A Pre-defined Scheme for Optimum Energy Consumption in Wireless Sensor Network

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***Abstract*—One of the fundamental issues that needs a serious attention in Wireless Sensor Network (WSN) is node deployment. A proper node deployment scheme can help extending the lifetime of WSN's by reducing the energy consumption. In this paper, we implement Improved Harmony Search (IHS) algorithm with several modifications in determining the best position for each sensor node in order to obtain an optimum energy consumption. The number range in selecting the random number to determine a new harmony is expended. Based on the experiment, the result obtained gives lower energy consumption rate. To enhance the energy performance, we test the best sink node's position to obtain the best position for sink node.**

***Index Terms*—Energy Consumption; Improved Harmony Search; Node's Deployment; Wireless Sensor Network.**

I. Introduction

In WSN, the nodes do two important tasks which are collecting the data within their range and forward the data which are far away from the sink node. This leads to unequal power consumption among the sensor nodes. Hence, a proper node's deployments strategies are needed to be carried out. Figure 1 explains what WSN is all about. Finding the suitable location of sensors that gives optimum coverage area is what node deployment all about [1]. A suitable sink placement strategy can strongly increase both lifetime of network and decreases the energy consumption by decreasing the distance between the sensor nodes and sink node. Therefore, in this paper we explore nodes placement strategies for WSNs to provide better energy-efficiency, and at the same time, prolong network lifetime.

In this paper, the sink placement strategy is inspired by Harmony Search (HS) method. HS basically is about finding a perfect match of harmony by the musician. A musician composes a new song by combining and adjusting the existing harmony until it gives a new lovely harmony. It is similar to the optimization problem where the objective is to extent the best solution available to the problem under known objectives and constraints. The selection of parameters should be conducted very wisely, since it determines the success of the proposed algorithm and gives a fine performance of HS. Parameters included in HS are Pitch Adjustment Rate (PAR) and Bandwidth (BW).

The paper consists of 6 sections. Section 2 outlines the related and previous work. Section 3 describes the problem statement of the experiments. Section 4 introduces the system model of the method used. Section 5 presents the result of the experiment. The conclusion is finally given in Section 6.

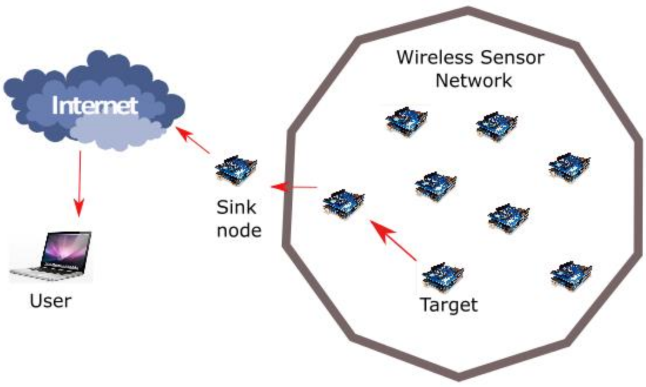

Figure 1: Wireless Sensor Network

II. Related Works

A. Harmony Search Algorithm

Harmony Search (HS) algorithm is very simple in concept and easy in execution. It operates with only a few parameters. Figure 2 shows the flowchart of Harmony Search process. It is very effective for optimization purpose and demonstrates various benefits of using the optimization techniques [2]. Harmony Search algorithm has been applied in variety field such as power system. Ren Ping in [3] uses Harmony Search algorithm in solving the short-term cascade hydroelectric power generation system plan. The main purpose is to minimize the fuel cost of thermal power plant. The algorithm is categorized by a cascade flow continuously variable network, reservoirs and water transport natural delay between inflows. The overall power generated used after applying the method gives decreasing reading compared to the normal method. Mir Nahidul Ambia in his paper [4] uses HS algorithm to design the proportional-integral (PI) controllers of a grid-side voltage source cascaded converter.

HS is applied in Response Surface Method (RSM) model. RSM model is a statistical method that is used to build a mathematical model by finding the connection between the design variables and the reaction. Generic Algorithm (GA) and Generalized Reduced Gradient (GRG) method are also applied in the model, and the result is compared.

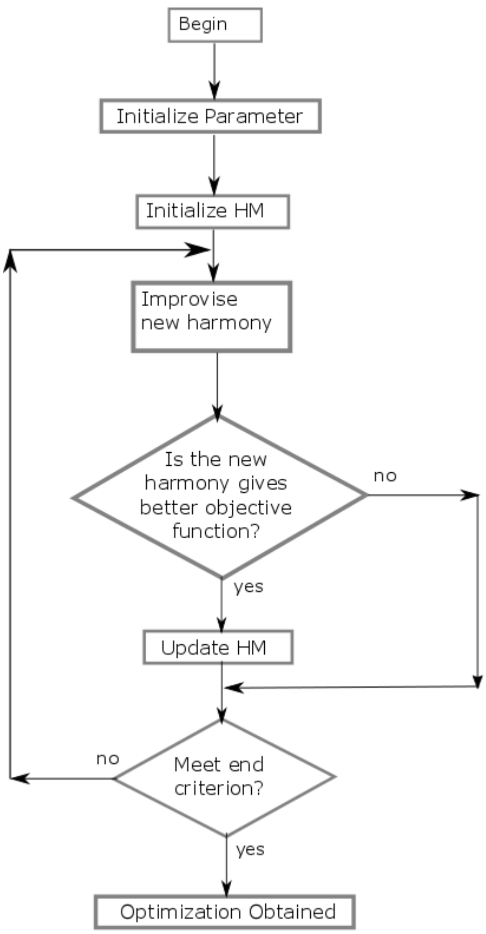

Figure 2: Harmony Search flowchart

B. *Sensor Nodes Deployment*

The node deployment strategy is focusing on what type of nodes are necessary and where it should be placed to attain the requirement set up [1]. S. Mini in [5] proposes a method to get the optimum deployment strategy of the sensor nodes with the pre-specified range and to schedule them in order to obtain a maximum network lifetime with the required coverage level. The first objective which is to deploy the sensor nodes such that the lifetime would be prolonged; the author compares 3 methods which are heuristic sensor deployment, Artificial Bee Colony algorithm and Particle Swarm Optimization (PSO). Based on the results, PSO algorithm contributes a better performance compared to the other two. The next procedure is scheduling. The purpose is to control the wake-up state of the sensors. The method proposed for nodes scheduling is weight-based method for defining the cover set. To decide the precedence of sensor nodes, weight assignment is performed. The higher the weight, the higher the priority.

In performing the nodes deployment, one of the factors needed to be considered is the environment with obstacle. Figure 3 shows the sensor node deployment. S. Mini in her paper [1] proposes a method that reflects outdoor environmental aspects with several number of nodes for Surveillance and Reconnaissance Sensor Networks (SRSN). The method proposed consists of four strategies. Environmental factor is first being analyzed. The sensor nodes will then be deployed. The Monitoring site is selected, and the last part is relaying node deployment. The result shows the coverage and network connectivity are improved by 20.9% and 21% from the initial deployment. In some recent research, HS algorithm is applied to determine the location of mobile nodes. In [6], Abdulqader Mohsen uses Markov model to determine the position of static nodes. The results show that node deployments based HSA maximize the overall coverage. It first finds the lowest number of further mobile nodes and their best positions in the field. It then are compared with the state-of-the-art algorithms like GA.

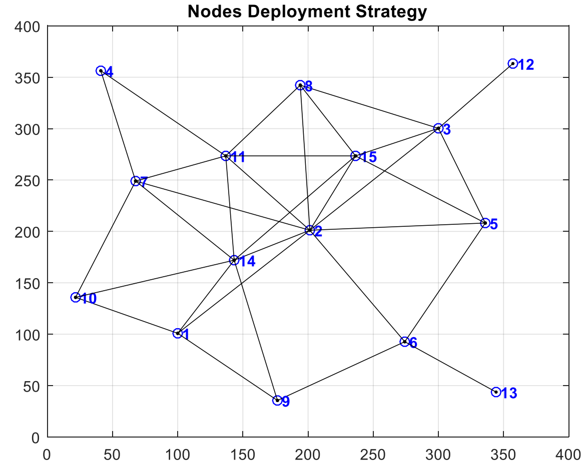

Figure 3: Node deployment strategy

III. PROBLEM STATEMENT

For this paper, the field with size 2D area with length × width dimension is assumed. Also, it is expected that all sensor nodes have identical sensory and communication ranges and homogenous. To find an optimal sensor placement, several conditions are needed to be fulfilled [1]. The conditions are:

1. The sensors are placed in a 2D area.
2. Sensors must have a good connectivity and can communicate with each other.
3. Hotspot areas must be covered by at least k sensors.

Improved Harmony Search algorithm is used to improve the energy efficiency of the sensor network as connectivity and k-coverage is well-kept. Fixed parameter length, width, and sensor numbers were used throughout the experiment.

IV. SYSTEM MODEL

HS algorithm procedure to achieve optimization consists of five steps as shown below:

1. Initialization of parameters
2. Initialization of Harmony Memory (HM)
3. Improvisation
4. Harmony Memory Update
5. Terminating Criteria Checked

Improved Harmony Search (IHS) method is slightly different compared to the conventional HS at the improvisation section. Basically, a new harmony vector, $x' = (x_1', x_2', L\, x_n')$ is created and is being compared with the existing vector in HM [10]. The new harmony vector is improvised according to the three rubrics which are:

1. HM consideration
2. Pitch adjustment
3. Random selection

IHS specifies the pitch adjustment rate (PAR) by including the minimum and maximum values of PAR. IHS also specifies the bandwidth (bw) the same way as PAR as shown in Equation (1).

$$x_i' \leftarrow \begin{cases} x_i' \pm rand(0,1) \times bw(gn) & with\ probability\ PAR(gn) \\ x_i' & with\ probability\ (1 - PAR(gn)) \end{cases} \quad (1)$$

where gn stands for generation number, bw(gn) is an arbitrary distance bandwidth (a scalar number) and rand(0,1) is a uniformly distributed random number between 0 and 1.

In this paper, we are applying Improved Harmony Search algorithm where the PAR(gn) increases linearly and bw(gn) decreases exponentially, as the number of iteration increases. Equation (2) and (3) show the expression of the new PAR and new bw(gn).

$$PAR = PAR_{min} + \frac{(PAR_{max} + PAR_{min})}{NI - 1} \times (ci - 1) \quad (2)$$

$$BW = BW_{max}\, e^{\frac{\ln \frac{BW_{min}}{BW_{max}}}{NI} \times (ci - 1)} \quad (3)$$

A. Initialization of parameters

In the first step, the parameters are set. Harmony Search algorithm operates with few parameters which are bandwidth (BW) and pitch adjustment rate (PAR). Table 1 shows the parameters used in the simulation.

Table 1
Parameters for the simulation

Parameters	Value
Data bits	250 bytes
HMS	10
HMCR	0.9
PARmin	0.4
PARmax	0.9
BWmin	0.0001
BWmax	1
Comm_Radius	100
Number of sensor	15
Area (width x length)	400 x 400
ϵ_{amp}	100pJ/bit/m2
E_{elec}	50nJ/bit

V. Experimental Analysis

Matlab programming language is used to simulate the energy efficiency problem. A platform similar to T. Emre Kalaci proposes in his paper is created [8]. Shohreh Ebrahim Nezhad in his paper implements Improved Harmony Search (IHS) algorithm and the result shows that the application of the IHS algorithm gives lower energy consumption. In this paper, we implement the IHS algorithm to the platform, but with several modifications in terms of random range number used in Equation (9). From the equation, the uniformly distributed random number is ranged from 0 to 1. For this experiment, we are expanding the range number from 0 to 5. The number of hotspot is set to be 1.

Figure 4 shows the results obtained for three ranges which are 0 to 1, 0 to 3 and 0 to 5. The simulation is done until the number of iteration reach 2000. From the results obtained, it can be clearly seen that the range number of 0 to 5 gives the lowest energy consumption. According to the equation, the random number is then be multiplied with bandwidth. The number is then be added to the current x and y value to create another new node placement. As the range number increases, more variety of node placement is produced. As can be seen in Figure 4, the overall graph shows a decreasing pattern for all three range numbers. It can be concluded that as the number of iteration increases, the energy consumption of the system decreases. The result proves that the Harmony Search concept does really give the optimum result. Table 2 shows the value of the energy consumption for each iteration.

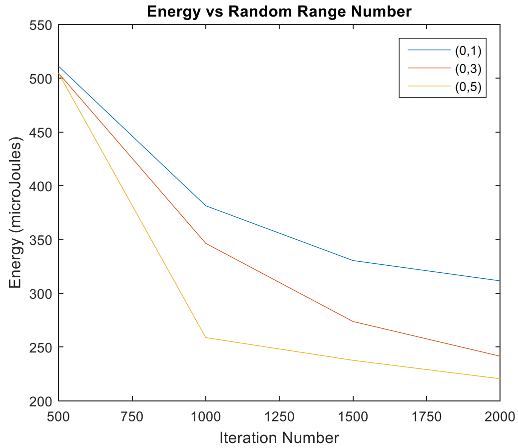

Figure 4: Energy reading as the range number increase.

Table 2
Energy consumption for different number range

Range number	500	1000	1500	2000
(0,1)	511.0406	381.3162	330.3737	311.4835
(0,3)	504.554	346.3627	273.696	241.4349
(0,5)	504.6	258.6946	237.61	220.47

The experiment is then continued by changing the sink node's location to find the ideal location to obtain a better result. The sink node's location is varied to three position which are (100,100), (200,200) and (300,300). Figure 5 shows the result obtained as the sink node's location changed. From Figure 5, it shows that the nodes deployment strategy with sink node is being located at (300,300) gives the lowest energy consumption compared to the other two sink node's locations.

The result is influenced by the initial node location at the beginning of the simulation. The nodes are densely deployed at the area between x = 150 and y = 300. During the initial energy calculating process, the energy stored in HM is lower compared to other sink node's location as the distance between other nodes to the sink node is nearer. Hence, the energy calculated is lower compared to others. Table 3 shows the energy consumption for each iteration.

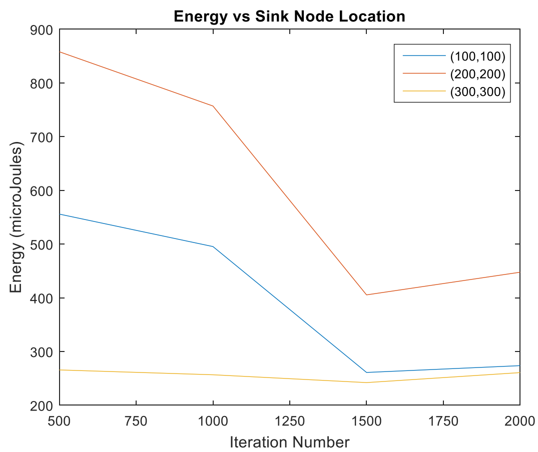

Figure 5: Energy reading as the sink node's location is being changed.

Table 3
Energy consumption for different sink node's position

Sink node's position	500	1000	1500	2000
(100,100)	555.81	495.39	261.033	273.701
(200,200)	857.99	757.04	405.45	447.63
(300,300)	265.72	256.723	242.1512	260.75

VI. Conclusion and Future Work

This paper implements Improved Harmony Search algorithm in sensor nodes deployment strategy with some modification made in the equation where the range number of selecting the random number is increases. The location of the sink nodes is also changed to find the ideal location and reduce the energy consumption of the nodes. The results for both experiments give positive reaction where the energy consumption decreases as the range number increases. For future work, the percentage of coverage area might be included as the criterion in determining the optimum energy consumption in each of the sensor nodes deployment. Besides that, the presence of mobile nodes can help in preserving the energy.

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References

[1] Y. Kim, M. Yeo, D. Kim and K. Chung, "A Node Deployment Strategy Considering Environmental Factors and the Number of Nodes in Surveillance and Reconnaissance Sensor Networks", *International Journal of Distributed Sensor Networks*, vol. 2012, pp. 1-11, 2012.T.

[2] N. Goyal and P. Singh, "Harmony Search Algorithm Based Optimal Placement Of Static Capacitors For Loss Reduction In Radial Distribution Network", *International Research Journal of Engineering and Technology (IRJET)*, vol. 3, no. 2, pp. 1047-1052, 2016.

[3] R. Ping and L. Nan, "Optimal Scheduling of Power System Using Harmony Search Algorithm", *International Conference on Fuzzy Systems and Knowledge Discovery*, vol. 12, 2015.

[4] M. Ambia, H. Hasanien, A. Al-Durra and S. Muyeen, "Harmony Search Algorithm-Based Controller Parameters Optimization for a Distributed-Generation System", *IEEE Transactions on Power Delivery*, vol. 30, no. 1, pp. 246-255, 2015.

[5] S. Mini, S. Udgata and S. Sabat, "Sensor Deployment and Scheduling for Target Coverage Problem in Wireless Sensor Networks", *IEEE Sensors J.*, vol. 14, no. 3, pp. 636-644, 2014.

[6] A. Mohsen, "A Robust Harmony Search Algorithm Based Markov Model For Node Deployment In Hybrid Wireless Sensor Networks", *International Journal of Geomate*, 2016.

[7] S. Ebrahim Nezhad, H. Jalal Kamali and M. Ebrahimi Moghaddam, "Solving K-Coverage Problem in Wireless Sensor Networks Using Improved Harmony Search", *International Conference on Broadband, Wireless Computing, Communication and Applications*, 2010.

[8] X. Liu and D. He, "Ant colony optimization with greedy migration mechanism for node deployment in wireless sensor networks", *Journal of Network and Computer Applications*, vol. 39, pp. 310-318, 2014.

[9] O. Abdel-Raouf and M. Abdel-Baset Metwally, "A Survey of Harmony Search Algorithm", *International Journal of Computer Applications* (0975 – 8887), vol. 7, no. 28, pp. 17-26, 2013.

[10] A. Abdolalipour and A. Alibabaee, "Harmony Search algorithm", *International Journal of Academic Research in Applied Science*, vol. 1, no. 3, pp. 13-16, 2012.

[11] S. Sengupta, S. Das, M. Nasir and B. Panigrahi, "Multi-objective node deployment in WSNs: In search of an optimal trade-off among coverage, lifetime, energy consumption, and connectivity", *Engineering Applications of Artificial Intelligence*, vol. 26, no. 1, pp. 405-416, 2013.

[12] A. Pannu and D. Kumar, "Clustering and General Self-Organized Tree-based Energy-Balance Routing Protocol for Wireless Sensor Network (CGSTEB)", *International Journal of Computer Applications*, vol. 118, no. 19, pp. 45-49, 2015.

[13] M. Azharuddin, P. Kuila and P. Jana, "Energy efficient fault tolerant clustering and routing algorithms for wireless sensor networks", *Computers & Electrical Engineering*, vol. 41, pp. 177-190, 2015.