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Performance of mobile base station in extending network lifetime for wireless sensor networks using genetic algorithms

Idrus Salimi Ismail, Nurul Adilah Abdul Latiff *

School of Ocean Engineering, University Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia

Abstract: Wireless sensor network is composed of large number of sensor nodes and base station. 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 mobile base station using Genetic Algorithms to find optimal position for base station. 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.

Key words: Wireless sensor networks; Mobile base statio; Energy efficiency; Genetic algorithms

1. Introduction

The wireless sensor networks (WSNs) are family of ad hoc networks in which comprising 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 and Poellabauer, 2010).

One of the major drawbacks of WNS is limited power or energy used by sensor node. Most of sensor nodes are using battery as their energy source. (Arkin et al., 2014) and (Alsalih et al., 2007) have stated that lifetime of the network is greatly depending on the lifetime of the sensor node energy and the lifetime of the network can be defined with the energy of one of the sensor nodes or the entire sensor nodes are run out. 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.

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. The recent interest of applied the mobile base station (MBS) is able to minimized energy used by the network. In (Far et al., 2014) shows that energy is minimizing by using a two-level fuzzy logic with mobile base station. Besides that, by applying MBS, average residual energy of the sensor nodes can be minimized as shown in (Chakrabarti et al., 2014), resulting in extend the lifetime of the network as agreed by (Latiff et al., 2011). Furthermore, the MBS can be applied while network is operational and be able to improve the overall of network performance as proved by (Akkaya et al., 2007).

In this paper, a new protocol is designed based on mobility of BS by using Genetic Algorithms to improve the network lifetime, data delivery to the BS and energy efficiency of wireless sensor network. The objective in designing this routing protocol is to determine the optimal location of a BS to stop for data collection from sensor node. The performance of the protocol also included in consideration of difference situation. The rest of this paper is organized as follows: In section 2 networks model are presented. For section 3, protocol description is defined for the proposed protocol. Simulations and results of the proposed protocol are presented in section 4 before concluding the paper.

2. Networks model

In this paper, the network model that has been used is similar with (Latiff et al., 2011) and

* Corresponding Author.

(Heinzelman et al., 2000). For this work, a network is integration of following features:

•All sensor nodes have same amount of initial energy and ability.

•Each sensor node produce same amount of data per time and the data unit have same length.

•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.

•Base station can move to certain location within the sensing field.

•For simplicity, time taken for base station movement is negligible.

•Energy dissipated only occurs at sensor nodes while transmitting message.

Next, for the energy model in this paper is based on first model of radio energy model 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 used minimum energy as possible to reach the receptions. 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 d2, the energy dissipates by the radio is given by:

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

$= l \times E_{elec} + l \times \varepsilon_{MS} \times d^4$, if $d \geq d_o$ (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 given by:

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

E_{elec} for transmitting a l-bit message is same as E_{elec} for receiving a l-bit message. In this paper, l is set to be 2000-bit packet length. It is assumption that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given SNR. The simulations described in this paper only consider energy dissipated by transmitting message on sensor nodes because energy dissipated at sensor nodes only occurs while transmitting message (Heinzelman et al., 2000). The communication energy parameters are set as Table 1.

Table 1: Table Type Styles

Parameter	Value
E_{elec}	50 nJ/bit
ε_{FS}	10 pJ/bit/m2
ε_{MS}	1.3 fJ/bit/m2

2.1. 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, $1 \leq j \leq N$. For the problem involve of BS, let $S = \{s_1,\ldots s_j,\ldots s_Q\}$ where $1 \leq j \leq Q$ be the OP-sites which are the point within the network field the BS can visit and Q is number of point. The number of OP-sites, Q is the same number of cluster, K.

By assuming that BS have unlimited power source, BS is performing the operation of proposed protocol which is based on Genetic Algorithms (GAs). The location for OP-sites as well as which cluster that sensor nodes belong to are also determined by BS using GA. Initially, the position of BS is located at the center of the network field. Then, the BS start to move to the first OP-site until stop at Q OP-site and each time BS stop at the OP-sites, it collected sensing data from nearby sensor nodes. For each trip while collecting data from the first OP-site to the Q OP-site, it is called round.

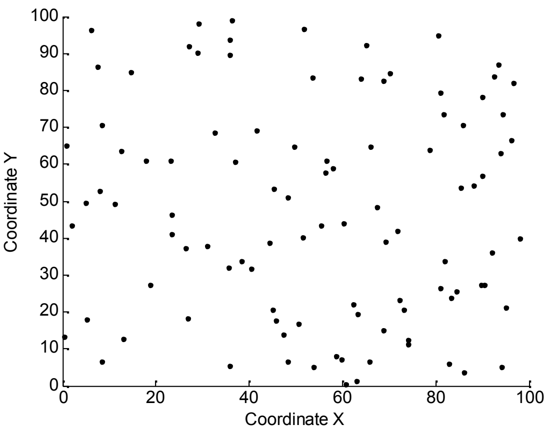


Fig. 1: Sensor nodes in 100m x 100m field.

3. Protocol description

3.1. 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; 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.

3.2. Fitness function

The fitness function or objective function in this algorithm used to find the location of the OP-sites in order to minimize the distance between sensor nodes and OP-sites. 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 BS as the receiver. Let (xj , yj) be the coordinate of the distributed sensor nodes and (xk, yk) be the coordinate of the BS location. If the free space propagation model is used, the distance between the sensor node j and the BS location k is given by:

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

The total energy expended by sensor nodes can be minimized by minimizing the total distance of between all sensor nodes and the BSs. To archive that, the BSs need to move to the location where the sum total distance is smallest and this location is called the OP-site. The cost function is defined as:

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

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.

3.3. 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 on the location of sensor nodes. Thus, all sensor nodes must send the information about their locations to the BS. Then, BS will run the GAs to find the location the OP-sites. After that, sensor nodes will decided itself which cluster it belong to.

Steady state takes place when all locations of OP-sites are determined. All sensor nodes transmit the sensed information to the BS when the BS visits the OP-sites in their cluster. TDMA (Time Division Multiple Access) is used to schedule the data transmission of sensor nodes at the BS. The sensor nodes only turn on to transmit their sensed information during their transmit time.

4. Simulation and analysis

4.1. Experiment setup

The performance of the proposed protocol is executed via simulation using MATLAB. 100 of sensor nodes are placed randomly in $Lx \times Ly$ 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 is at quarter of $Lx \times Ly$. The number of cluster is set to Q which is also the number of OP-site. The experiment was carried out to exam the performance based on different network field and number of OP-site, Q.

The GAs was run in the MATLAB to optimize the fitness function, the equation (5) to find the location of OP-sites based on distance between sensor nodes and OP-site. After several experiment on GAs, the parameter for the GAs used in this experiment is shown in Table 2. After GAs is run, Fig. 2 had shown cluster formation and OP-sites from randomly distributed sensor nodes as in Fig. 1. Difference color and shape mean the cluster of sensor nodes and for filled round shape are the OP-sites for the BS for each cluster.

Table 1: GAs Parameters

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

a. Two times number of OP-site
b. L is length of network field or Lx

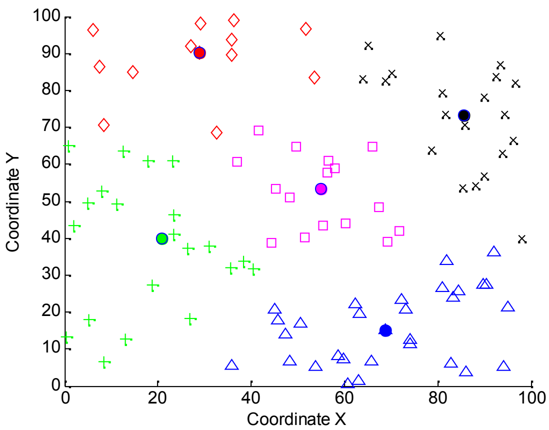
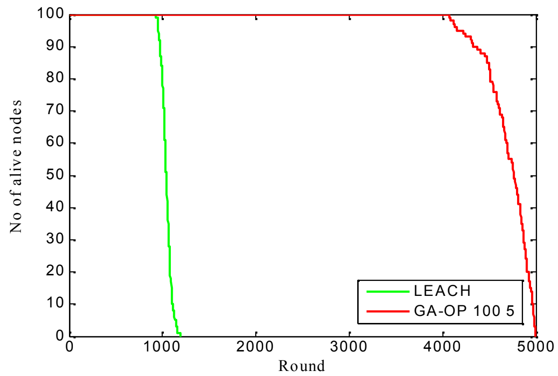


Fig. 2: Cluster formation and OP-sites location.

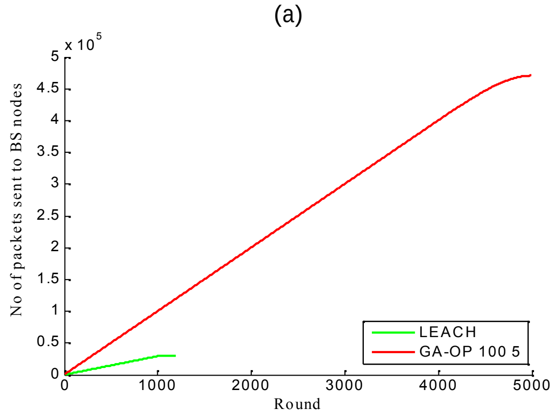
From the initial position, BS starts to move to OP-sites for data collection from sensor nodes in that cluster. After the end of TDMA schedule in a cluster, BS moves to next OP-site position for more data collection. The simulation continues until all sensor nodes in the network use up all their energy. The comparison between LEACH and proposed protocol BSOP will consider on 100m x 100m network field in term of network lifetime, packet data send to BS and also sum of energy for sensor node in the network. The experiment also carried out for the proposed protocol in different $Lx \times Ly$ area for 100m x 100m, 250m x 250m and 500m x 500m and numbers of OP-site, 5 and 10 for every network filed area.

4.2. Result and analysis

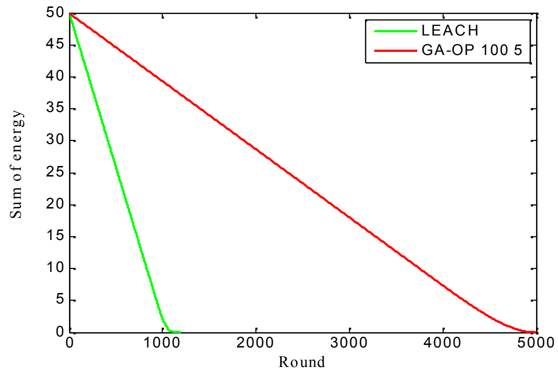
By referring to Fig. 3(a), it is shown that the lifetime of the proposed protocol GA-OP is significantly increasing compare to LEACH. Both protocol carried out on 100m x 100m network field and GA-OP protocol have 5 OP-sites. The lifetime for GA-OP is extended to round of 4998 compare to LEACH at round of 1196 for all sensor nodes used all their energy. This improvement is due to the shorter distance between sensor nodes and BS. Since the energy dissipated is greatly depending on distance, the GA-OP has the advantage compare to LEACH. Another reason for the improvement of the lifetime using GA-OP is energy dissipated only based on data transmission. The GA-OP only considers data transmission from sensor nodes to BS without energy dissipated for data receiving. However, LEACH makes certain sensor node as cluster head which mean, that particular sensor nodes use it energy for data received from sensor nodes in it cluster and then transmitted the aggregation data back to BS.



(a)



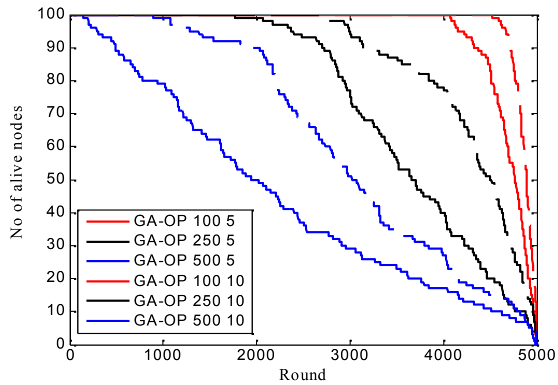
(b)



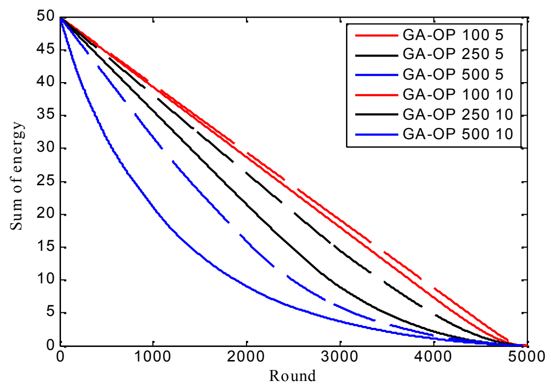
(c)

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

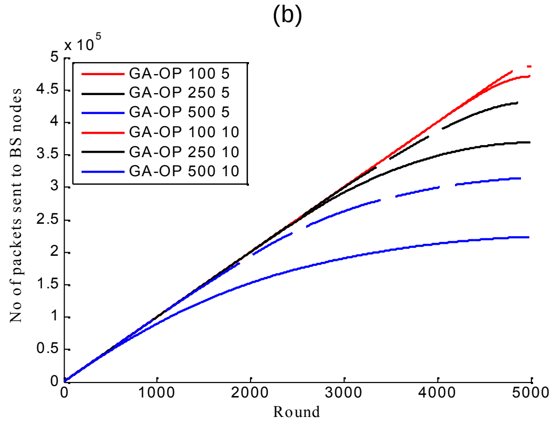
The network lifetime of LEACH and GA-OP lead to the change of number of packet sent to BS and sum of energy of sensor nodes. Fig. 3(b) shown that the packet data sent to BS for LEACH stop at round 1196 after all sensor nodes died likewise for the sum of total energy of sensor node in Fig. 3(c). The result for the experiment on performance of proposed protocol is shown in Fig. 4(a), Fig. 4(b) and Fig 4(c) with different network filed (100m x 100m, 250m x 250m and 500m x 500m) and number of OP-site (5 and 10). Fig. 4(a) shown that the number of sensor nodes alive against round where the first node died decrease in round with increasing number of network field. This situation is due to the increasing of the distance between sensor node and BS for the larger network field. However, it can be overcome with increase the number of OP-site. In this experiment, when the OP-site is increased from 5 to 10, round for the first node died increased due to decreasing of the distance between sensor nodes and BS. The round for all sensor nodes died is almost the same due to optimized location of BS from the proposed protocol using GAs.



(a)



(b)



(c)

Fig. 4: (a) Number of nodes alive over round for network field for GA-OP. (b) Sum of energy over round for GA-OP. (c) Number of packets data sent to BS over round for GA-OP.

The increasing of distance between each sensor nodes and BS site also lead to decreasing in total energy of all sensor nodes in network. As shown in Fig. 4(b), the sum of energy for all sensor nodes in the network is decreasing rapidly over round compare to others. This is because of the number of sensor node in the network is also rapidly died as more energy is used in transmitting packet data to BS.

Finally, Fig. 4(c) is for the number of packets sent to BS over round. By referring to Fig. 4(b), total packets successfully transmitted to the BS for 100m x 100m network field is greatly more than others network field. From Fig. 4(c), if the comparison is take place at around 2000 round, there are very small packets data have to be transmitted to BS for 500m x 500m network field compare to 100m x 100m where packets data transmitting to BS is still increasing. This is also due to number of sensor node alive to transmit the packet data to BS.

Conclusions

In this paper a new protocol for mobile base station problem is described for wireless sensor networks. The proposed protocol used mobile base station to extend the network lifetime using Genetic Algorithms. Genetic Algorithms is used to find the optimal position for BS location based on the distance between base station and sensor nodes. From the simulation result, the proposed protocol can significantly increase the lifetime of network compare to LEACH protocol. In addition, the proposed protocol also compared with difference network field and number of OP-site for BS location 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.

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References

Akkaya, Kemal, M. Younis, W. Youssef, and Southern Illinois. 2007. "Positioning of Base Stations in Wireless Sensor Networks." Communications Magazine, IEEE 45(April): 96–102.

Alsalih, W., S. Akl, and H. Hassanein. 2007. "Placement of Multiple Mobile Base Stations in Wireless Sensor Networks." 2007 IEEE International Symposium on Signal Processing and Information Technology: 229–33.

Arkin, Esther M. et al. 2014. "Data Transmission and Base-Station Placement for Optimizing the Lifetime of Wireless Sensor Networks." Ad Hoc Networks 12: 201–18. http://dx.doi.org/10.1016/j.adhoc.2011.09.010.

Chakrabarti, Suriti, Arunava Bhattacharyya, and Utsav Ganguly. 2014. "An Energy Aware Routing Design to Maximize Lifetime of a Wireless Sensor Network with a Mobile Base Station." : 2135–41.

Coley, Da. 1999. "An Introduction to Genetic Algorithms for Scientists and Engineers." : 125–26.

Dergie, Waltenegus, and Christian Poellabauer. 2010. Fundamentals of Wireless Sensor Networks.

Far, Bahmanyar Esfandiari, Sh Alirezaee, S Alirezaee, and S Makki. 2014. "Wireless Sensor Network Energy Minimization Using The Mobile Sink." : 1184–88.

Heinzelman, Wendi Rabiner et al. 2000. "Energy-Efficient Communication Protocol for Wireless Microsensor Networks." Proceedings of the 33rd Annual Hawaii International Conference on System Sciences 00(c): 3005–14. http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=926982.

Latiff, Nurul Adilah Abdul, Nurul Mu'azzah Abdul Latiff, and R Badlishah Ahmad. 2011. "Prolonging Lifetime of Wireless Sensor Networks with Mobile Base Station Using Particle Swarm Optimization." 2011 Fourth International Conference on Modeling, Simulation and Applied Optimization: 1–6.

Singiresu S. Rao. 2009. Engineering Optimization Theory and Practice. http://doi.wiley.com/10.1002/9780470549124