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A Genetic Algorithm Based Optimal Sink and Relay Nodes Placement Strategy for Increasing the Lifetime of the Wireless Sensor Network

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Abstract— the wireless sensor networks (WSN) are widely used for the scientific, industrial and social applications such as earth science, machines data logging, air pollution measurements etc. In most of the applications the network nodes has to be relay on their battery sources because of their placements or any other reasons. Since the battery can provide only limited power the node there is always a possibility of complete power drainage of nodes which can deeply affect the overall communication of the network. Since the node nearest to sink has to deal with maximum traffic which drain it quickly, hence to minimize the power relay node are used which are supplied by some high capacity power source and used to communicate with sink nodes. However the placement of relay nodes and sink nodes are also crucial because every node need to communicate with it and larger distance may cause greater power requirements for transmission. This paper presents a genetic algorithm based optimal sink and relay node placement technique to minimize the energy usage while managing and considering as possible as practical conditions like nodes distribution, nodes data transmission rates, transmission range of the nodes, processing power requirements of nodes etc.

Keywords— Wireless Sensor Network, relay node, sink node, genetic algorithm

I. Introduction

Wireless Sensor Network (WSN) consists of many low-cost and low-power sensor nodes (SNS) [1]. Sensing and short-range communication for transmitting sensed information to the base stations are two of the most important functions of the nodes. In typical applications of wireless sensor networks, sensor nodes are placed all over the sensing field and left unattended to continuously monitor and report the sensed data from the field. To ensure reliability, low-cost sensor nodes are usually arranged densely in this area, on the other hand, redundant sensor nodes can be in sleep mode to conserve energy because in many cases it is very difficult, if not impossible, replace the power supply for sensor nodes that are already deployed. Hence the energy conservation is must for such type of networks. Because energy consumption is proportional to the transmission distance and given as d^k, where k is a constant depends upon the remote transmission environment. To extend the Network lifetime under certain network specifications , researchers have proposed the use of a small number of WSN relay node (RN), whose main function is to communicate with Sensor Nodes (SNs) and other RNs [2], [5]. The contribution of this paper is to implement a sink node and relay nodes placement strategy which can minimize the power required to properly run the network without compromising the service quality.

II. Related Work

Energy saving is critical to longer life of Sensor Network. Many approaches for energy efficient monitoring have been proposed for minimizing energy consumption. This section presents a brief review of some of them. Dejun Yang [1] presented two-tiered constrained relay node placement problem, where relay nodes can be placed only in some predefined candidate locations. To meet the requirement of the connection, they study the connected single-cover problem, where each sensor node to which relay node (which sensor node may transmit data), and relay nodes form a network connection with a base station. Their study focuses on computational complexity of the problems and proposes a new polynomial time approximation algorithms for these problems. Yanyan Zhuang et. al. [5] proposed, analyze and evaluate the energy consumption models of wireless sensor networks with probabilistic distance distribution. These models were validated numerical and simulation results, showing that they can be used for optimize grid size and minimize energy consumption accurately. Optimal number of sinks placement is described in [6] the authors explore the benefits of location and optimum number of sinks for wireless sensor networks (WSN) to extend the life of the network, assuming that the number of hops from each sensor to its closest sink is nothing more than h ≥ 1 and the location of the sink area is given in advance. Similar problem is dealt in [8] and solved using Gene Expression Programming. Hongbo Jiang et. al. [3] proposed clustering-based data collection design of energy-efficient framework in wireless sensor networks by integrating adaptively switched on/off prediction scheme. In proposed clustering approach the cluster head represents all sensor nodes in the cluster and collects data values from them. An adaptive management system is used for the prediction of control. Minimum Data-Latency-Bound based sink placement scheme is proposed by Donghyun Kim et. al. [9] they proposed a new multiple-sink positioning problem in wireless sensor networks to best support real time applications. They formally define this problem as the k–Sink Placement Problem (k-SPP) and prove that it is APX-complete.

III. GENETIC ALGORITHM

A genetic algorithm (GA) is a heuristic search technique that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization problems and search engines. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), the solutions to optimization problems using techniques inspired by natural evolution to generate as inheritance, mutation, selection and crossover. In a genetic algorithm to a population of strings developed (chromosomes), the candidate solutions (fitness value) to encode optimization problem to better solutions. Traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. The development usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of each individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Usually, the algorithm terminates when either a maximum number of generations has been produced, or has reached a sufficient condition for the population. If the algorithm is terminated by a maximum number of generations, a satisfactory solution may or may not be achieved.

A typical genetic algorithm steps:

- A genetic representation of the solution domain,
- A fitness function to evaluate the solution domain.

Generally the solution is represented as an array of bits. Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations can be used, but in this case of complicated crossover. Tree-like representations are explored in genetic programming and graphic representations in the form of evolutionary programming. The fitness function is defined over the genetic representation and measures the quality of the represented solution. The fitness function is always problem dependent. Once the genetic representation and the fitness function defined, GA is an order (usually random) initialize a population of solutions and then improved it by repeated application of mutation, crossover, inversion and selection of contractors.

IV. MODEL CONSIDERATIONS

Following considerations are taken while simulating the network.

1. The location of each node in the network in known.
2. All nodes have predefined limited power.
3. Relay nodes also have limited power.
4. Sink is considered to be externally powered.
5. The maximum transmitting range of normal and relay nodes are predefined.
6. For each node packet inter arrival time and packet size is normally distributed

V. RADIO ENERGY MODEL

The basic radio energy model is used in this work. Path loss co-efficient is considered as [1]. According to the model, we have:

$$E_{T,x}(l,d) = \begin{cases} l * E_{elec} + l * E_{Fs} * d^2, if\ d < d_0 \\ l * E_{elec} + l * E_{Tr} * d^4, if\ d > d_0 \end{cases} \ldots (1)$$

$$E_{R,x} = l * E_{elec} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

where E_{Ts} is the transmission energy, $E_{R,x}$ is the energy used in reception, d is the distance between two nodes or between a node and the sink, E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, E_{Fs} and E_{Tr} depend on the transmitter amplifier model, d_0 is threshold transmission distance. l is the length of the data transmitted. We have used the same values as used in Ref. [10]

VI. Formulation of Objective Function

Since the objective of the algorithm is to find the optimal placement of sink and relay node to minimize the energy consumption during transmission. The objective function for the proposed algorithm is formulated as given in equation 3.

$$f_{obj} = \sum_{i=1}^{N} \left(\frac{1}{L_{ni}} + C_{ni} \right) + \sum_{i=1}^{M} \left(\frac{1}{L_{ri}} + C_{ri} \right)$$

Where

L_{ni} *is the life time of* i^{th} *noraml nodes.*

C_{ni} *is the data transmission cost of* i^{th} *noraml nodes*

L_{ri} *is the life time of* i^{th}*relay nodes.*

C_{ri} *is the data transmission cost of* i^{th} *relay nodes.*

N is the total numbers of normal nodes.

M is the total numbers of relay nodes.

VII. Proposed Algorithm

The proposed algorithm can be explained as follows
Step 1: firstly the numbers of relay nodes are calculated.
Step 2: now M sets of 2*(n + 1) chromosomes are generated. Where M is the population size and n is the number of relay nodes.
Step 3: now odd chromosomes of each set is used as x coordinate location of the relay nodes and sink node and even chromosomes is used as y coordinate locations for same.
Step 4: Ones the locations of all relay nodes and sink node is calculated the life time and transmission cost of each relay nodes and normal nodes are calculated according to equation (1) and (2).
Step 5: Calculate the fitness value for each of M sets of chromosomes using equation (3).
Step 6: Select the chromosomes with best fitness value and perform crossover to get the new generations and delete the others.
Step 7: repeat steps 3 to 7 till the maximum generations completed or the goal is found.

VIII. Simulation Results

The proposed model is tested for various configurations and the simulation results for each configuration are shown below.
Configuration 1:

$N = 100 \; and \; M = 5$

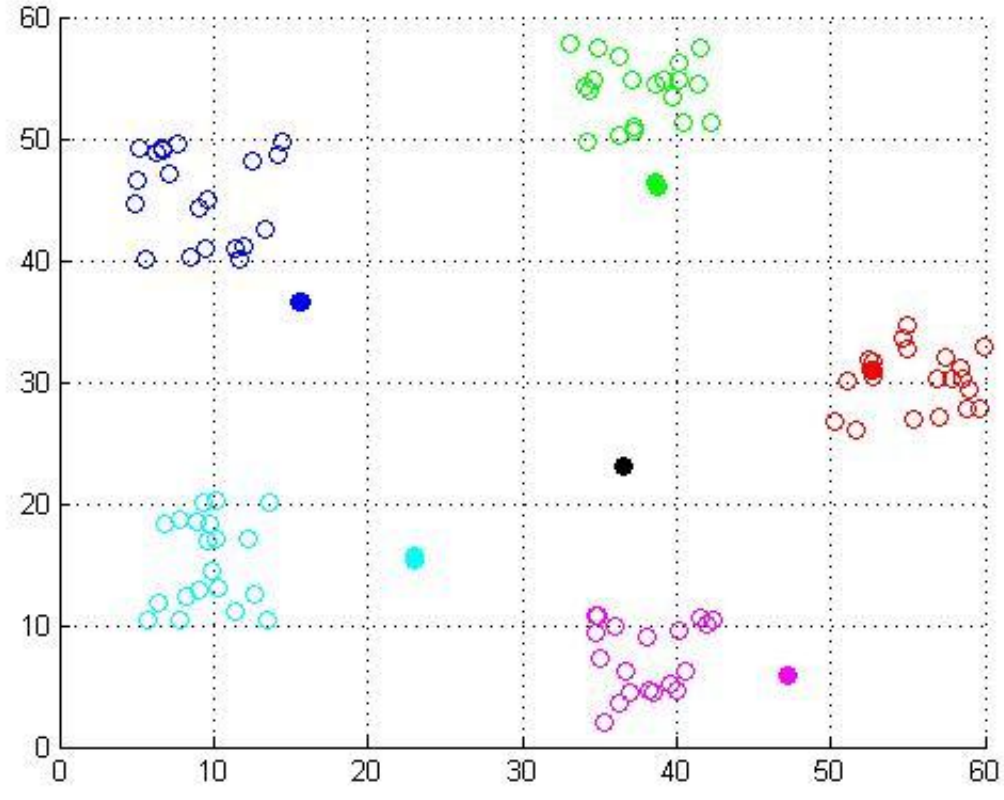

Figure 1: Simulation results for 100 nodes black node is representing sink node.

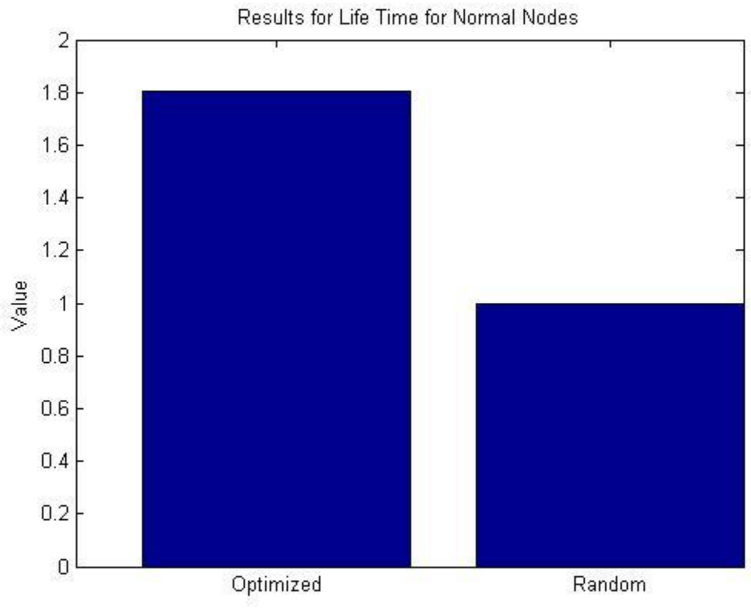

Figure 1(a): Life time comparison for normal nodes with respect to random placements.

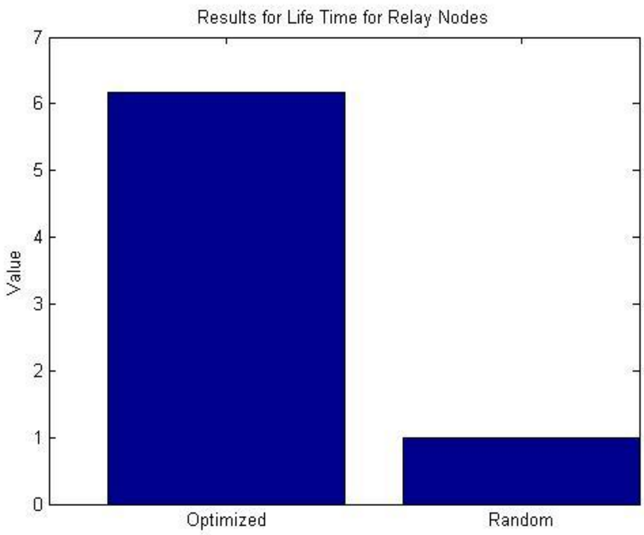

Figure 1(b): Life time comparison for relay nodes with respect to random placements.

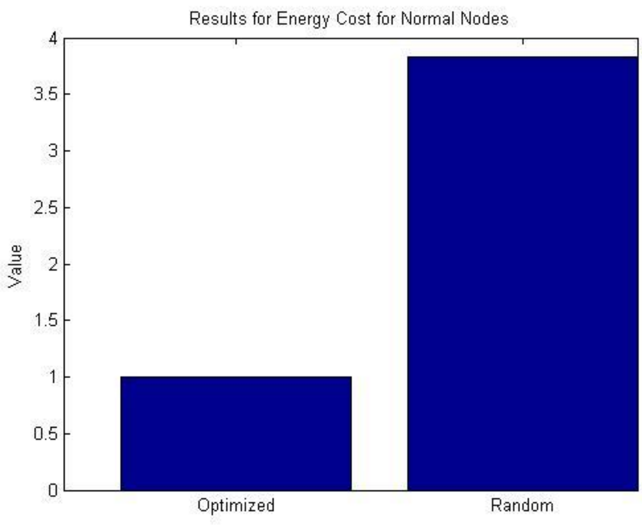

Figure 1(c): Transmission energy comparison for normal nodes with respect to random placements.

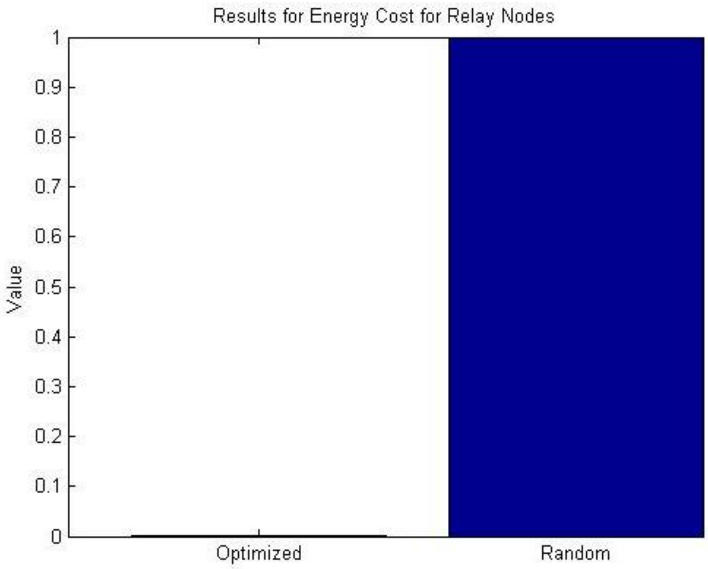

Figure 1(d): Transmission energy comparison for relay nodes with respect to random placements.

Configuration 2:

$N = 50 \; and \; M = 5$

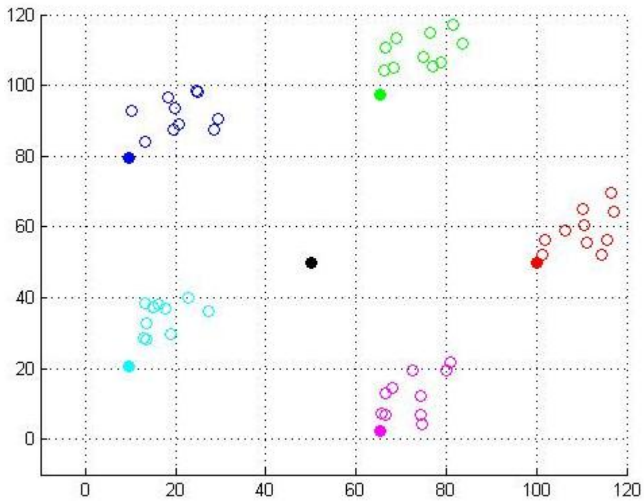

Figure 2: simulation results for 50 nodes black node is representing sink node.

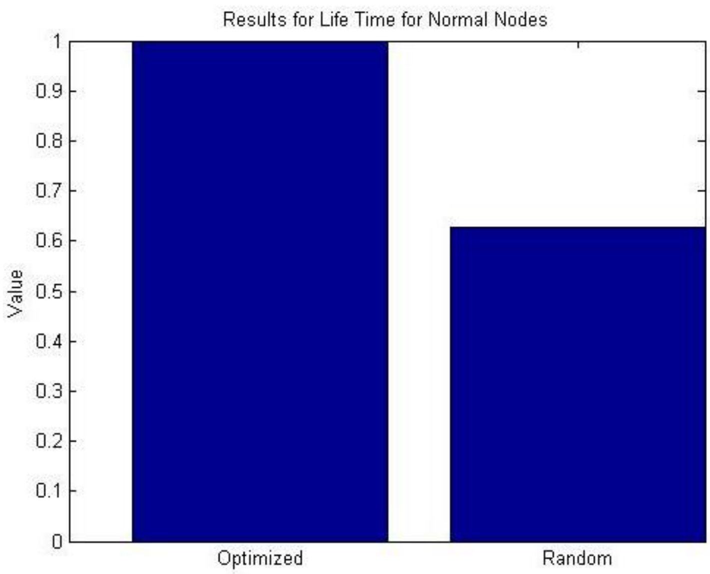

Figure 2(a): Life time comparison for normal nodes with respect to random placements.

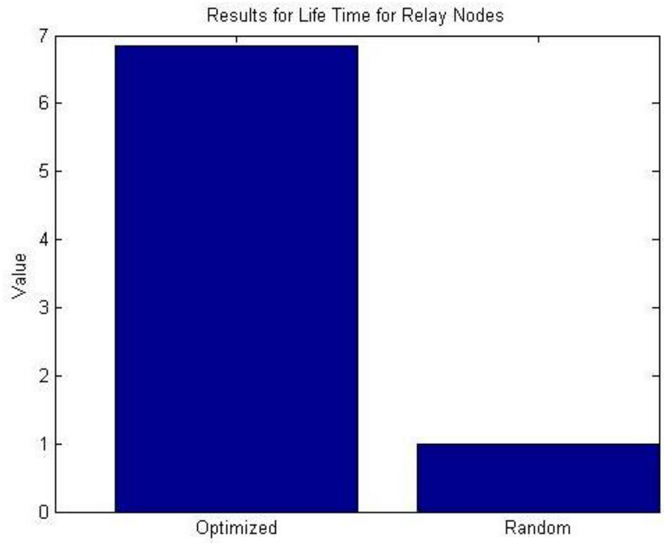

Figure 2(b): Life time comparison for relay nodes with respect to random placements.

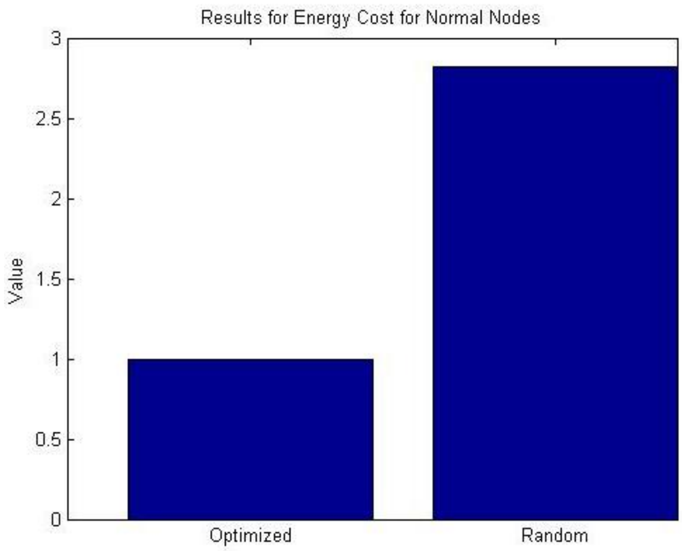

Figure 2(c): Transmission energy comparison for normal nodes with respect to random placements.

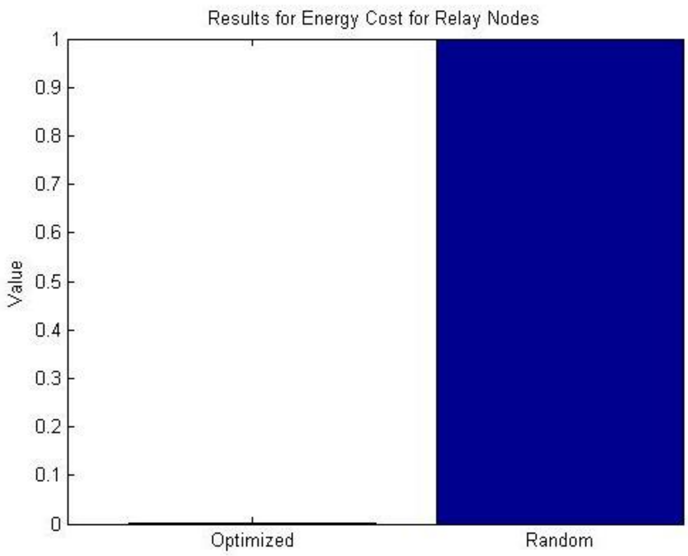

Figure 2(d): Transmission energy comparison for relay nodes with respect to random placements.

Configuration 3:

$N = 30\ and\ M = 3$

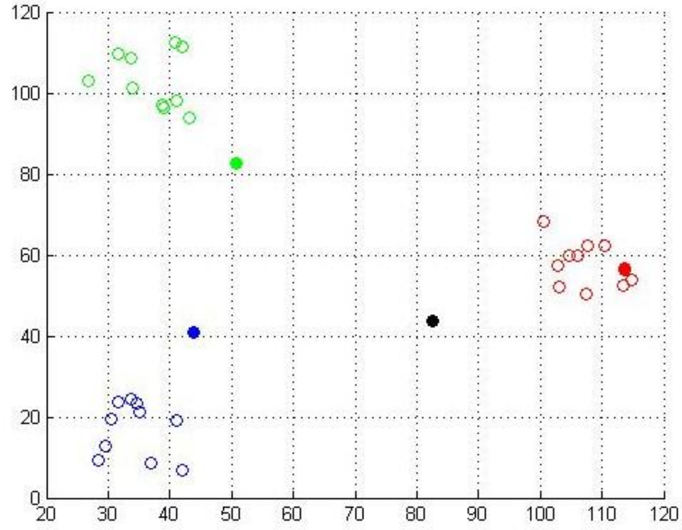

Figure 3: simulation results for 30 nodes black node is representing sink node.

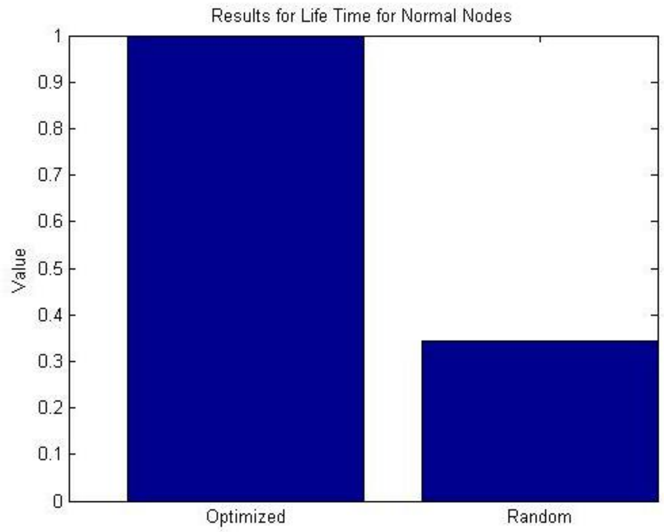

Figure 3(a): Life time comparison for normal nodes with respect to random placements.

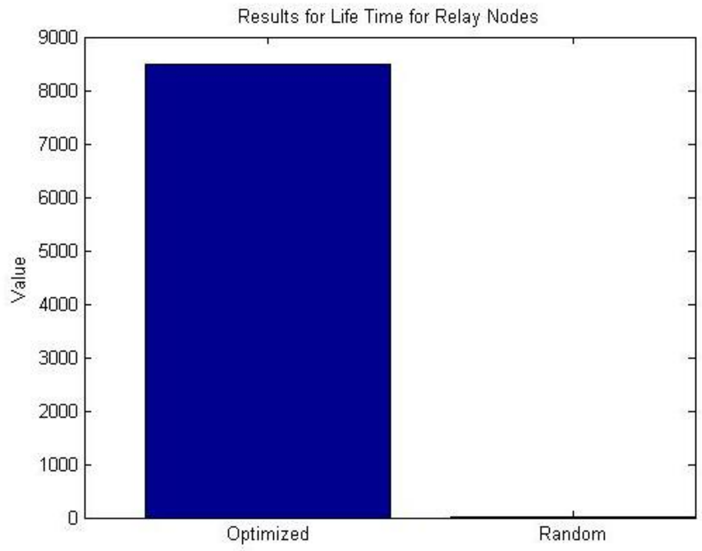

Figure 3(b): Life time comparison for relay nodes with respect to random placements.

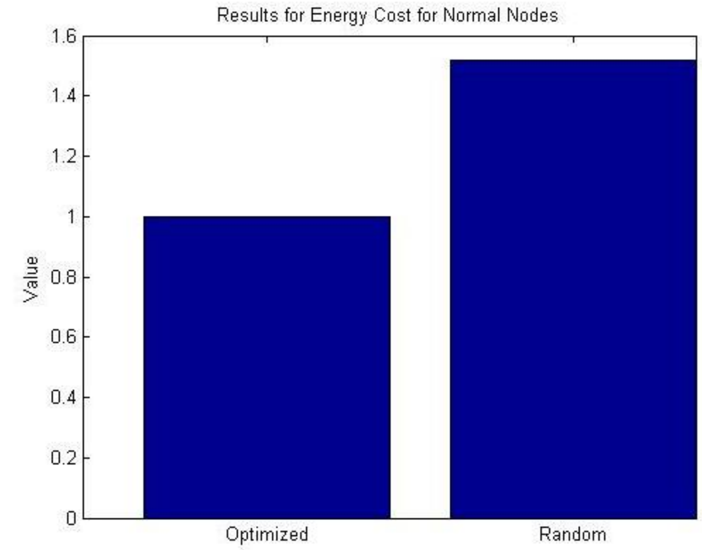

Figure 3(c): Transmission energy comparison for normal nodes with respect to random placements.

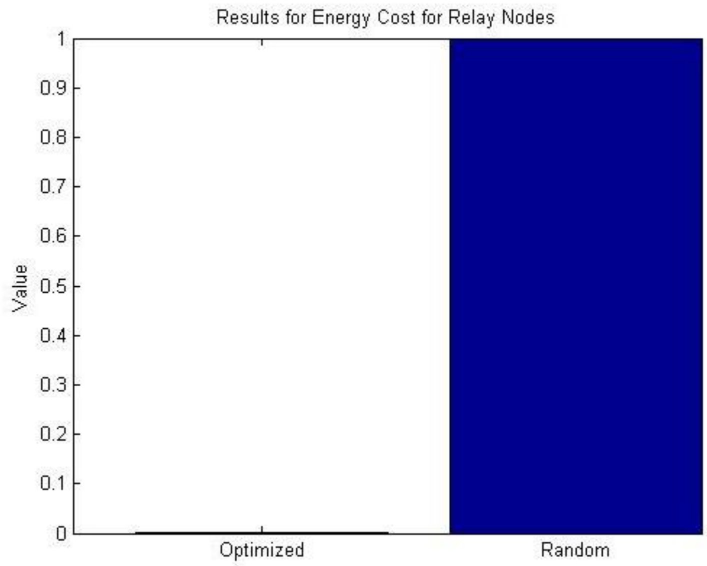

Figure 3(d): Transmission energy comparison for relay nodes with respect to random placements.

IX. Conclusion

In this paper, we present a framework for energy critical WSNs with best placement locations for given numbers of relays. We have found that: 1) for such applications, it is important to ensure that the maximum node is limited decrease message latency, and 2) it is better to limit that make smaller to meet this real-time systems improve. We also recognized that we design such a WSN by the use of multiple relays and make it more effective by careful selection of the placement locations of the relay and sink.

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