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Performance of mobile base station using genetic algorithms on network lifetime in different base station patterns

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***Abstract*— Wireless sensor network is basically composed of large number of sensor nodes and a base station. The sensor nodes usually are irreplaceable and powered 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 a protocol for mobile base station using Genetic Algorithms to find optimal position for base station from predetermined location of base station. The predetermined locations of base station are from three mobility patterns for the base station; random, grid and circle mobility patterns. Simulation results have shown that the normalized network lifetime using grid mobility pattern are higher than random and circle mobility patterns.**

***Keywords*—sensor node; mobile base station; Genetic Algorithms; network**

I. Introduction

The wireless sensor networks (WSNs) are family of ad hoc networks in which comprising large numbers of sensors called as sensor nodes. These sensor nodes are used as a sensing component, on-board processing, storage capabilities and also communication not only with each other but also with a sink or a base station using their wireless radios. Typically, WSNs are used to monitor physical or environmental conditions such as temperature, sound, vibration, pressure, motion or pollutants. This is achievable with WSNs as the sensor nodes were distributed around the sensing area that are usually unreachable by human due to harsh environmental conditions [1].

Many types of application based on WSNs have been developed for human facility in general, for example environmental monitoring. The system in [2] was used to maintain the safety of people and also protect the ecosystem of the mountain. Besides that, WSNs also have been used in application for example giving an early warning to the natural disaster such as earthquake [3], flood [4],and also monitoring an active volcano [5] which is able to save millions of lives. Other examples of application using WSNs are industrial WSNs [6] which enable low-cost instrumentation, target tracking in [7] used low energy consumption, transportation system in [8] enable intelligent system that contains scheduling center, vehicle system and station system and also health monitoring [9] for the control center (base station) to perform active monitoring where sensor nodes send information of patients continuously to the control center.

Various researches have been done to improve one of major problem in WSN which 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 a base station (BS) and sensor nodes. Usually, communication cost in WSN can be related to the distance between the sensor node with other sensor nodes and also with the BS of the network. The recent interest of this application is the mobile base station (MBS) is able to minimized energy used by the network. In [10] shows that energy is minimized by using a two-level fuzzy logic. Besides that, by applying MBS, average residual energy of the sensor nodes can be minimized as shown in [11] resulting in extending the lifetime of the network as agreed by [12]. Furthermore, the MBS can be applied while network is operational and be able to improve the overall of network performance as proved by [13].

In this study, a new protocol is proposed based on Genetic Algorithms (GA) to study the performance of base station (BS) mobility within network field on network lifetime by using BS mobility patterns. The objective in designing this routing protocol is to determine the optimal location of a BS for data collection from sensor nodes and to study the characteristic of three base station mobility patterns (random, grid and circle) on WSN lifetime.

II. The System Model

A. *Network model*

In this study, the network model that have been used is similar with [12], [14]. The sensor network for this work is with the merger of following assumptions;

1) All sensor nodes have same amount of initial energy and ability.
2) All sensor nodes produce same amount of data per time and the data unit have same length.
3) All sensor nodes always have data to send to the base station.
4) All sensor nodes are stationary and homogeneous with limited energy.

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5) All sensor nodes have power control capabilities to vary their transmit power.

6) The location of base station and sensor nodes is known by the base station.

7) Base station initially located at middle of the sensing field.

8) Base station can move to predetermined location within the network field.

9) Time taken for base station movement is negligible for simplicity.

B. *Energy model*

The energy model in this paper is based on first model of radio energy model as in [14]. In this model, radio dissipates energy to run the radio electronics (transmitter or receiver circuitry) and transmit amplifier. This radio model can also perform power control of 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:

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

$$= l \times E_{elec} + l \times \varepsilon_{MS} \times d^4 \quad \text{if } d \geq d_o \qquad (2)$$

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 do is the threshold transmission distance. For energy dissipated by the radio for receiving the message is given by:

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

E_{elec} for transmitting an *l*-bit message is same as E_{elec} for receiving an *l*-bit message. 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.

C. *Problem definitions*

A network topology with *N* number of sensor nodes was distributed randomly over a network field. This randomly distributed sensor nodes are considered to be in *LxL* network field, where L is the length and width of the network field in meters. Fig. 1 is an example of network field in 100m x 100m with (●) is the sensor nodes. A single BS is considered to be moveable to set of predetermined location within the network field. Three different mobility patterns is designed for the BS in different network filed which are random pattern, grid pattern and circle pattern. By assuming that the BS has unlimited power source, the proposed protocol based on GA is able to apply on the BS. The optimization problem is to find the optimized location for BS (utilized BS) to move within the predetermined location of the mobility patterns.

TABLE I. COMMUNICATION ENERGY PARAMETERS

Parameter	Values
l	2000-bit packet length
E_{elec}	50 nJ/bit
ε_{FS}	10 pJ/bit/m^2
ε_{MS}	1.3 fJ/bit/m^4

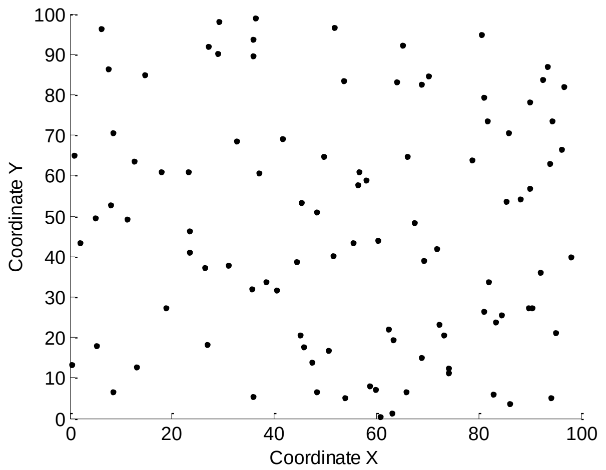

Figure 1. Sensor nodes in 100m x 100m field.

III. Protocol Descriptions

As stated earlier, the proposed protocol in this study is designed based on mobility of BS using GA to find the optimized location of BS and to determine which sensor node will be sent their data to this optimized location of BS. The sensor nodes that send the data will act as transmitter meanwhile the BS will perform as receiver as it receives data from sensor nodes. Both of the operation used the energy model as explain earlier in previous section.

A. *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 [15], [16]. The algorithm starts with creating a random initial population. Then, series of new population is created based on old population called generation. To create new population, the algorithm applied selection of individual as parents for next population based on their fitness value. The next generation is produced by combination of crossover, mutation of parents from previous generation and also elite members which are the parents that became the member of next generation. The children from previous generation became parents for next generation. Usually, GA is required to find the minimum value of the fitness function. In GA, the term fitness function or objective function is the function that needs to be optimized. The fitness function consists of individual, which is the potential solution to the optimization problem. The group or array of individual known as population or in others word the population is the potential solution for optimization problem. The smallest fitness function value for any individual in the population is the solution for the optimization problems.

For this study, a set of population refers to utilized BS which is the potential optimized locations from predetermined BS locations of mobility pattern. The objective of using GA is to find these potential optimized locations by minimizing the fitness function. The fitness function is referred to the distance between the potential utilized BS from predetermined BS locations of mobility pattern and sensor node. For example, let say that there are 9 predetermined BS locations and 5 utilized BS will be used. From this problem, there will be only 5 number of predetermined BS locations will be used by the base station to move from total 9 predetermined BS locations. It means that, there only 5 potential locations and these potential locations is referred to one set of population that has 5 numbers of individual.

Let (x_j , y_j) be the coordinate of the distributed sensor nodes and (x_k , y_k) be the coordinate of the predetermined BS. If the free space propagation model form energy model is used, the distance between the sensor node j and the predetermined BS location k is given by:

$$d(s_k, n_j) = \left[(x_k - x_j)^2 + (y_k - y_j)^2\right]^{\frac{1}{2}} \quad (4)$$

The total energy expended by sensor nodes can be minimized by minimizing the total distance of between all sensor nodes and the utilized BS. To archive that, the BS needs to move to the location where the total distance is smallest. The fitness function, f is defined as:

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

Where K is total number of utilized BS and $|C_k|$ is total number of sensor nodes that send the packet data to the closed utilized BS. These sensor nodes are selected based on the location of utilized BS, which are the nearest to that utilized BS.

B. *Setup and steady phase*

In this protocol, setup phase only occurs once at the beginning of the protocol. At the starting of this setup phase, all sensor nodes send their information regarding location to the BS and the initial location of BS is at the center of the network field. For simplicity, the energy expended by sensor nodes to send the information is negligible. In addition to the location of all sensor nodes, the BS also knows the locations of predetermined BS of the mobility patterns. Based on the information of all sensor nodes and predetermined BS locations, BS runs the proposed protocol based on GA operation to get the locations of utilized BS. After that, the sensor nodes decide itself to which utilized BS locations it will transmit the packet data to, based on the distance between the sensor nodes to the nearest locations of utilized BS. Setup phase ends after BS obtains the information about the locations of utilized BS for the BS to move

Steady phase takes place with the BS started to visit the utilized BS location and all the nearest sensor nodes to that utilized BS location transmitted the packet data to the BS. TDMA (Time Division Multiple Access) is used to schedule the data transmission of sensor nodes at the BS. To save the energy of sensor nodes, the sensor nodes will only be switched on to transfer their sensed information during their transmit time and after that it turns to sleep mode. After all sensor nodes finish sending its data, the BS move to next utilized BS and data transmission process will be repeated. One trip of BS that is from first utilized BS location to the final utilized BS location is called round and the network lifetime is organized into round. The network lifetime for this study is considered to be the first sensor node that died during the steady phase.

TABLE II. GA PARAMETERS

GA Parameter	Values
Population size	200
Number of variables	5
Lower bound, upper bound	0 , L
Crossover Fraction	0.8
Number of Elite count	10
Number of mutation	30

IV. Simulation And Analysis

A. *Experiment setup*

The series of experiments for the proposed protocol were executed via simulation using MATLAB. N (100 and 50) numbers of sensor nodes were placed randomly in network field area for wireless sensor network. Fig. 2 showed an example of predetermined BS for (a) random, (b) grid and (c) circle mobility pattern in 300m x 300m network field. The experiment was run on three different network fields (100m x100m, 300m x300m and 500m x 500m) and for each network field, there were 7 other experiments for different number of predetermined BS donated as (*Na*). From the Fig. 2, the number of *Na* used was 25 where there were 25 locations of predetermined BS. For example of experimenting parameters, there will be 100 sensor nodes for 500m x 500m network field with 49 number of predetermined BS for random mobility pattern for BS. Table 2 is GA parameters used in MATLAB in the experiments. Population size is also referred to the set of population and the number of variables is referred to the number of individual in one set of population. Crossover fraction is fraction for number of crossover children. The total population is the total of crossover children (crossover fraction time population size), elite children and also mutation children.

As stated earlier, the network lifetime is considered to be in round. In this experiment, normalized network lifetime is used. Network lifetime normalization can be achieved by dividing the network lifetime in each experimenting parameters with the largest value of network lifetime. The experiment for the proposed protocol is run at least 100 times for each parameter.

B. *Results and Analysis*

Overall, Fig. 3 shows that the network lifetime for random mobility pattern is higher than grid and circle mobility patterns, and grid mobility pattern is higher than

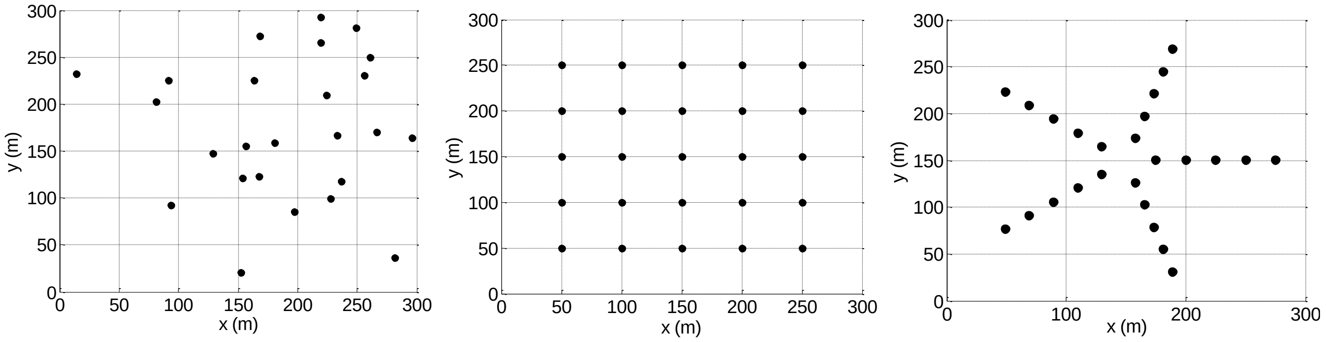

Figure 2. Mobility patterns for base station.

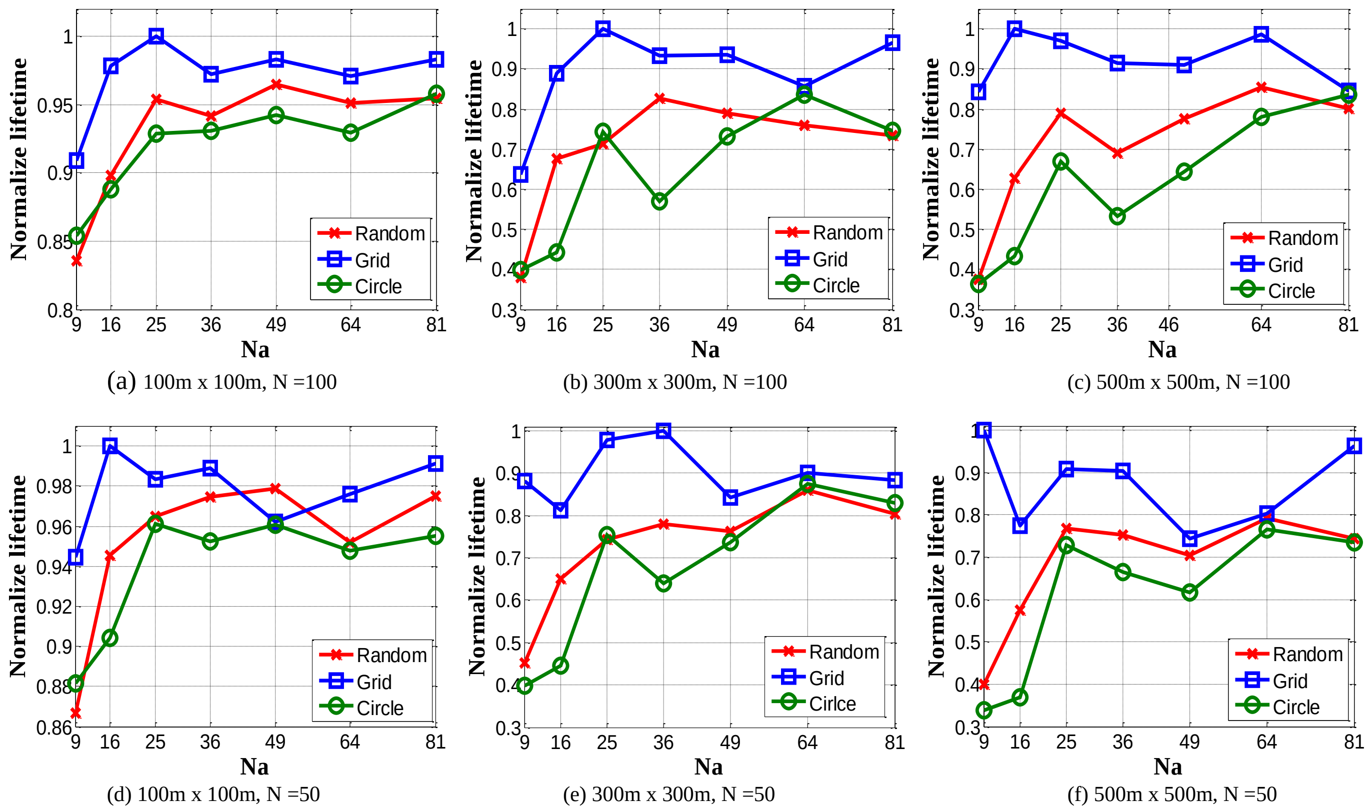

Figure 3. Normalized lifetime for different network field and number of sensor node.

circle mobility pattern for all parameters. This can be explained by referring to the example of mobility patterns in Fig. 2 where the predetermined BS for grid mobility pattern is able to cover more area of the network field. In addition, the increasing number of predetermined BS (*Na*) will also increase the area that can be covered by the BS. However, the area covered for random mobility pattern is not constantly covered unlike grid mobility pattern, for example in Fig 2 (a) where there are no predetermined BS to cover the bottom left area of the network field. This situation has caused the sensor nodes at that area expending more energy to transmit the data to the nearest BS.

Fig. 3 (a), (b) and (c) show the network lifetime for the proposed protocol using 100 sensor nodes while Fig. 3 (d), (e) and (f) show the network of proposed protocol using 50 sensor nodes. The maximum network lifetime for each parameter was not constantly same as shown in Fig. 3. For example, the maximum network lifetime for grid mobility for Fig. 3 (a), (b) and (c) occurred at *Na* = 25 for Fig. 3 (a) and (b) meanwhile *Na* = 16 for Fig. 3 (c). The maximum network lifetime for Fig. 3 (a), (b) and (c) occurred for random mobility and circle mobility were at *Na* = 49, 36 and 64, and *Na* = 81, 64 and 81 respectively. The results have shown that, the higher number of *Na* was not required to obtain the higher network lifetime for the experiment using 100 sensor nodes. However, different results were obtained when using 50 sensor nodes. This was due to lower number of sensor nodes per area in the network field. As the protocol was using GA to find the optimized position of utilized BS and at the same time the protocol runs at least 100 times, there were significant different in network lifetime between each experiment results.

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C. Conclusions

In this paper a new protocol for mobile base station problem has been described for wireless sensor networks. The proposed protocol used mobile base station using Genetic Algorithms in order to find the optimal positions of virtual BS. These positions were based on the location of predetermined BS in three different network fields for three different mobility patterns; random mobility, grid mobility and circle mobility. From the simulation results, it is shown that the overall normalized network lifetime for random mobility was higher than grid and circle mobility patterns. Future works include using other energy model such as MICA2.

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