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Prolonging Lifetime of Wireless Sensor Networks with Base Station Repositioning using Genetic Algorithms

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ABSTRACT

The sensor node usually is irreplaceable and power by limited power supply. Taking the fact into consideration, a network should operate with minimum energy as possible to increase lifetime of network for improving the overall energy efficiency. In this work, we proposed an energy efficiency protocol for base station repositioning using Genetic Algorithms to find optimal position for cluster heads and base station in order to improve the network lifetime. In addition, the optimal position of cluster heads also included in this protocol based on position of sensor nodes and the cluster heads. Both problems involved base station reposition and cluster heads selection is transformed to be the cost function for GAs to minimize. Simulation results show that the proposed protocol can improve significantly the network lifetime compared to existing energy efficiency protocol developed for this network. Furthermore, the simulation result for proposed protocol also compared to each other’s for difference network field in term of network lifetime, data delivery and energy dissipated.

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INTRODUCTION

Wireless Sensor Networks (WSNs) became one of most important technologies for the past decade and probably in future as several of research activities have been done in development of WSNs. WSN is a family of ad hoc networks which comprises large numbers of sensors called as sensor nodes. Although these sensor nodes are generally used as a sensing component, they also have on-board processing, storage capabilities and capable to communicate not only with each other's but also with a sink or base station (BS) using their wireless radios. Typically, the application of WSN is used to monitor physical or environmental conditions such as temperature, sound, vibration, pressure, motion or pollutants. This is achievable with WSN as the sensor nodes distribute around the sensing area that are usually cannot be accessible by human due to harsh environmental conditions (Dergie & Poellabauer, 2010).

One of the major drawbacks of WNS is limited power or energy used by sensor nodes. Most of the sensor nodes are using battery as their energy source. Lifetime of the network is greatly depending on the energy of the sensor node and the network lifetime can be defined as the energy of one of the sensor nodes or the entire sensor nodes are run out. Various researches have been done to improve one of major problem in WSN that is lifetime of network due to limited energy of sensor nodes. One of the factors in energy dissipated of the sensor nodes is communication cost between BS and sensor nodes. Usually, communication cost in WSN can be related to the distance between the sensor node with others sensor node or with the BS. In order to deal with this problem, many researchers have developed protocols and algorithms in objective of increasing the lifetime of network including optimizing the energy used by networks (Alsalih, Akl, & Hassanein, 2007).

In this paper, a new protocol is designed based on energy aware cluster-based protocol to improve the network lifetime, data delivery to the BS and energy efficiency of wireless sensor network using Genetic Algorithms. The objective in designing this proposed protocol, BS repositioning using Genetic Algorithms (BSR-GA) is to find the optimum location for the BS for data collection from sensor node by minimizing the cost communication between sensor nodes to cluster head and cluster head to BS. The rest of this paper is organized as follows: In section 2 networks model are presented. For section 3, problem definitions are explained. In section 4, protocol description is defined for the proposed protocol. Simulations and results of the proposed

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protocol are presented in section 5 before concluding the paper.

Networks Model:

The network model that has been used in this paper is similar as in (Abdul Latiff, Abdullatiff, & Ahmad, 2011; Heinzelman *et al*., 2000; Latiff, Tsimenidis, Sharif, & Kingdom, 2007). For this work, a network is integration of following features:

- All sensor nodes have same amount of initial energy and ability.
- Each sensor node produces same amount of data per time and the data unit have same length.
- Each sensor node always has data to send to the base station.
- All sensor nodes are stationary and homogeneous with limited energy.
- All sensor nodes have power control capabilities to vary their transmit power.
- Base station initially located at middle of the sensing field.
- All sensor nodes are capable to operate as cluster head and sensing node.
- The total data message sent to BS can be reduce by data fusion.

Next, the energy model in this paper is based on first model of radio energy model as in (Heinzelman *et al*., 2000). In this model, radio dissipates energy to run the radio electronics (transmitter or receiver circuitry) and transmit amplifier. This radio model also can perform power control for the radio to use minimum energy as possible to reach the receptions. In order to achieve an acceptable Signal-to Noise-Ratio (SNR) for transmitting l-bit message over a distance d and also assuming energy loss due to channel transmitting d^2, the energy dissipates by the radio is given by:

$$E_{TX}(l, d) = l \times E_{elec} + l \times \varepsilon_{FS} \times d^2 \text{ if } d < d_o \quad (1)$$
$$= l \times E_{elec} + l \times \varepsilon_{MS} \times d^4 \text{ if } d \geq d_o \quad (2)$$

where E_{elec} is the energy dissipated to run the transmitter or receiver circuitry, ε_{FS} and ε_{MS} depend on transmitter amplifier used and d_o is the threshold transmission distance. For energy dissipated by the radio for receiving the message is given by:

$$E_{RX}(l) = l \times E_{elec} \quad (3)$$

E_{elec} for transmitting an l-bit message is same as E_{elec} for receiving an l-bit message. In this paper, l is set to be 2000-bit packet length. It is assumed that the radio channel is symmetric such that the energy required for transmitting a message from node A to node B is the same as the energy required for transmitting a message from node B to node A for a given SNR. The communication energy parameters are set as Table 1.

Table 1: Communication Energy Parameters

Parameter	Value
E_{elec}	50 nJ/bit
ε_{FS}	10 pJ/bit/m^2
ε_{MS}	1.3 fJ/bit/m^2

Problem Definitions:

A network topology with N number of sensor nodes distributed randomly over network field. This randomly distributed sensor nodes are considered to be in 100m x 100m network field as shown in Fig. 1. This distributed sensor nodes, $V = \{n_1, \ldots n_j, \ldots n_N\}$ then grouped into K group or cluster $\{C_1, \ldots C_k, \ldots C_K\}$ where C_k is set of sensor nodes in cluster k, $1 \leq j \leq N$. By assuming that BS have unlimited power source, BS is performing the operation of proposed protocol which is based on Genetic Algorithms (GAs). GAs is used to select the optimal cluster head from the distributed sensor nodes where the total distance between all cluster head and its cluster member will be minimum. Besides that, GAs also used to make the selection of cluster head based on energy efficiency of the network where ratio of total initial energy of sensor nodes with total energy of current cluster head will also minimum. Finally, GAs used to decide the location of BS where the total distance between BS and cluster head is also minimized.

Protocol Description:

Basic introduction to Genetic Algorithms

Genetic algorithms is one of an evolutionary computing technique, based on both principles of natural selection and natural genetics, the process that drives biological evolution (Coley, 1999; Singiresu S. Rao, 2009). In GAs, population refers to a set of random candidate solutions to the optimization problem, where the candidate solutions also refer to individual solution of population. At each step of GAs, the best individual solution is selected from current population to be parent to produce children for next generation. The basic elements used in genetic search procedure are selection, crossover and mutation. Selection is used to select the parents or individual that produces the population for the next generation. Crossover is used to combine pairs of parents to form children for the next generation. Mutation is used to apply random changes to the resulting offspring to form children.

Fitness Function:

The fitness function or objective function in this algorithm used to find the optimal cluster head from distributed sensor nodes. The optimal cluster head is the sensor node where total energy used to receive data from others sensor node and transmit the data back to BS is minimized by minimizing the distance between sensor nodes and cluster head. As stated earlier, the main factor of energy expended by sensor node in data transmission greatly depends on the distance between sensor nodes as the sender and cluster head and also BS as the receiver. Let (x_j, y_j) be the coordinate of the distributed sensor nodes and (x_k, y_k) be the coordinate of the cluster head location. If the free space propagation model is used, the distance between the sensor node j and the BS location k is given by:

$$d(s_k, n_j) = [(x_k - x_j)^2 + (y_k - y_j)^2]^{1/2} \qquad (4)$$

The total energy expended by sensor nodes can be minimized by minimizing the total distance of between all sensor nodes and the cluster heads. The cost function is defined as:

$$f = \arg\min \sum_{k=1}^{K} \sum_{j=1}^{|C_k|} d(s_k, n_j) \qquad (5)$$

where $|C_k|$ is the number of sensor nodes that belong to cluster C_k. The equation (5) is defined as the fitness function that the GAs need to minimized. In addition, the position of BS also moved to the location where total distance of all cluster heads and BS will minimum. This can be achieved by using equation (4) where (x_j , y_j) be the coordinate of the cluster head and (x_k, y_k) be the coordinate of the BS location.

Setup Phase and Steady State:

In this work, setup phase only occurs once at the BS followed by steady state phase where data transmission takes place. The operation of the proposed protocol that based on GAs is implemented at the BS. At setup phase, it is assumed that the BS did not have information of sensor nodes. Thus, all sensor nodes must send the information such as their locations and energy to the BS. Steady state takes place when all sensor nodes have sent the information to BS. Then, BS will run the GAs to find the location the cluster heads and sensor nodes will decided itself which cluster it belong to based on location of the cluster heads. All sensor nodes transmit the sensed information to the cluster heads and the cluster heads transmit back to the BS. TDMA (Time Division Multiple Access) is used to schedule the data transmission of sensor nodes and cluster heads to the BS. The sensor nodes only turn on to transmit their sensed information during their transmit time.

Simulation And Analysis:

The performance of the proposed protocol is executed via simulation using MATLAB. 100 of sensor nodes are placed randomly in *Lx x Ly* area for wireless sensor network is modeled. Initial energy for each sensor nodes is set to 0.5 Joules and initial position for the BS was (50, 50). The number of cluster is set to *K* which is also the number of cluster heads. The proposed protocol, BSR-GA was run to optimize the fitness function, the equation (5) to find the location of optimum cluster heads based on distance between sensor nodes.

After several experiment on BSR-GAs, the parameter for the GAs used in this experiment is shown in Table 2. The number of variable is also the number of cluster heads and *L* is length of network field which was 100m. Fig.2 showed cluster formation and location of cluster heads also the BS from randomly distributed sensor nodes as in Fig. 1. Difference shape means the clusters of sensor node, the red filled shape for each clusters are the cluster heads and the blue filled round shape is the BS.

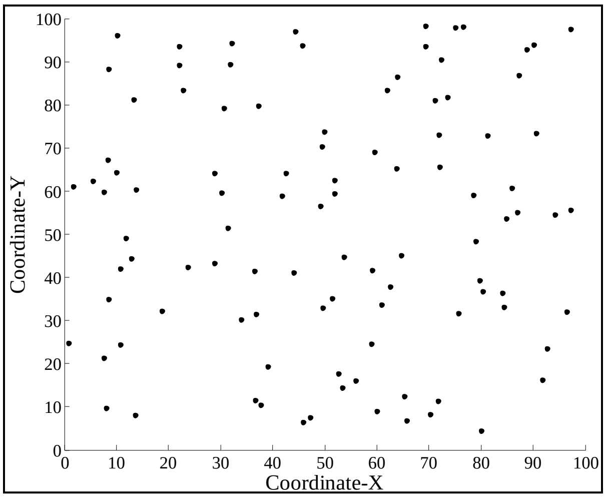


Fig. 1: Sensor nodes in 100m x 100m network field.

Table 2: Gas Parameters

GAs Parameter	Values
Number of variables[a]	10
Population size	200
Lower bound, upper bound	0 , L[b]

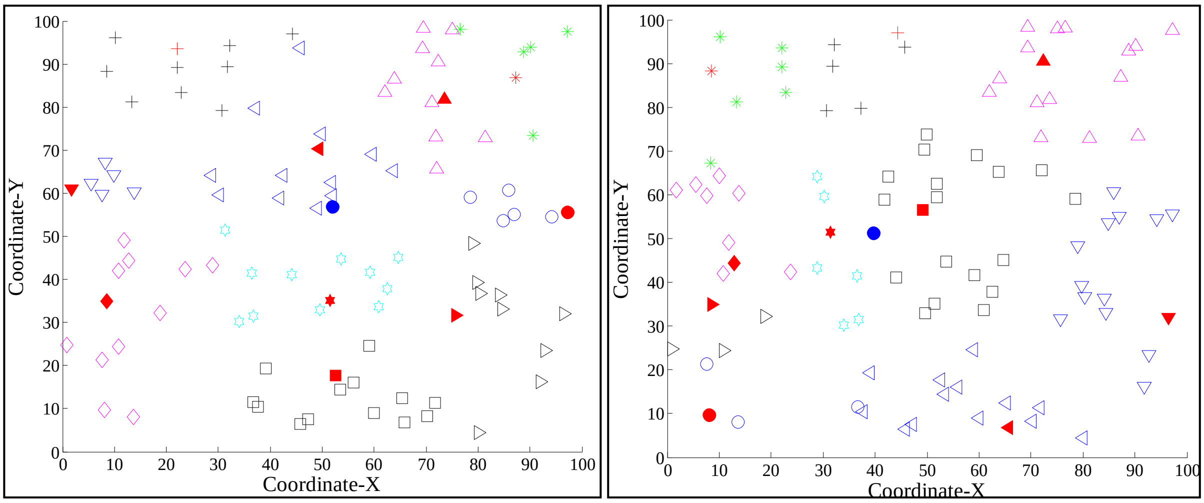
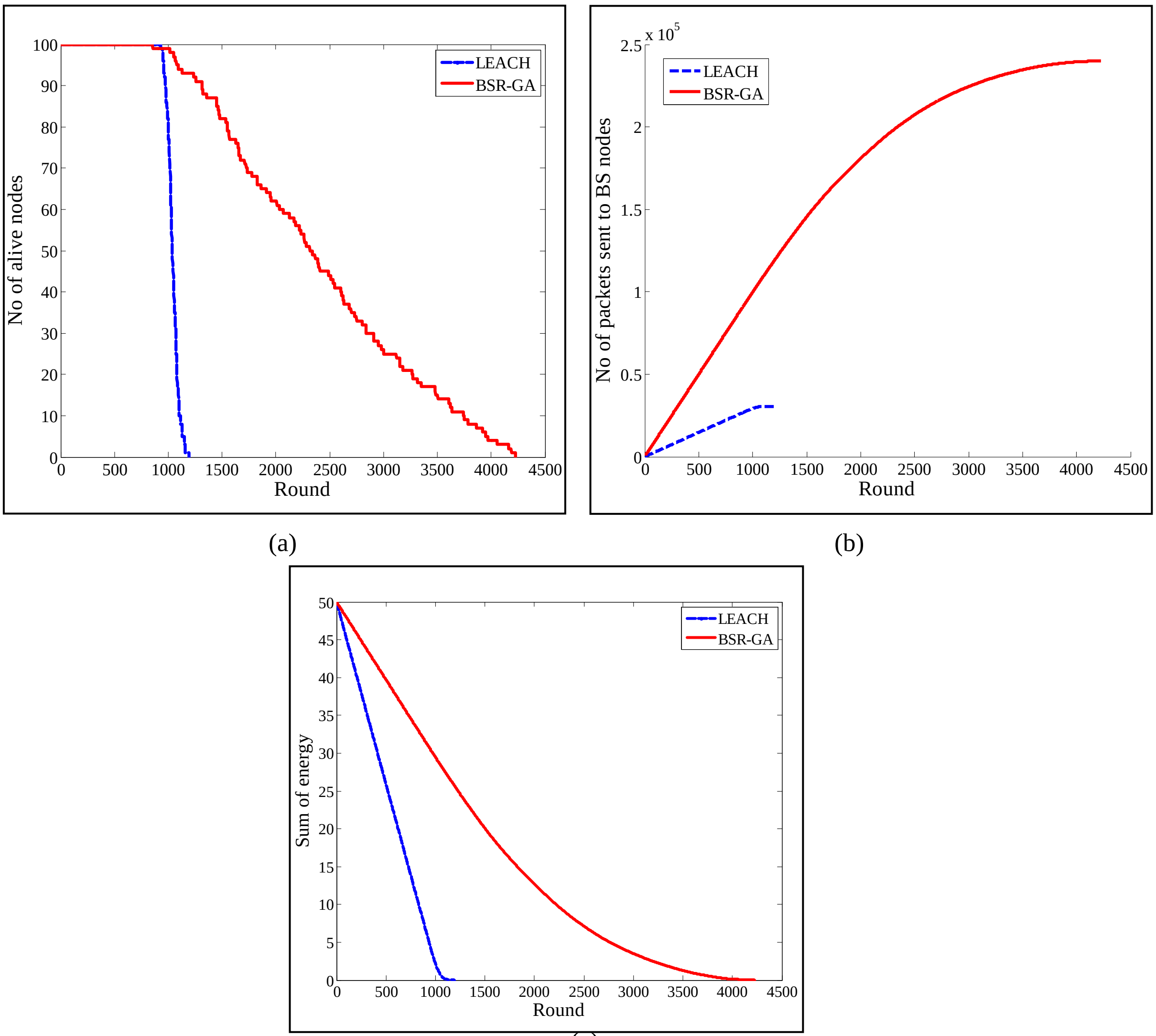


Fig. 2: Cluster formation, location of cluster heads and BS at (a) round 10 and (b) round 50.

Both protocol carried out on 100m x 100m network field. By referring to Fig. 3(a), it is shown that the lifetime of the proposed protocol BSR-GA is significantly increasing compare to LEACH. The lifetime for BSR-GA is extended to round of 4227 compare to LEACH at round of 1196 for all sensor nodes used all their energy. This improvement is due to the shorter distance between sensor nodes and cluster heads. The distance between cluster heads and BS also shorten as the BS reposition. Since the energy dissipated is greatly depending on distance, BSR-GA has the advantage compare to LEACH. In addition, the number of packet data sent to BS for LEACH is lowered than BSR-GA as shown in Figure 3(b). The packet data received by BS is terminated until round 1196 for LEACH compared to BSR-GA where the packet data continue received by BS. This is due to the number of sensor nodes that sent the data to its cluster heads is higher numbers for BSR-GA compared to LEACH. Based on both results in Figure 3(a) and 3(b), the sum of total energy as shown in Figure 3(c) for LEACH indicated that all sensor nodes used all their energy up until round 1196 compares to BSR-GA which is until round 4227. For all the results in Figure 3, it is concluded BSR-GA is better that LEACH in term of network lifetime, data delivery and energy dissipated.

Conclusions:

In this paper a new protocol for the problem involving BS reposition as well as the selection of optimal cluster heads is described for wireless sensor networks. Genetic Algorithms is used to find the optimal position for cluster heads location based on the distance between cluster heads and sensor nodes and also the optimal position for BS by repositioning based on the distance between cluster heads and the BS. From the simulation result, the proposed protocol can significantly increase the lifetime of network compare to LEACH protocol. In addition, the proposed protocol BSR-GA is also compared with LEACH protocol in term of network lifetime, packet delivery and energy efficiency. Future works include other optimization method for the mobile base station and network coverage by sensor nodes to the network performance.



(a) (b)

(c)

Fig. 3: (a) Number of nodes alive over round for network field. (b) Sum of energy over round. (c) Number of packets data sent to BS over round.

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