www.arpnjournals.com

PERFORMANCE OF MOBILE BASE STATION IN EXTENDING NETWORK LIFETIME FOR WIRELESS SENSOR NETWORKS

Idrus Salimi Ismail and Nurul Adilah Abdul Latiff
School of Ocean Engineering, Universiti Malaysia Terengganu, Kuala Terengganu, Terengganu, Malaysia
E-Mail: nuruladilah@umt.edu.my

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 the concept of trigonometric functions for the distributed sensor nodes. 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 others for difference network field in term of network lifetime, data delivery and energy dissipated.

Keywords: sensor networks, mobile base station, network lifetime, energy efficiency.

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. Typically, WSN consist of base station (BS) and also large amount of sensor nodes to sense physical information which have limited amount of power supply. However, cheap, small and smart sensors can be deployed in unpredictable physical area with recent advances in microelectronic mechanical system (MEMS) and wireless communication technologies (Pottie, 1998).

Many opportunities of application based on WSNs have been developed for human facilitatein general, for example environmental monitoring. The system in (Son, Her, Shim, & Kim, 2007) used to maintain the safety of people and also protect the ecosystem of the mountain. Besides that, WSNs also used in application to give an early warning to the natural disaster such as earthquake (Wang & Guo, 2012), flood (Liang, Sekercioglu, & Mani, 2007) and also monitoring an active volcano (Werner-Allen *et al*., 2006) which is able to save millions of live. Others example of application using WSNs as it's based are industry WSNs (Gungor & Hancke, 2009) which enable low-cost instrumentation, target tracking in (Z. Zhang, Li, Han, & Zhu, 2012) can used low energy consumption, transportation system in (Lang, Zurong, & Fen, 2009) enable intelligent system that contains scheduling center, vehicle system and station system and also health monitoring (R. Zhang, Yuan, & Wang, 2007) 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 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, Alirezaee, Alirezaee, & Makki, 2014) shows that energy is minimizing 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 (Chakrabarti, Bhattacharyya, & Ganguly, 2014), resulting in extend the lifetime of the network as agreed by (Latiff, Latiff, & Ahmad, 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, Younis, Youssef, & Illinois, 2007).

In this paper, a new protocol is designed based on mobility of BS called BSOP 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 path and 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.

NETWORKS MODEL

In this paper, the network model that has been used is similar with (Latiff *et al*., 2011) and (Heinzelman, W.R.; Chandrakasan, A.; Balakrishnan, 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, called optimize site or OP site.
- 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, W.R.; Chandrakasan, A.; Balakrishnan, 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 d^2, the energy dissipates by the radio is given by:

$$E_{TX}(l , d)= l \; x \; E_{elec} + l \; x \; \varepsilon_{amp} \; x \; d^2 \tag{1}$$

E_{elec} is the energy dissipated to run the transmitter or receiver circuitry and ε_{amp} is transmit amplifier. Then, energy dissipated by the radio for receiving the message given by:

$$E_{RX}(l)= l \; x \; E_{elec} \tag{2}$$

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, W.R.; Chandrakasan, A.; Balakrishnan, 2000). The communication energy parameters are set as: $E_{elec} = 50$ nJ/bit and $\varepsilon_{amp} = 10$ pJ/bit/m^2.

PROTOCOL DESCRIPTION

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 Lx x Ly network field as shown in Figure-1 where Lx and Ly is equal to 100m. For the problem involve of BS, let $S = \{s_1,...s_j,...s_Q\}$ 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. Before OP sites can be determined, temporary sites must be defined $Temp\ S = \{ts_1,...ts_j,...ts_Q\}$ where the points of $Temp\ S$ are determined using trigonometric functions as follows:

$$tsx_j = sinkxi +(Lx / 4) \; x \; cos(\theta \; x \; j) \tag{3}$$

$$tsy_j = sinkyi +(Ly / 4) \; x \; sin(\theta \; x \; j) \tag{4}$$

where,

$$\theta = (2 \; x \; \pi) \; / \; Q \tag{5}$$

The tsx_j and tsy_j are the temporary sites of the BS for x coordinate and y coordinate respectively. The j is the number of temporary sites for the BS to move in and θ is the angle between temporary sites and initial positions of BS. Then $sinkxi$ and $sinkyi$ are for the initial positions of the BS in x and y coordinate which is at the middle of the network field. $Temp\ S$ have a function to cluster the sensor nodes into K clusters $\{C_1,...C_k,...C_K\}$, where number of OP sites, number of $Temp\ S$ and number of K clusters are the same. After clusters are formed, the point of OP sites can be calculated by using center of gravity of distribution sensor nodes for each cluster. The OP site, S can be calculated using equation as follows:

$$S(x_K) = (\textstyle\sum_i x_i) / (\textstyle\sum i) \tag{6}$$

$$S(y_K) = (\textstyle\sum_i y_i) / (\textstyle\sum i) \tag{7}$$

where $\sum i$ is the total number of sensor nodes in the cluster, x_i and y_i are the the location of the sensor nodes for x-coordinate and y-cordinate respectively in the cluster. By using both equations above, the OP site, S is :

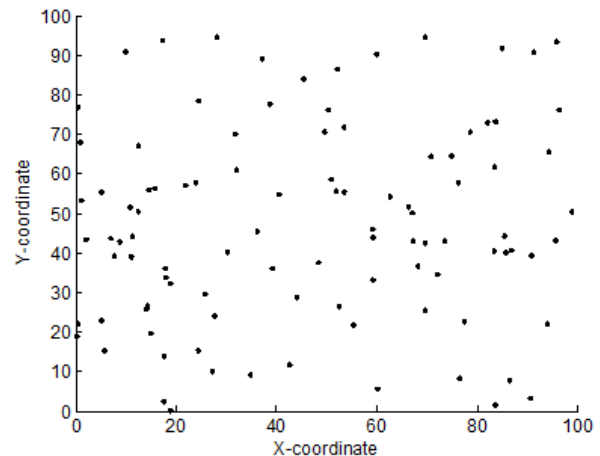$$S = (\; S(x_K), S(y_K) \;) \tag{7}$$

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

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 is based on center of gravity 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, sensor nodes will decided itself which cluster it belong to by referring to the $Temp\ S$. After clusters are forms, BS runs the proposed protocol to determine the positions of data gathering point.

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.

SIMULATION AND ANALYSIS

Experiment setup

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 where Lx x Ly is 100m, 200m, 300m, 400m and 500m. Initial energy for each sensor nodes is set to 0.5 Joules and initial position for the BS is at quarter of Lx x Ly. The number of cluster is set to 5 which is also the number of Temp S site and OP site. Figure-2 shown cluster formation from randomly distributed sensor nodes as in Figure-1. Difference color and shape mean the cluster of sensor nodes. Empty round shape is the Temp S site and filled round shape is the OP sites for the BS for each cluster.
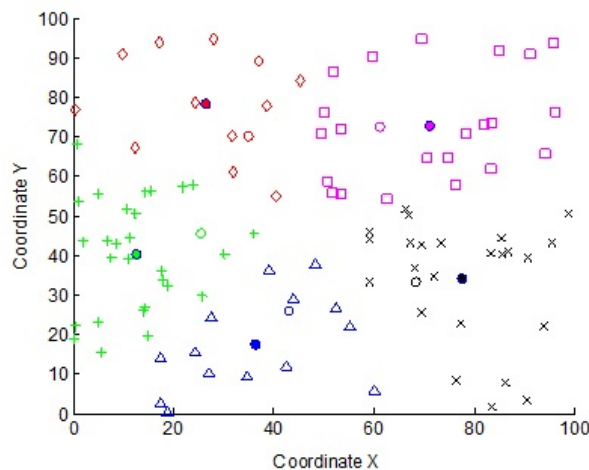

Figure-2. Cluster formation and Temp S and OP base station.

From the initial position, BS start to move to intended destination for data collection from sensor nodes in that cluster. After the end of TDMA schedule in a cluster, BS move 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. Then, the experiment continue with the comparison of proposed protocol BSOP with difference network field in term of network lifetime, packet data send to BS and also sum of energy for sensor node in the network.

RESULT AND ANALYSIS

There are two experimenting result in this work; first simulation result is the comparison of proposed protocol BSOP and LEACH using the same parameter for both protocols. Then for the second simulation result is the comparison among BSOP protocol using same numbers of OP site which is 5 and difference length and width for the network field, 100m x 100m, 200m x 200m, 300m x 300m, 400m x 400m and 500m x 500m. The experiment is investigating on the lifetime of the network, number of packet data sent to BS and also the total sum of energy.

By referring to Figure-3, it is shown that the lifetime of the proposed protocol BSOP is significantly increasing compare to LEACH. The lifetime for BSOP is extended to round of 4981 compare to LEACH at round of 1692 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 BSOP has the advantage compare to LEACH. Another reason for the improvement of the lifetime using BSOP is energy dissipated only based on data transmission. The BSOP 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.
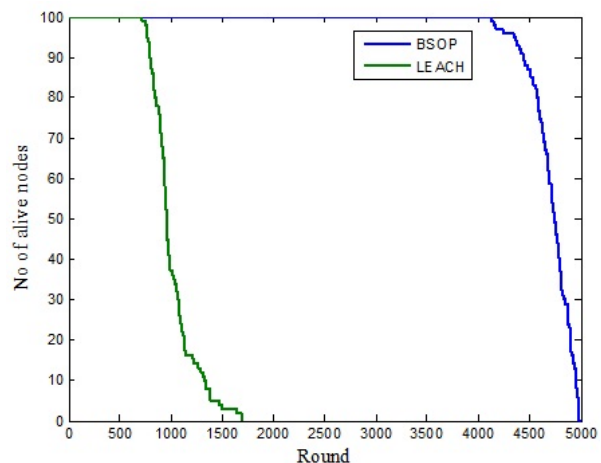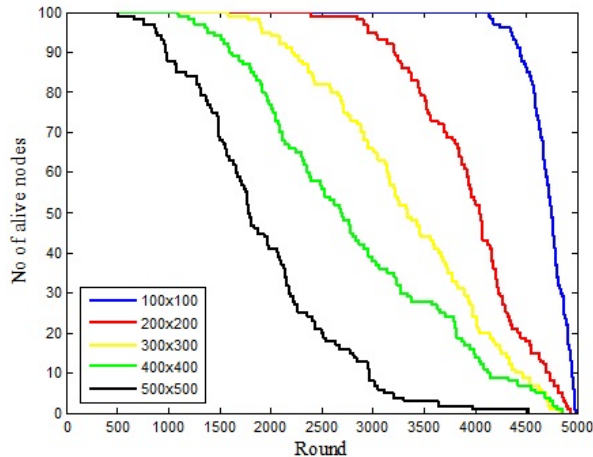

Figure-3. Number of nodes alive over round for network field, LEACH and BSOP.

For the second experiment, the simulation result in Figure-4 show the number of node alive with increasing round. The BSOP protocol using in the 100m x 100m network field is more preferable compare to others network field. Moreover, by referring to Table-1, the 1st sensor node that died for the 100m x 100m network field is at round 4128 compare to others as the round is increasing. This situation is due to increasing in distance between each sensor nodes to BS site in the network.

The network lifetime also referred the total round for all sensor nodes used up their energy. Table-1 also

www.arpnjournals.com

shows that the network lifetime for 100m x 100m network field is longer than other network field. However, from the Table-1, the lifetime for 200m x 200m network field is longer than 300m x 300m network field which is supposed to be shorter. This is due to mobility of the BS which is changing its location if there is a sensor node die.

network field. From Figure-6, if the comparison is take place at around 3000 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.

Figure-4. Number of nodes alive over round for variuos network field.

Table-1. Comparison of BSOP with difference network field in term of round.

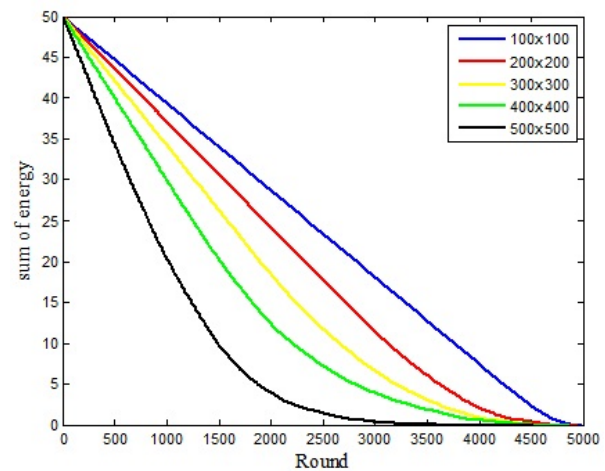| Lx x Ly network field (m)	1st node died	All nodes died[a]	Total packet[b]
100 x 100	4128	4981	471402
200 x 200	2390	4934	396962
300 x 300	1589	4817	334980
400 x 400	1095	4854	281573
500 x 500	506	4522	192296

a. Network lifetime
b. After all sensor node died

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 Figure-5, 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, Figure-6 is for the number of packets sent to BS over round. By referring to Figure-6 and also Table-1, total packets successfully transmitted to the BS for 100m x 100m network field is greatly more than others

Figure-5. Sum of energy over round for variuos network field.
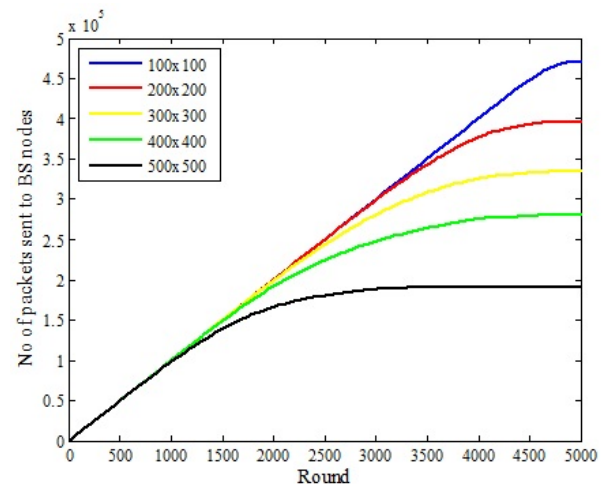
Figure-6. Number of packets data sent to BS over round for variuos network field.

CONCLUSIONS

In this paper a new protocol for mobile base station problem is described for wireless sensor networks. By using concept of trigonometric functions for the distributed sensor nodes, an optimal position for base station to visit can be calculated to minimize 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 in term of network lifetime,

www.arpnjournals.com

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.

REFERENCES

[1] Akkaya K., Younis M., Youssef W. and Illinois S. 2007. Positioning of Base Stations in Wireless Sensor Networks. Communications Magazine, 45, 96–102. doi:10.1109/MCOM.2007.343618

[2] Chakrabarti S., Bhattacharyya A. and Ganguly U. 2014. An Energy Aware Routing Design to Maximize Lifetime of a Wireless Sensor Network with a Mobile Base Station, pp. 2135–2141.

[3] Far B. E., Alirezaee S., Alirezaee S. and Makki S. 2014. Wireless Sensor Network Energy Minimization Using the Mobile Sink, pp. 1184–1188.

[4] Gungor V. C. and Hancke G. P. 2009. Industrial Wireless Sensor Networks: Challenges, Design Principles, and Technical Approaches. IEEE Transactions on Industrial Electronics, Vol. 56, No. 10, pp. 4258–4265. doi:10.1109/TIE.2009.2015754.

[5] Heinzelman W.R., Chandrakasan A., Balakrishnan H. 2000. Energy-efficient communication protocol for wireless microsensor networks. Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, pp.1–10.

[6] Lang P., Zurong N. and Fen X. 2009. Design for wireless sensor network-based intelligent public transportation system. In 3rd International Conference on Anti-counterfeiting, Security, and Identification in Communication, ASID 2009, pp. 1–4. doi:10.1109/ICASID.2009.5276953.

[7] Latiff N. A. A., Latiff N. M. A. and Ahmad R. B. 2011. Prolonging lifetime of wireless sensor networks with mobile base station using particle swarm optimization. Fourth International Conference on Modeling, Simulation and Applied Optimization, pp. 1–6. doi:10.1109/ICMSAO.2011.5775487.

[8] Liang O., Sekercioglu Y. A. and Mani N. 2007. A Low-Cost Flooding Algorithm for Wireless Sensor Networks. IEEE Wireless Communications and Networking Conference, 3495–3500. doi:10.1109/WCNC.2007.641.

[9] Pottie G. J. 1998. Wireless sensor networks. 1998 Information Theory Workshop (Cat. No.98EX131). doi:10.1109/ITW.1998.706478.

[10] Son B., Her Y. S., Shim K. and Kim J. G. 2007. Development of an Automatic People-Counting and Environment Monitoring System Based on Wireless Sensor Network in Real Time; To realize in Korea Mountains. International Conference on Multimedia and Ubiquitous Engineering (MUE'07), pp. 579–584. doi:10.1109/MUE.2007.120.

[11] Wang W. and Guo L. 2012. The Application of Wireless Sensor Network Technology in Earthquake Disaster. International Conference on Industrial Control and Electronics Engineering, pp. 52–55. doi:10.1109/ICICEE.2012.22.

[12] Werner-Allen G., Lorincz K., Welsh M., Marcillo O., Johnson J., Ruiz M. and Lees J. 2006. Deploying a wireless sensor network on an active volcano. IEEE Internet Computing, 10(April), pp. 18–25. doi:10.1109/MIC.2006.26.

[13] Zhang R., Yuan D. and Wang Y. 2007. A Health Monitoring System for Wireless Sensor Networks. 2nd IEEE Conference on Industrial Electronics and Applications, 2(i), pp. 1648–1652. doi:10.1109/ICIEA.2007.4318689.

[14] Zhang Z., Li J., Han S. and Zhu Q. 2012. Multi-target tracking using the sign of innovations in wireless sensor networks. 24th Chinese Control and Decision Conference (CCDC), pp. 3353–3357. doi:10.1109/CCDC.2012.6244533.