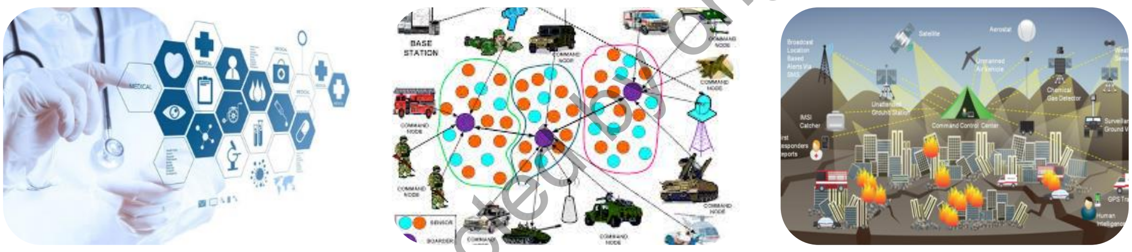
WSNs can be used in the commercial field to help merchants improve the process of storing the delivery of goods. It is also possible for a WSN to know at any time the position, state and direction of a given piece of merchandise or cargo. Thus, a customer waiting for a given item can receive a delivery notice in real time. In addition, end-of-life products could be better disassembled and recycled or reused thanks to WSNs. Manufacturing companies, via the WSN, could also follow the production process, from raw materials to final delivery of a given product. Thus, through the use of WSN in the commercial field, companies could offer a better quality of service while reducing their costs.

1.1.6 Home automation applications

Home automation is a field of application in which WSNs are increasingly emerging. A WSN can be deployed for habitat monitoring, and sensor nodes provide an intelligent environment to provide all the information needed for comfort, safety, and maintenance applications within a habitat. In such applications, the sensors are generally presence detection sensors, sound sensors, wireless sensor cameras, etc. In other applications, home automation systems for heating, cooling, lighting, or water distribution could help maximize efficiency through sensor nodes in tiles, building walls, etc.

1.1.7 Agricultural applications

WSNs can be deployed in the field of agriculture and incorporated into the soil to measure certain parameters, such as moisture content and temperature. Collecting these parameters, which are usually sent to a treatment centre, can help farmers optimize irrigation or nutrients. The WSN can be queried to determine the driest areas and irrigate them first. This application of WSNs in the agricultural field is increasingly common today and is often referred to as "smart farming or precision farming." It allows the use of a WSN as a decision support tool and provides farmers with better process control.



Medical applications Militaries applications Monitoring applications

Commercial applications Home Automation Agricultural applications

Figure 1.1: Wireless sensor network applications (Akyildiz at el, 2002)

1.2 Research Motivation

Wireless sensor network is a self-organized network consist of big number of sensors that are deployed randomly through wireless communication in regional surveillance. WSN has become ultimate technology in the filed of communication and computer science with its broad implementation in military recognition, medical assistance, environmental monitoring, logistics management and other business sectors. Sensor nodes depend on battery power supply, their communication capacity and energy storage capacity are very restricted, so how to use node energy effectively, balance network energy consumption and extend the lifetime of the network has become main design goal for WSN.

For example, a sensor network deployed to monitor road traffic detects traffic congestion during peak hours or due to an accident. Once the detection application is complete, these sensors would need to run a new application, diverting vehicles towards alternative roads by activating traffic signs accordingly. Similarly, in a forest fire detection application, when fire is detected and fire fighters arrive, they may want to reprogram the sensor network to initiate search and rescue operations. In these applications, nodes perform multiple functions; however, these nodes only support one application throughout the network. Most wireless sensor networks are limited because an application must be installed prior to deployment and, once deployed, is rarely changed. These are just a few examples of an urgent need for WSNs to be able to execute multiple applications.