Dynamic base station positioning algorithm for wireless sensor networks

Ahmed Salim

Department of Mathematics, Faculty of Science, Zagazig, University, P.O. Box 44519, Zagazig, Egypt

Department of Mathematics, Faculty of Science and Arts, Al-mithnab, Qassim University, P.O. Box 931, Buridah, Al-mithnab 51931, Kingdom of Saudi Arabia

Abstract—*Clustering is one of the most popular approaches used for energy efficiency in wireless sensor networks (WSNs). We considered a clustered based WSN with a mobile base station (BS). In this paper, after cluster head (CH) nodes election and cluster formation, the best location of the BS is specified with respect to the CHs. The location of the BS is determined so that the minimum energy cost is imposed for data communication; this is because the energy consumption depends on the distance between the cluster heads and the BS. Simulation results show that the proposed algorithm has a more advantage in energy conservation.*

Keywords - *Wireless sensor networks, clustered based network, mobile base station, LEACH, Data-gathering.*

I. INTRODUCTION(SIZE 10 & BOLD)

A WSN is a hot domain in wireless network technology. The vast development in wireless communications leads to mass production of battery-powered and portable detection stations called sensor nodes. These nodes can record parameters at diverse locations as weather conditions, physical parameters, and vital body functions. Hundreds or thousands of sensor nodes can be randomly deployed and self-organize to form large-scale networks. They communicate with the destination through their wireless interfaces as multi-hop [1, 2].

Data gathering is a technique of gathering and routing the sensed data from the sensor nodes. The power limitation of a sensor node is an important obstacle in Data-gathering [11]. Therefore, many protocols have been aimed to collect data and communicate between sensor nodes [3, 4]. Cluster-based hierarchy and non-hierarchy are the kinds of data collection protocols [5]. Directed Diffusion [6] is an example of non-hierarchical protocols, while LEACH [3] is an example of the hierarchical protocols.

Hierarchical protocol designed as series of rounds with two phases. In the first phase, the WSN arranged into disjoint groups called clusters (this phase called cluster formation or cluster setup). Each cluster has a CH node selected from all the nodes in the cluster.

The CHs were responsible for data aggregation and transmission from sensor nodes to the BS directly in data transmission phase [11]. Achievement of the energy consumption balance among nodes was firstly tried using LEACH protocol.

During the transmission phase, it was observed that the BS location affects the network performance. Thus, our paper focuses on designing an efficient algorithm to detect the best location of the BS based on the locations of the new CH nodes per round.

II. RELATED WORK

WSNs have been widely used recently in many fields of interest as in detection of forest fires, a monitoring system of health and border surveillance services [8]. The main issue attracted the researcher's attention is to prolong the lifetime of the WSN by of energy conservation of sensor nodes.

However, the ad-hoc formation and limited resources of sensor nodes often associated with disregarded deployment, they motivate the creation of special techniques relying on WSN design and management [9].

Effective utilization of the sensor nodes energy is the target of many developed techniques. Placement of the sink node in the most favorable position is one of these techniques. The network performance may be affected by the position of the BS because various relay nodes are required for routing the data from the source sensor to the distant far BS. That leads to increasing the consumption of energy, the aggregate delay and link errors that hazards packet loss [9].

A geometrical approach giving an algorithm have figured out the optimal locations of the BS [10]. In [11] PSO is used to find the sink node optimized position. This method is tested by using a query-driven model of WSN to allow the relation between the nodes and sink.

Going with the same purpose of increasing network lifetime of clustered WSNs a Mobile Sink based Routing Protocol (MSRP) is purposed where the mobile sink is recording the remained energy from the CHs while gathering data from them and the neighbor nodes. The mobile sink decides to move to the higher energy CHs [12].

Other proposed study named HUMS leads to network equilibrium in energy consumption. The mobile sink does as an energy harvester by moving towards the highest residual energy node [13].

While depending on a centroid algorithm, a centroid dynamic sink location method (CDSL) aimed to decrease mobile-clustered WSN energy consumption by allowing the mobile sink to move in each round to the nearest location among all CHs [14].

LMREM is proposed in [15]. In LMREM, the sink periodically moves to a new location with the highest stay value. The BS stay value is calculated by metrics like average residual energy and the number of neighbors. In [16] the best position of the BS is determined in a distributed manner. Later research maximizes the network lifetime by using the mathematical model of MILP. It specified the sink path to collect data from all CHs in t_dr (data reporting time) time span [17].

III. ALGORITHM DESCRIPTIONS

As stated before, sensors have limited power and computing resources. Therefore, the sensor energy has to be managed wisely to maximize the lifetime of the network. Clustering sensor nodes in sensor networks have two major phases. First, is to elect one cluster head nodes. Second, is to form the clusters.

Therefore, it is important to consider the energy dissipation metric in the process of CH election. We use the same setting in [3], wherein to transmit a l-bit message a distance d, the radio power consumption will be,

$$E_{Tx}(l,d) = \begin{cases} l\,E_{elec} + l\,\epsilon_{fs} d^2 & d < d_0 \\ l\,E_{elec} + l\,\epsilon_{mp} d^4 & d \geq d_0 \end{cases} \quad (1)$$

and to receive this message, the radio expands will be

$$E_{Rx}(l) = l\,E_{elec} \quad (2)$$

where d is the distance between sender and receiver, $E_{Tx}(l,d)$ is the cost of transmitting an l-bit message for a distance d, $E_{Rx}(l)$ is the cost of receiving and l-bit message for a distance d, E_{elec} is the electronics energy that depends on the circuit itself, ϵ_{mp} is the energy consumed bythe transmitter amplifier for longer distance, ϵ_{fs} the energy consumed by the transmitter for shorter distance, the threshold distance $d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$, and E_{DA} is the energy for data aggregation.

Assume that n nodes are uniformly distributed, and there exist k clusters in the topology. Thus, on an average, there will be $\frac{n}{k}$ nodes per cluster. In a cluster, there will be one CH and $(\frac{n}{k} - 1)$ cluster members.

Energy consumed by the CH involves energy consumed while receiving data from all the cluster member nodes($(\frac{n}{k} - 1).E_{Rx}(l)$), energy consumed during aggregation of data ($\frac{n}{k}.l.E_{DA}$) and forwarding of data to the BS ($E_{Tx}(l, d_{toBS})$). Consequently, the total energy consumption by the cluster head can be calculated as follows [3]:

$$E_{CH} = (\frac{n}{k} - 1).E_{Rx}(l) + \frac{n}{k}.l.E_{DA} + E_{Tx}(l, d_{toBS}) \quad (3)$$

Where the l is the number of bits in each data message, and d_{toBS} is the distance from the CH node to the BS.

As indicated in equations 1 and 3 the distance between sender and receiver can affect the node lifetime. The BS is located far from the network area. Therefore, all other sensor nodes will use high power to transmit its data to this far BS, and this will result in higher energy dissipation (where E_{Tx} cost will be increased as d_{toBS} are increased).

In some cases, the BS can be placed in the center of a network area. However, in this case, a node that is located at the edge of the sensing area will deplete more energy to send data to the BS compared to nodes that are located near the BS. This will create not evenly distributed energy dissipation between all sensor nodes and furthermore reduce the network energy efficiency. To improve the situation, the best location of the BS is the main issue in this case.

As a result, we aim to find an approach by which we can reduce the value of the distance d_{toBS}. We try to take advantage of BS mobility connotation and save the CH's power. The position of a BS can significantly affect extending the network lifetime. Since the power consumption is a function of the distance between the CH's and the BS; our algorithm aims to reduce the total consumed energy by sensor nodes especially cluster head nodes which are more sensitive to energy drains for their role in the network. The mobile BS will be aware of new CH locations to move into the nearest best position between them. **Fig. 1** presents the flow chart of the proposed approach.

The main idea of our algorithm, the BS needs information about the new CH nodes locations. These locations information can be sent by the new CHs periodically after being elected to BS. The BS gets this information from all CHs in the current round and gets the medoid of the CHs as a new position for it. The following algorithm describes our approach todetermine the position

1. m: total number of CH nodes
2. $CH_i.x$: x- coordinate for cluster head i (CH_i)
3. $CH_i.y$: y- coordinate for cluster head i

4. Calculates $cx = \frac{1}{m}\sum_{i=1}^{m} CH_i.x$
5. Calculates $cy = \frac{1}{m}\sum_{i=1}^{m} CH_i.y$
6. Set $j = 1$ $\{index\ for\ CH_1\}$
7. Calculates $w_1 = \sqrt{(cx - CH_1.x)^2 + (cy - CH_1.y)^2}$ {weight for CH_1}
8. Set $w_{min} = w_1$ {minimum weight}
9. ***for*** $i = 2$ *to* m
10. Calculates $w_i = \sqrt{(cx - CH_i.x)^2 + (cy - CH_i.y)^2}$
11. ***if*** $w_{min} > w_i$
12. Set $w_{min} = w_i$
13. Set $j = i$
14. ***end if***
15. ***end for***
16. The new location for the BS is the location of CH_j

We calculate the weight value (w) for each CH (as shown in steps 7 and 10); the location of the CH which has minimum weight value will be selected as new BS location.

After the BS finds the new location, it moves to that new location that is suitable for all CHs. When it moves to its new location, it broadcast beacon message contains its new location to the network. Then, depending on one of the clustering algorithms used, CHs aggregate data from a node in their cluster and finallyCHs send their aggregated data to the BS at its new location.

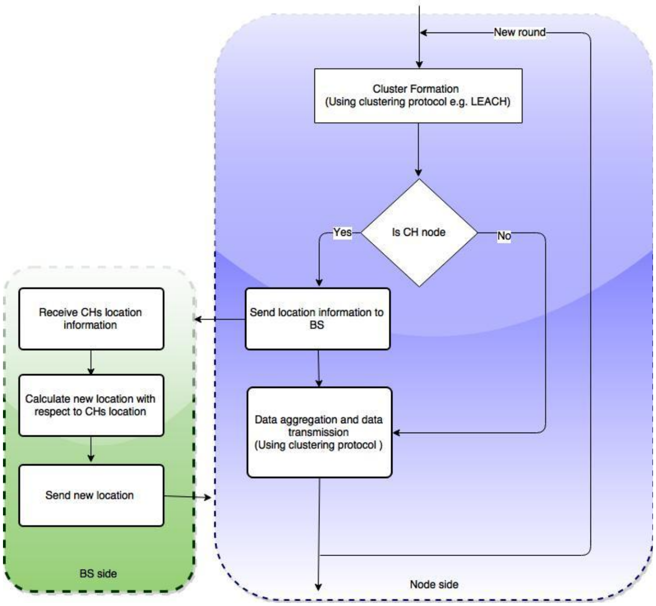


Fig. 1. The process of overall operations in our approach

IV. RESULTS

We evaluate the performance of our proposed algorithm using a simulator that has been implemented by $C\#$. In our simulation, 100 sensor nodes are randomly deployed in a region of size $200m \times 200m$ with BS at the center of the network.

In our experiments, selecting 0.05 of nodes as CHs and clustering are performed on the base of LEACH [3]. We use the same energy parameters and radio model as discussed in [3] wherein, $\epsilon_{mp} = \frac{13}{10000}\ pJ/bit/m^4$, $\epsilon_{fs} = 10$ bit/m^2, $E_{DA} = 5\ nJ/bit\ /signal$ and $E_{elec} = 50\ nJ/bit$.

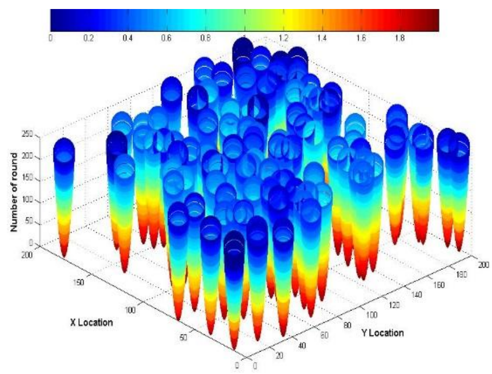
The performance evaluation of our algorithm is compared with CDSL [14], LMREM [15], MSRP [12], the algorithm in [16] (called optimal location) and static BS at center. The performance of our approach is evaluated mainly, according to the following metrics.

- **Average Energy Consumption:** It is the average energy consumed by all the nodes per round until the first node die, and it is given by:

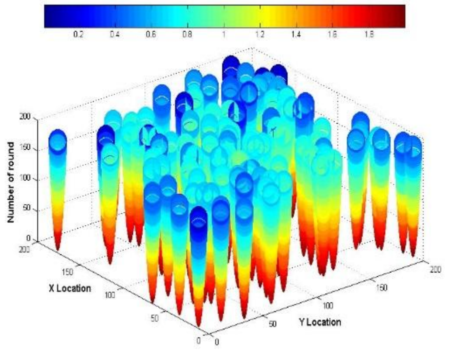
$$E = \sum_{i=1}^{N} \frac{E_i}{r} \qquad (4)$$

Where N the total is number of nodes, and r is the number of rounds.

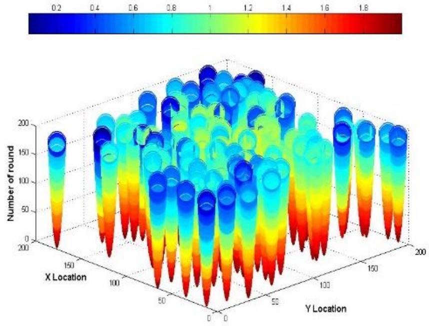
- **The standard deviation of node residual energy:** The standard deviation represents the spread of different energy depletion in the WSN.
- **Network lifetime:** It is the period between the start of WSN operation and the death of the first node.



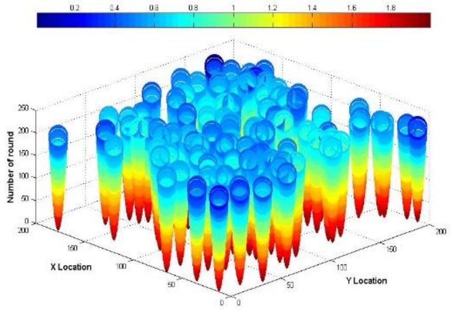
(a)



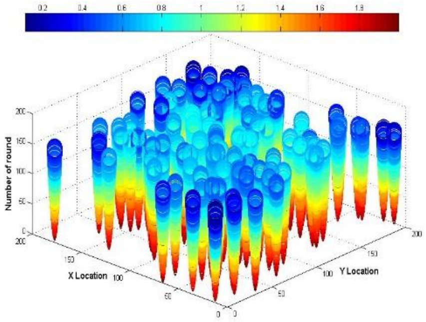
(b)



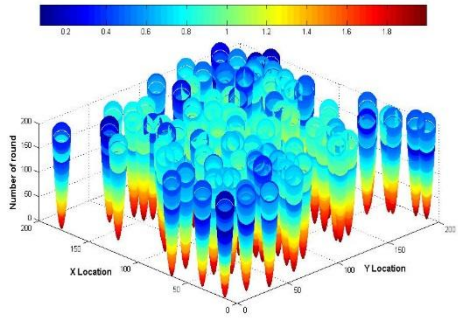
(c)



(d)



(e)



(f)

Fig.2. Residual energy map for (a)CDSL. (b)LMREM. (c)MSRP. (d)Our algorithm (e) Algorithm in [16]. (f) Static BS at center.

Fig. 2 shows the remaining energy map overall nodes compared with other protocols. We note that the distribution of energy consumption over all sensors in other protocols is irregular compared with the distribution of wasted energy over all nodes in our protocol. From **Fig. 2**, it is obvious that our protocol achieves the balancing of consuming energy distribution.

The increase rate of power depletion of our protocol is much lower than the rate of others; this is because in our protocol the power consumption is evenly distributed over all sensor nodes and the position of BS is not always centered in the middle. Also, the gathering process is considered by round level. On the other side, others protocol depend on the presence of BS in the middle. Therefore, the nodes that are found on the border always lose much energy compared to the center.

This was confirmed in **Fig. 3**, which shows the standard deviation of average energy dissipation. Our protocol performs well compared to other protocols. Also, all nodes in our protocol approximately have the same average energy consumption rate, and at the same time also has less average energy consumption rate (as seen in **Fig. 2**) which reflects a distribution of energy dissipation overall sensor nodes compared with others protocols.

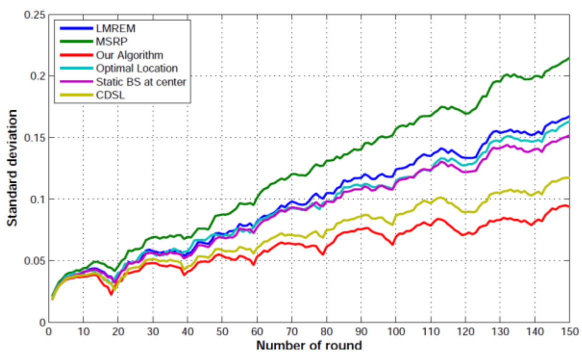


Fig. 3. Standard deviation of energy dissipation vs. round

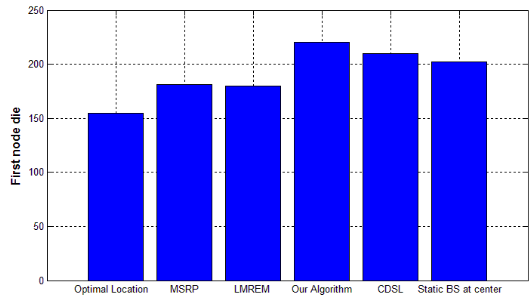


Fig. 4. Network lifetime cost for different protocols.

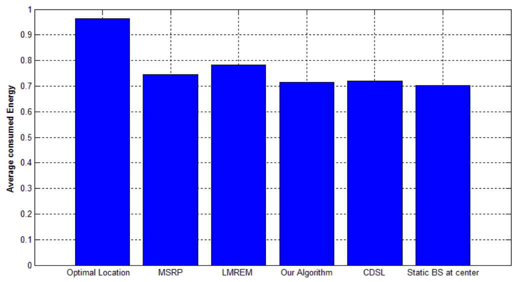


Fig. 5. Average energy consumption cost for different protocols.

Fig. 4 and **Fig. 5** show the network lifetime and the average energy consumption for our algorithm and other protocols. In **Fig. 4**, we compare the network lifetime of our algorithm with the optimal location, MSRP, LMREM, CDSL and Static BS at the center. The Figure shows that in the case of the algorithm in [16], MSRP, LMREM, CDSL and Static BS at center first node dies at 155, 181, 180, 210, and 202 round respectively, however, in our algorithm first node dies at 220 rounds.

V. Conclusions

In this paper, we have proposed dynamic base station location algorithm for clustered-based wireless sensor networks. The best location of the BSis determinedwith respect to the cluster heads. Results show that our algorithm outperformed CDSL, LMREM, MSRP, the algorithm in [16], and static BS at center in terms of the network lifetime and average energy dissipation.

VI. References

[1] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal, Wireless sensor network survey, ComputerNetwork, 52 (12) (2008) 2292-2330.

[2] V. Potdar, A. Sharif, E. Chang, Wireless sensor networks: A survey, in: Advanced Information Networking and Applications Workshops, 2009. WAINA '09. International Conference on, 2009, pp. 636-641.

[3] A. C. W. R. Heinzelman, H. Balakrishnan, Energy-efficient communication protocol for wireless microsensor networks, Proceedings of the 33rd Hawaii International Conference on System Sciences (2000) 1-10.

[4] C.-j. J. Y. Z. Min X, Wei-ren S, Energy efficient clustering algorithm for maximizing lifetime of wireless sensor networks., J AEU-International Journal of Electronics and Communications 64 (2010) 289298.

[5] 7X. Liu, A survey on clustering routing protocols in wireless sensor networks. Sensors (14248220) 12 (8) (2012) 11113-11153.

[6] 9C. Intanagonwiwat, R. Govindan, D. Estrin, J. Heidemann, F. Silva, Directed diffusion for wireless sensor networking, IEEE/ACM Trans. Netw.11 (1) (2003) 2-16.

[7] 11C.-M. Liu, C.-H. Lee, L.-C. Wang, Distributed clustering algorithms for data-gathering in wireless mobile sensor networks, Journal of parallel and distributed computing 67 (11) (2007) 1187-1200.

[8] 12P. Rawat, K. Singh, H. Chaouchi, J. Bonnin, Wireless sensor networks: a survey on recent developments and potential synergies, The Journal of Supercomputing 68 (1) (2014) 1-48. doi:10.1007/s11227-013-1021-9.

[9] 13K. Akkaya, M. Younis, W. Youssef, Positioning of base stations in wireless sensor networks, Communications Magazine, IEEE 45 (4) (2007) 96-102. doi:10.1109/MCOM.2007.343618.

[10] 14B. Paul, M. A. Matin, M. J. Showkat, Z. Rahman, Optimal placement of base stations in a two tiered wireless sensor network, WTOC 9 (1) (2010) 43-52. URL http://dl.acm.org/citation.cfm?id=1852321.1852326

[11] 15R. Alageswaran, R. Usha, R. Gayathridevi, G. Kiruthika, Design and implementation of dynamic sink node placement using particle swarm optimization for lifetime maximization of WSN applications, in: Advances in Engineering, Science and Management (ICAESM), 2012 International Conference on, 2012, pp. 552-555.

[12] 16B. Nazir, H. Hasbullah, Mobile sink based routing protocol (MSRP) for prolonging network lifetime in clustered wireless sensor network, in: Computer Applications and Industrial Electronics (ICCAIE), 2010 International Conference on, 2010, pp. 624-629. doi:10.1109/ICCAIE.2010.5735010.

[13] 17B. Yanzhong, S. Limin, M. Jian, L. Na, K. Imran Ali, C. Canfeng, Hums: An autonomous moving strategy for mobile sinks in data-gathering sensor networks, EURASIP Journal on Wireless Communications and Networking (2007) 1-15.

[14] 18M. A. Mizher, S. H. Al-Sharaeh, M. C. Ang, A. M. Abdalla, M. A. Mizher, Centroid dynamic sink location for clustered wireless mobile sensor networks, Journal of Theoretical and Applied Information Technology 73 (3) (2015) 481-491.

[15] 19C.-g. Tan, K. Xu, J.-x. Wang, S.-q. Chen, A sink moving scheme based on local residual energy of nodes in wireless sensor networks, Journal of Central South University of Technology 16 (2) (2009) 265-268.

[16] 21M. Khodashahi, F. Tashtarian, M. Moghaddam, M. Honary, Optimal location for mobile sink in wireless sensor networks, in: Wireless Communications and Networking Conference (WCNC), 2010 IEEE, 2010, pp. 16. doi:10.1109/WCNC.2010.5506171.

[17] 22F. Tashtarian, M. Moghaddam, S. Effati, Energy efficient data gathering algorithm in hierarchical wireless sensor networks with mobile sink, in: Computer and Knowledge Engineering (ICCKE), 2012 2nd International eConference on, 2012, pp. 232-237. doi:10.1109/ICCKE.2012.6395384.