# OPTIMIZATION TOPOLOGY OF ENERGY CONSTRAINED WIRELESS SENSOR NETWORKS

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## Abstrak

Sangatlah penting untuk pembaharuan sebuah kebutuhan konsumsi energi yang efisien pada peralatan wireless sensor network yang dapat digunakan untuk pemantauan dilingkungan dalam skala yang lebih luas seperti di belantara hutan disaat pengunaannya peralatan ini sangat memerlukan kebutuhan energi yang banyak. Sejak peralatan wireless sensor network mengunakan energi mengunakan baterai. Permasalahan mengantikan baterai pada peralatan wireless sensor network akan sulit dilakukan jika kondisi sudah terpasang dihutan. Pada paper ini, akan menyajikan bagaimana optimasi pengunaan energi pada perangkat router/coordinator cluster WSNs dengan tujuan untuk memaksimalkan sumber daya energi agar router dapat bertahap hidup lebih lama pada disebuah sensor network dengan mengunakan algoritma genetika.

**Kata Kunci:** Genetik algoritma, lifetime, WSNs, konsumsi energi.

## Abstract

It is important to improve energy efficiency of wireless sensor network (WSN) for measurement of environmental data in wide areas such as forests and wilds since replacement of batteries in the sensor nodes is quite expensive. This paper presents optimization of router/coordinator cluster deployment of WSNs to maximize their lifetime based on the genetic algorithm.

**Keywords:** Genetic Algorithm, Lifetime, WSNs, Energy consumption.

## 1. Introduction

Wireless sensor networks (WSNs) have many practical applications such as home and industrial security monitoring, measurement of physical and chemical states factories and plants, health monitoring in hospitals and monitoring of environmental data such as temperature, humidity and particle density in, for example, swamp peat forest (Teguh,2012; Yick, 2008).

In general, WSN is composed of sensor nodes, routers/coordinator cluster and base-station, which are working together to monitor an area to collect data about the environment. The sensors detect and measure environmental data and send them to the routers or directly to the base station. The routers collect data from the sensor nodes to send them to the base station. The base station controls communications among the sensor and router nodes to collect all the data in WSN.

In this work, we consider WSNs for wild fire detection. For the design of such WSNs, communication protocol and sensor deployment have to be determined to maximize coverage and energy efficiency. It is particularly important to improve energy efficiency and extend lifetime of WSNs as long as possible for wild fire detection because it is quite expensive and sometime dangerous to replace batteries in the sensors and routers. To maximize the lifetime of WSNs, energy-efficient communication algorithms and protocols have been developed (Younis, 2008; Kalpakis, 2003).

In LEACH (*Low-Energy Adaptive Clustering Hierarchy*), for example, sensor nodes are clustered into groups. Then a cluster head, which collects data from the cluster members and sends them to the base station, is autonomously selected at communication round in each group to homogenize the energy consumption in the cluster members (Heinzelman, 2000).Sensor deployment has been optimized to maximize the coverage and minimize the economic costs using genetic algorithm in (Wu, Q, Rao, 2007). In this paper, we present an optimization method of router deployment in WSNs to maximize the lifetime. The positions of the sensor nodes are fixed in the optimization because they would be determined from the coverage and cost. We employ GA for the optimization because of its excellent ability of global search. Although there have been many studies on application of heuristic methods, such as GA and artificial neural networks, for optimal design of WSNs (Kulkarni, 2011), there have been no attempts to optimize router deployment to maximize the lifetime.

## 2. Optimization Method

### 2.1 Network Model

Our topology network model is shown in Fig 1, in which measurement data are sent to the base station by multi-hoping. The router node makes aggregation of data from the sensor nodes and forward data toward the base-station. The positions of the base station and sensor nodes are fixed, while those of the routers, represented by $\boldsymbol{X_1}$ to $\boldsymbol{X}_5$ in this example, are optimized to minimize the energy consumption for communication. The base station collects all the sensed data from the routers and sensor nodes. It is assumed that the base station has unlimited energy for its operation. On the other hand, the routers and sensor nodes are assumed to obtain energy from the batteries mounted on them so that they are energy constrained. The sensor nodes detect environmental data such as temperature and humidity and send them to the nearest routers or base station. The routers collect data from the sensor nodes to send them to the base station. Due to the limitation in the energy of the routers and sensor nodes, they will use up the energy within the finite duration.

It is important to maximize their lifetime because the replacement of the batteries is very expensive especially when the sensors are deployed in a wide area. The aim of our study is to maximize the lifetime of the sensor network. If the lifetime is defined by the longest longevity of the sensor nodes as in (Heinzelman,2000), maximization of the lifetime leads to trivial deployment; a sensor is placed just near the base station, for example. We are interested in the maximization of the global lifetime of the sensor network.

### 2.2 Problem Formulation

We consider there the following optimization problems.

**Problem A:** the maximum energy consumption of the sensor nodes is minimized:

$$\max_{i \in S} E_i \to \min$$

(1)

where $\boldsymbol{S}$ is the index set of the sensor nodes.

**Problem B:** The maximum energy consumption of the routers is minimized:

$$\max_{i \in R} E_i \to \min$$

(2)

where $\boldsymbol{R}$ is the index set of the sensor nodes.

**Problem C:** The total energy consumption of the sensor nodes is minimized:

$$\sum_{i \in S} E_i \to \min$$

(3)

**Problem D:** The total energy consumption of the routers is minimized:

$$\sum_{i \in R} E_i \to \min$$

(4)

In the optimization, we assume that the energy $\boldsymbol{E}_i$ is assumed to be proportional to the square of the communication distance (Heinzelman, 2000).

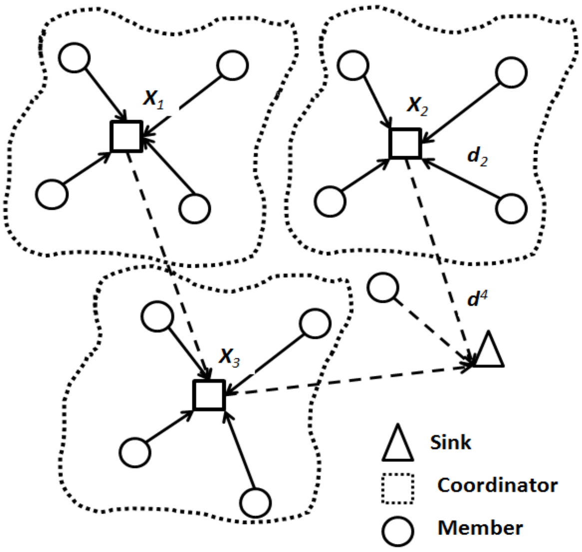


**Fig. 1.** Network topology sensor model

## 2.3 Real-Coded Genetic Algorithms

In this work, we employ the Real-coded Genetic Algorithms (RGA) for the optimization of router positions $\boldsymbol{X}_i$. The genotype of RGA is here an array of the router positions $[\boldsymbol{X}_1, \boldsymbol{X}_2,\ldots,\boldsymbol{X}_n]$. In order to search solutions which have high fitness, any genetic operations (see Fig.2) are conducted in RGA. In particular, searching ability of RGA depends on crossover operation largely. In this work, the Blend crossover (BLX-α) is adopted for the crossover operator (Herrera,1998).

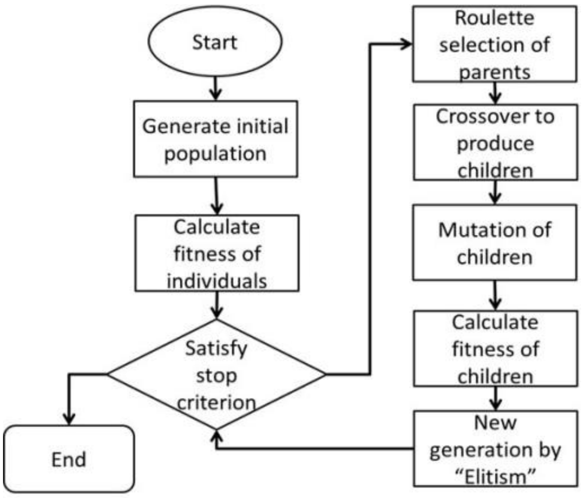


**Fig. 2.** Flowchart of the Genetic algorithm workflow.

The cross-over process of the BLX is shown in Fig. 3. Moreover, optimization procedure of the RGA is shown below:

1. Initial population is generated which has $N_{pop}$ size.
2. $N+1$ parents are randomly selected from the population, where $N$ is the number of design variables. Then, the crossover operator is applied to the parents, and $N_c$ child individuals are created.
3. The parents are replaced with child individuals whose fitness is higher in the children.
4. Mutation operation is performed for $M$ individuals.
5. Steps 2 to 4 are repeated until convergence conditions of optimization are fulfilled.

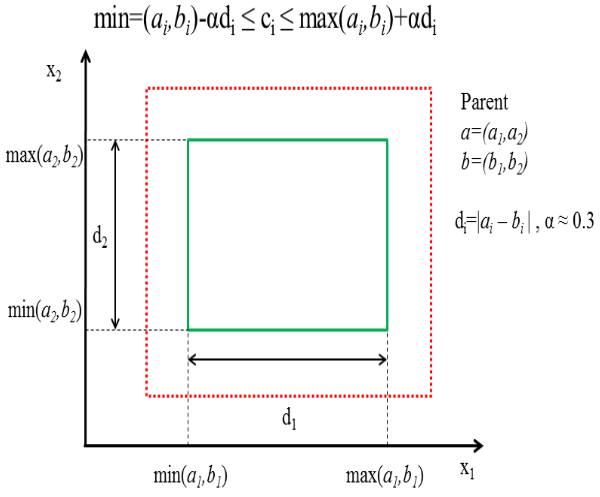


**Fig.** 3. The cross over process of the BLX-α

## 3. Computational Results

For our experiments, we assume that the target field size is 500 x 500 m$^2$. In this model, sensor and router nodes are placed randomly and the latter positions are optimized. We use the same random seed for all the problems. We place 100 sensors and 10 routers in the target field whose transmission radii are assumed to be 150m and 300m, respectively. The position of the base station is (500,250).

We assume that the communication energy dissipation is based on the first order radio model (Heinzelman, 2000). We develop of simulation model using MATLAB code to perform the optimization. The optimization parameters in RGA are summarized in Table 1.

Table 1. The GA parameter setting

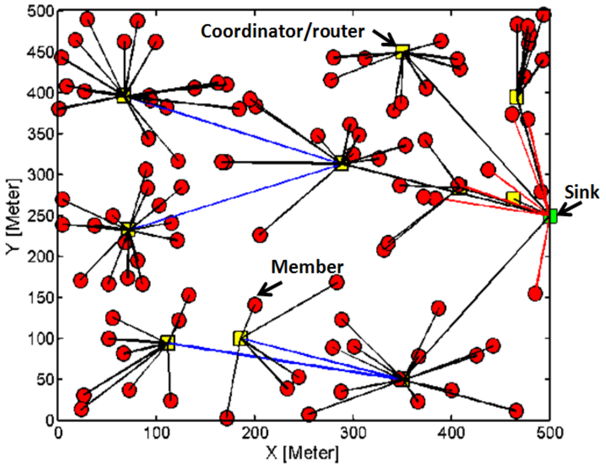
| Parameter | Values |
|---|---|
| Population Size $N_{pop}$ | 100 |
| Number of Crossover $N$ | 50 |
| Number of Mutation $M$ | 5 |
| Generation size | 100 |

Optimization results are shown in Figs. 4-7. The maximum and mean energies are summarized in Table II. We can see in there results that the histogram of energy consumption in Fig.4 is much different from those in Figs. 5-7; there are many sensors which consume relatively high energy in the result of Problem A. The mean energy consumption in this case is higher than those in the other resutls. The reason for this results is that we pay attention only to the maximum energy consumption in the sensor nodes in Problem A. On the other hand, the results of Problem B shown in Fig. 5 are similar to those in Figs.6 and 7.

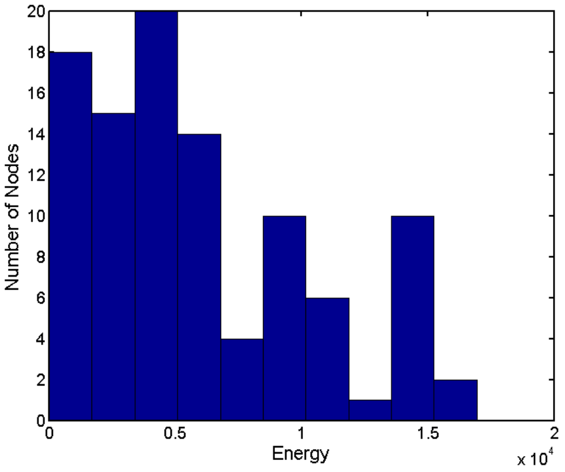
This would be due to the fact that the enegry consumption of a router depends on the distances to the sensors connected to it. Hence minimization of the maximum energy consumption in the routers would lead to minimization of mean energy consumption of the sensors. From results shown in Figs.6 and 7, in which singnicicant differentces cannot be found, we can see that minimization of the mean enegy consumption results in supression of the maximum energy consumption. Figure 8 shows an example change in the fitness during the optimization process. The fitness monotonously increases with the generation

Table 2. The maximum and mean of energy

| Case problem | Maximum | Mean |
|---|---|---|
| Problem A | 0.0677 | 0.0241 |
| Problem B | 0.0838 | 0.0226 |
| Problem C | 0.0750 | 0.0188 |
| Problem D | 0.0677 | 0.0193 |

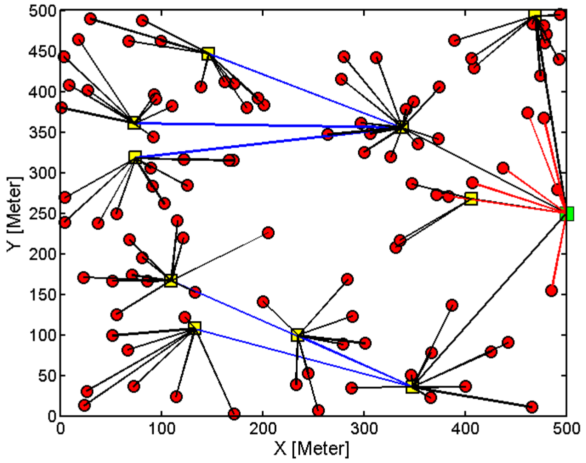


(a) Optimized network topology

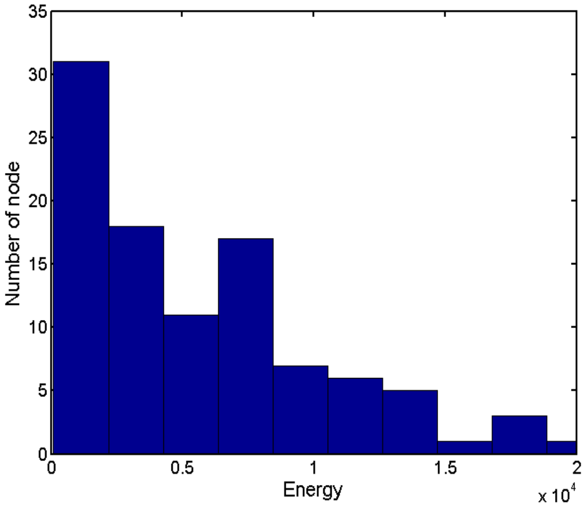


(b) Histogram of energy consumption

Fig. 4. Optimization results for Problem A.

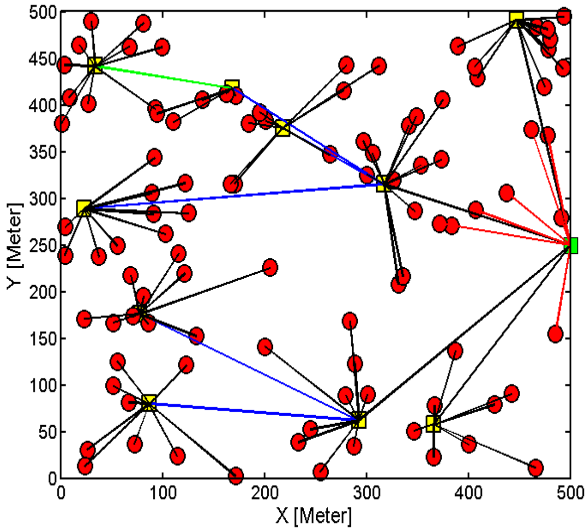


(a) Optimized network topology

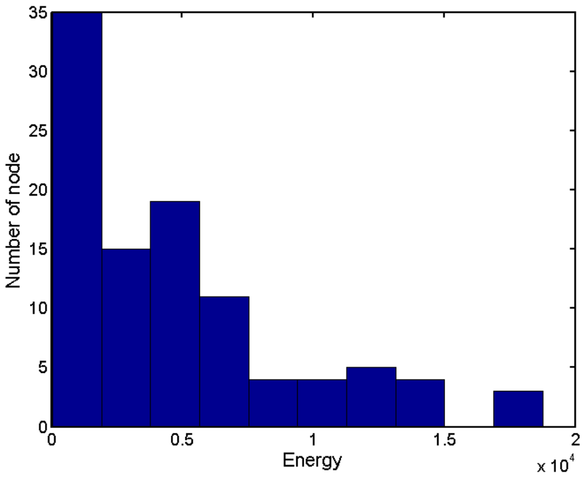


(b) Histogram of energy consumption

Fig. 5. Optimization results for Problem B.

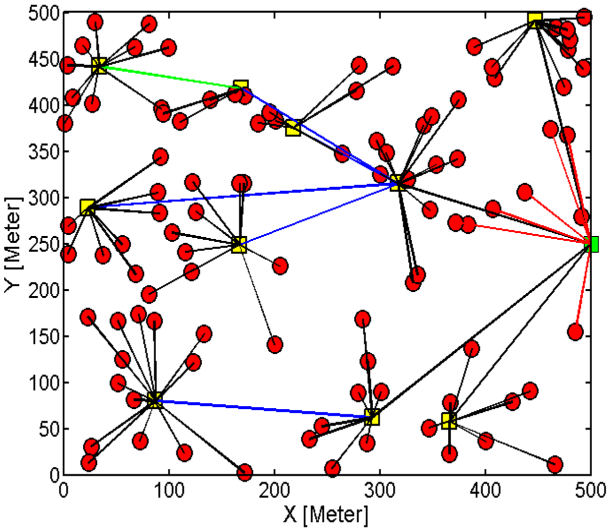


(a) Optimized network topology

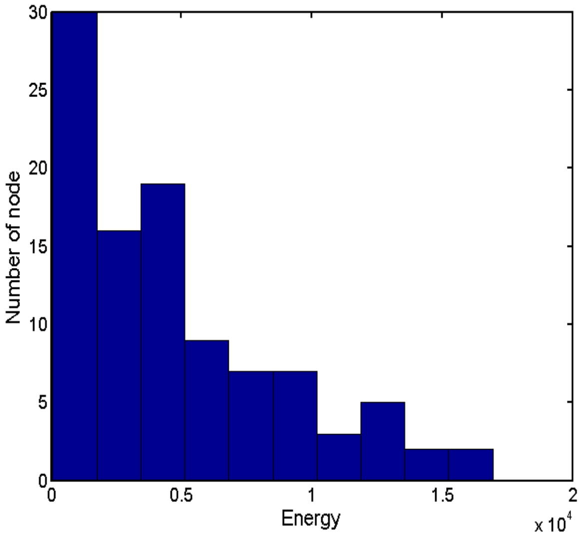


(b) Histogram of energy consumption

Fig. 6. Optimization results for Problem C.



(a) Optimized network topology



(b) Histogram of energy consumption

Fig. 7. Optimization results for Problem D.

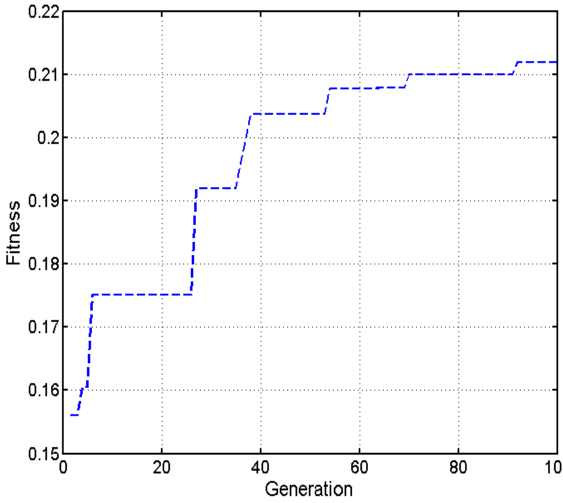


Fig.8 Evolutional history for Problem C

## 4. Conclusions

In this paper, we have proposed a design method of energy-constrained WSNs. In the present method, the router positions are optimized using RGA to minimize the energy consumption in WSN. It has been shown that the optimization is successfully performed for the four model problems. It is found that minimization of the mean enegy consumption results in supression of the maximum energy consumption. In future work, we will consider dependece of communication distance on the geography can features in the optimization of router deployment. Moreover, we will optimize the number of routers/coordinator and their deployment to minimize the energy consumption and economic cost.

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