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EMBS: ENERGY EFFICIENT MULTIPLE BASE STATION PLACEMENT IN A CLUSTERED WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor networks consist of energy constrained sensor nodes. The main challenge of the researchers is to utilize the energy of the wireless sensor network in an efficient manner. By minimizing the energy usage, the network lifetime can be improved. Energy efficiency can be obtained by using various techniques. Optimal base station placement is one of the techniques used to minimize the energy consumption. The sensor nodes in the network forward their sensed data to the base station either directly (single-hop) or indirectly (multi-hop). The distance between the source and the sink determines the level of energy consumption. The more distance between the sender and the receiver consumes more energy. By using proper routing algorithms, the distance between the node and the base station can be minimized. In our paper, we propose an energy efficient base station placement in a clustered wireless sensor networks (EMBS) to improve the lifetime of the wireless sensor networks. Network Simulator tools were used to evaluate the performance of the system.

Index Terms - *Base Station Positioning, clustering, energy efficiency, multiple base stations, Wireless Sensor Network.*

1. INTRODUCTION

Recent developments in semiconductor and networking technologies are inspiring the use of large-scale Wireless Sensor Networks (WSNs). Together, these technologies have combined to enable a new generation of WSNs that differ greatly from wireless networks developed and deployed as recently as 5 to 10 years ago. The WSNs have lower deployment and maintenance costs, last longer and are more rugged [1]. Wireless Sensor Networks usually consist of a large number of faraway dispersed nodes that are equipped with sensors to monitor environmental phenomenon such as temperature, sound, vibration, pressure, motion or pollutants. These devices work independently and are sensibly linked by self-organizing way [2]. As in figure 1, the sensor nodes transmit their data through the network to a base station (BS) or a sink, where the data can be observed and analyzed. A sink or base station acts like an interface between users and the network. Typically a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals.

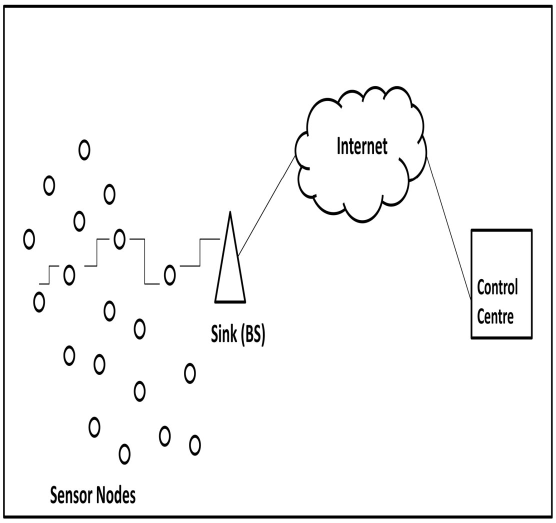

Figure1: Wireless Sensor Network Topology

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A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components. The nodes in a wireless sensor network (WSN) have limited processing speed, storage capacity, and communication bandwidth. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication with them. Then the on-board sensors start collecting information of interest [3]. Since a sensor network is usually expected to last several months to one year without recharging, optimal energy consumption, i.e., Minimizing energy consumed by sensing and communication to extend the network lifetime, is an important design objective [4].

The working mode of the sensor nodes may be either continuous or event driven. Global Positioning System (GPS) and local positioning algorithms can be used to obtain the location and positioning information. Wireless sensor devices can be equipped with actuators to "act" upon certain conditions. These networks are sometimes more specifically referred as Wireless Sensor and Actuator Networks as described in [5]. Due to the limited battery capacity of sensor nodes, base station placement directly affects the lifetime of the sensor network. Moreover, the expensive price of BS makes the designer to focus on accurate placement [6]. The rest of the paper is organized as follows: Section 2 describes the related works in the base station placement. Section 3 proposes a new approach in base station placement. Section 4 contains a detailed performance evaluation of EMBS against previously proposed approaches. Finally, we conclude the paper in Section 5.

2. RELATED WORKS

Integer linear programming [7] and exhaustive search [8] approaches are used only for small-scale Wireless Sensor Networks. They employ global knowledge of the network, e.g., where the nodes are located, such that position-awareness of sensor nodes becomes a serious issue. Chang et al. formulated the problem of routing information from a set of sources to a set of destinations with the objective of maximizing system lifetime [9]. They designed a linear program for the problem and provided several algorithms, although no theoretical analysis of the running time of these was provided.

Efrat et al. [10] provided a solution when the wireless sensor network is not constrained to be a tree and when there is no limit on the number of hops for the messages to reach the base-station. Shi et al. [11] provided a general framework for base-station location problems with different objectives, and showed that their approach achieves approximation for the objective of maximizing lifetime. Buragohain et al. [12] also deal with the sub-problem of finding an optimal routing scheme to maximize the lifetime of the WSN when the base-station location is fixed. The number of hops in the transmission tree is not restricted. They prove that the problem is NP-hard. Pan et al. [13], considered the network to consist of clusters of nodes, with three types of nodes: sensor nodes (SN), which generate and capture some real-time data, application nodes (AN), which are responsible for collecting data from SN s, and a base-station (BS), which collects data from all ANs. They do not obtain any theoretical bounds on the complexity of the problem. Bogdanov et al. [14] tackled the case of multiple base-station positions. The aim was to find a base-station location for different numbers of base-stations, by considering a regular grid of unit cells in the WSN region.

Hou et al. [15] considered extending the lifetime of a Wireless Sensor Network by moving the base-station to different locations. In their model, as is typically the case, the base-station has an unlimited power supply. The idea is that since the sensors around the base-station consume more energy than others, one can move the base-station to different locations, to balance the battery consumption among all sensors. Vincze. Z. et. al. [16] gives a mathematical model that determines the locations of the sinks by minimizing the average distance of the sensors from the nearest sink. In [17] sink placement and data routing problems have been formulated based on linear programming and the optimal locations of multiple sinks and data flow in the WSN are proposed. Another solution is presented in [18] based on iterative clustering algorithms, such as k-mean. The idea here is to define some initial clusters, place the sinks in the center of those clusters, and then reshape them, so as to allow sensors to choose the nearest sink. This procedure is repeated until the clusters are not reshaped anymore. Debasree Das et al. [19] propose to start with a partitioned network. The objective is to place a sink in every partition. It is assumed that each partition is divided into square-shaped, grid cells and it is also proposed that the size of the grid cells be based on the communication range of the sensor nodes.

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A self-organized sink placement strategy (SOSP) for multiple sinks in a large scale network is proposed in [20]. It is claimed that SOSP has lower communication overhead. Cheng et al. addressed a delay-aware data collection network structure for wireless sensor networks. The objective is to minimize delays in the data collection processes of wireless sensor networks which extends the lifetime of the network. Matin et al. considered relay nodes to mitigate the network geometric deficiencies and used Particle Swarm Optimization (PSO) based algorithms to locate the optimal sink location with respect to those relay nodes to overcome the lifetime challenge. Paul et al. proposed a geometrical solution for locating the optimum sink placement for maximizing the network lifetime. Most of the time, the research on wireless sensor networks have considered homogeneous sensor nodes. In The optimal base station placement method EMBS proposed in this paper reduces the energy consumption and improves the network lifetime.

3. PROPOSED NETWORK MODEL

In a cluster-based network, sensors organize themselves into local clusters by some mechanisms. Each cluster has a cluster head. The cluster head may or may not be a more powerful sensor than other sensors. The cluster head manages the sensors in its own cluster for communications between the cluster and the base station. In the Intra-cluster communication, sensor nodes sense the field and transmit the gathered data to the corresponding CHs. The member nodes use the TDMA schedule to transmit the data to the CH. The remaining nodes turn off their radio and they will be in sleeping mode. The CDMA spreading code is used to avoid the interference between the clusters. Each cluster will be using a separate spread code for its transmission.

In the Inter-cluster communication, CHs aggregate the received data and transfers it to the Base Station. The CH node which is having the highest residual energy will be selected as the CH leader node and all other CHs transfers the aggregated data to the base station through this CH leader node. The communication between cluster heads and the base station may be multi-hop through another cluster head [13]. It is observed that the CH which is far away from the BS will be consuming more energy than other CHs. The far away CH will have a shorter lifetime than other CHs. The distance between the BS and the CH determines the lifetime of the WSN. The main objective is to minimize the distance between the CHs and the sink. The number of base stations determines the lifetime of the network. In a traditional static wireless sensor network, a single base station is placed to collect the data from the sensor nodes. The number of base stations in a network is determined by the type of application in which the wireless sensor network is used. The brute force technique is to start with only one sink node, as stated in [21]. While incrementing the number of sink nodes by one, the network lifetime is evaluated. In the case of environmental monitoring such as forest fire monitoring, large scale wireless sensor network is required. The application not only decides the number of base stations, but also finding the suitable locations for placing the base stations. Base station location determines the lifetime of the wireless sensor network. The minimum distance between the base station and the CH extend the lifetime of the wireless sensor network.

To find the locations of the base station, the location of all the sensor nodes must be known. Localization schemes are classified as anchor based or anchor free, centralized or distributed, GPS based or GPS free, fine grained or coarse grained, stationary or mobile sensor nodes, and range based or range-free. In distributed schemes, the sensors calculate and estimate their positions individually and directly communicate with anchor nodes. There is no clustering in distributed schemes, and every node estimates its own position [22]. Range-based schemes are distance estimation and angle-estimation-based techniques. Important techniques used in a range-based localization are received signal strength indication (RSSI), angle of arrival (AOA) [23], time difference of arrival (TDOA), and time of arrival (TOA) [24]. In RSSI, distance between transmitter and receiver is estimated by measuring signal strength at the receiver [25]. In Angle of Arrival (AOA), unlocalized node location can be estimated using angle of two anchor signals. These are the angles at which the anchor signals are received by the unlocalized nodes [25]. In Time Difference of Arrival (TDOA), the time difference of arrival radio and ultrasound signal is used. Each node is equipped with a microphone and speaker [26]. In Time of Arrival (TOA), speed of wavelength and time of radio signals travelling between anchor node and unlocalized node is measured to estimate the location of the unlocalized node [27]. In centralized schemes, all information is passed to one central point or base station (Sink).

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Sink node computes the position of nodes and forwards information to respected nodes. Computation cost of the centralized based algorithm is decreased, and it takes less energy as compared with computation at individual node.

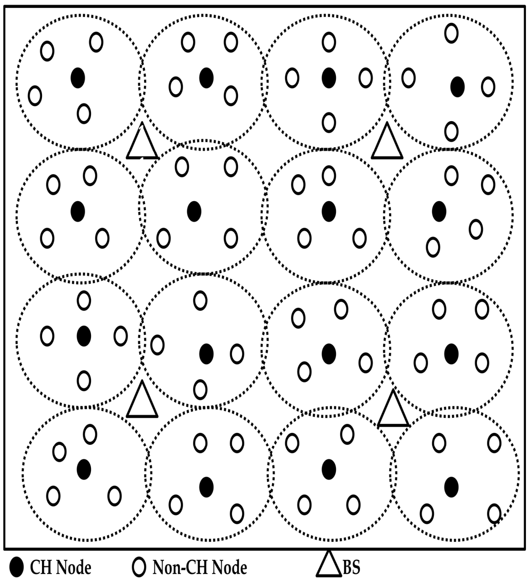

Figure 2: Multiple-Base station placement in a clustered WSN

In this proposed system, the wireless sensor network is divided into a number of clusters. The sensor nodes are sensing the target area and send the sensed data to the Cluster Heads. The Cluster Heads have the capability to aggregate the received data and transmit the aggregated data to the Base station which is nearest to the cluster heads. The base station would be placed in the optimal location to connect more number of cluster heads. Since there are more clusters, more than one base station should be placed. A base station must collect the data from many cluster heads. The centre position of the network is selected to place the base station.

The cluster heads transmit their aggregated data to the base station through one of the cluster head which has more residual energy. If more than one cluster heads have the same residual energy, then the cluster head, which is very near to the base station would be selected to transmit the data to the base station. When the data is transmitted by the cluster head to the base station, the current round will be completed. A new cluster head will be selected for each cluster, based on the residual energy of the sensor nodes. Load balancing is performed in this approach.

The node which has higher residual energy would become a cluster head. Hence, the network life is improved and increased. The network lifetime can be estimated using the following ratio in (1) as the reliability measure, which is a monotonically increasing function [6].

$$l(n) = \frac{\text{Total number of unreachable nodes}}{\text{total number of nodes}} \qquad (1)$$

Where l denotes the lifetime and n denotes the wireless sensor network. The network lifetime is defined to be associated with the number of unreachable sensors in the wireless sensor network. The readings of the wireless sensor network is considered to be unreliable, whenever the ratio of the unreachable sensors exceeds this threshold value, with l = 0.25 .Multiple base stations placed in the network to make the connectivity effective and extend the network lifetime.

4. PERFORMANCE ANALYSIS

The simulation has been carried out using Ns-2 simulator to show the performance of the proposed EMBS scheme. The initial energy of the nodes is 0.2J and the data rate is 10 bps. Note that the data rate and the initial energy of real-life sensors may not fall in the above range. We conducted simulation for different topologies with CHs ranging from 10 to 100 and data were generated randomly for the CHs. In figure 3, it is observed that the percentage reduction is significantly large in this field. The figure shows that the node ratio in the proposed system is reduced than the existing centroid method. When the number of nodes increased, the node ratio is minimized than the existing system.

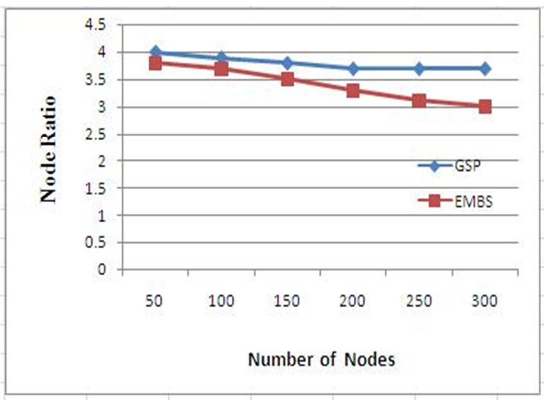

Figure 4: Average Percentage reduction

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Figure 4 shows the average distance between the base station and the sensor nodes in the sensor network. The simulation was done for different number of nodes and different lengths of field. All the nodes suffer from free space loss with the area side less than 150 meters.

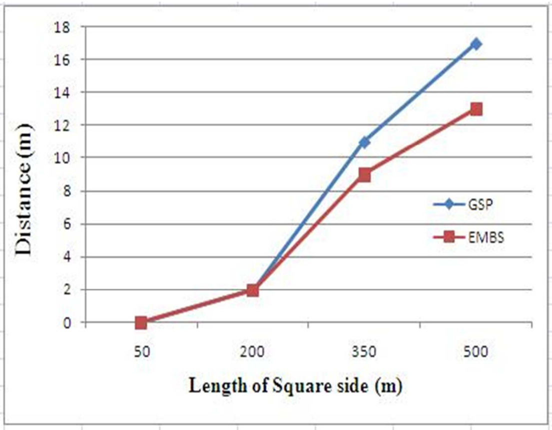

Figure 4: Average distance between the BS

The proposed EMBS system performs better than the existing system. When the length of square side is more than 150, the nodes suffer from multipath loss. The proposed EMBS system performs better than the existing system.

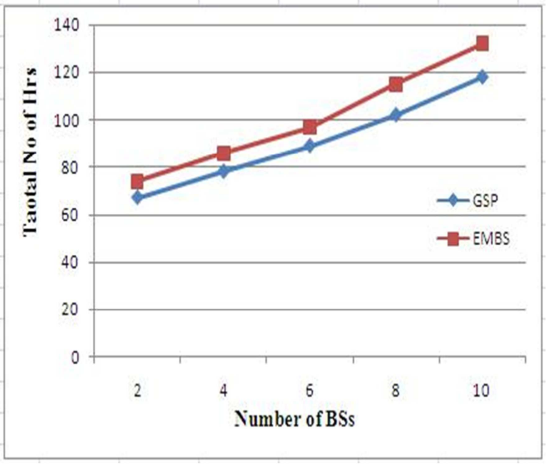

Figure 5: Network Life-time

Figure 5 shows the network lifetime based on the number of base stations. When the number of base stations increased, the load of the cluster heads is decreased. The transmitting energy would be decreased considerably. The lifetime of the sensor network is improved considerably when multiple numbers of base stations are placed in the network. The proposed system performs well than the existing system because of reducing the distance between the base station and the cluster heads.

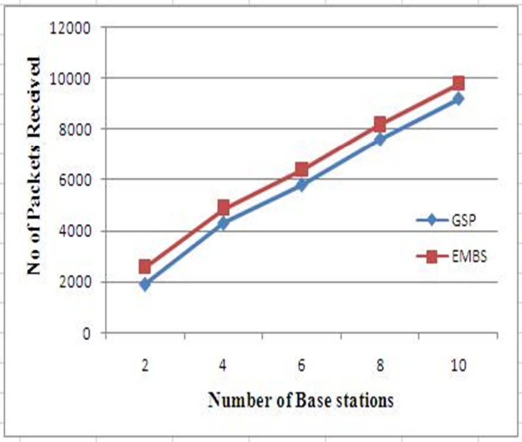

Figure 6: Total No of Packets Received

The above figure shows that the total number of packets received by the proposed system is more than the number of packets received by the existing system. The proposed EMBS method places multiple base stations in the network. The lifetime of the network is improved considerably. The EMBS system transmits more number of packets than the existing system. The results show that the proposed EMBS approach performs well and shows better performance than the existing system.

5. CONCLUSIONS

Energy efficiency in wireless sensor network is the main objective of this proposed EMBS system. Since all the sensor nodes in the network have limited energy resources, they must be utilized efficiently. Efficient placement of base stations is one of the techniques used to minimize the energy consumption in the network. In the proposed system, the network is divided into many clusters and multiple base stations can be placed to collect the data from the cluster heads. The distance between the source and the base station is reduced considerably. The energy spent on data transmission is reduced and the network life time is improved. The proposed EMBS system performs better than its comparatives. The result shows that the proposed system consumes minimum energy than its comparatives.

REFERENCES

[1]. *Tech. Report*, "evolution of wireless sensor networks", silicon Laboratories Inc., 2013.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[2]. Fabian Nack, "An Overview on Wireless Sensor Networks", *Institute of Computer Science (ICS),* Freie Universität Berlin, 2009.

[3]. S.Chinnappen-Rimer and G. P. Hancke, "Calculation of an Optimum Mobile Sink Path in a Wireless Sensor Network", *InTech,* 2012.

[4]. S. Kumar, T. H. Lai, and J. Balogh. On k-coverage in a mostly sleeping sensor network. In *Proceedings of the 10th Annual International Conference on Mobile Computing and Networking (Mobicom '04)*, pages 144–158, 2004.

[5]. K. Akkaya, M. Younis and M. Bangad, "Sink repositioning for enhanced performance in wireless sensor networks," *Computer Networks,* vol. 49, pp. 512-534, 2005.

[6]. Oyman I, Ersoy C. (2004) Multiple Sink Network Design Problem in Large Scale Wireless Sensor Networks. *In: IEEE International Conference on Communications,* Volume 6, pp.3663-3667.

[7]. H. Kim, Y. Seok, N. Choi, Y. Choi, and T. Kwon, "Optimal Multi-sink Positioning and Energy-efficient Routing in Wireless Sensor Networks," in *Lecture Notes in Computer Science(LNCS)*, vol. 3391, pp. 264–274, 2005.

[8]. R. Chandra, L. Qiu, K. Jain, and M. Mahdian, "Optimizing the Placement of Integration Points in Multi-hop Wireless Networks," in *Proceedings of the International Conference on Network Protocols (ICNP)*, (Berlin, Germany), 2004.

[9]. J.-H. Chang and L. Tassiulas. "Maximum lifetime routing in wireless sensor networks", *IEEE/ACM Transactions on Networking*, 12(4):609{619, 2004.

[10]. A. Efrat, S. Har-Peled, and J. Mitchell. "Approximation algorithms for two optimal location problems in sensor networks", In *Proceedings of the 2nd International Conference on Broadband Networks*, BROADNETS '05. IEEE, 2005.

[11]. Y. Shi, Y. Hou, and A. Efrat. "Algorithm design for base station placement problems in sensor networks", In *Proceedings of the 3rd international conference on Quality of service in heterogeneous wired/wireless networks, QSHINE '06*. ACM, 2006.

[12]. C. Buragohain, D. Agrawal, and S. Suri. "Power aware routing for sensor databases", In *Pro-ceedings of the 24th Annual Joint Conference of the IEEE Computer and Communications Societies*, INFOCOM '05. IEEE, 2005.

[13]. J. Pan, L. Cai, Y. Hou, Y. Shi, and S. Shen. "Optimal base-station locations in two-tiered wireless sensor networks", *IEEE Transactions on Mobile Computing*, 4(5):458{473, 2005.

[14]. A. Bogdanov, E. Maneva, and S. Riesenfeld. "Power-aware base station positioning for sensor networks", In *Proceedings of 23rd Annual Joint Conference of the IEEE Computer and Communications Societies*, INFOCOM '04. IEEE, 2004.

[15]. Y. Shi and Y. Hou. "Theoretical results on base station movement problem for sensor network", In *Proceedings of the 27th Annual Joint Conference of the IEEE Computer and Communica-tions Societies*, INFOCOM '08. IEEE, 2008.

[16]. Z. Vincze, R. Vida, A. Vidacs, Deploying Multiple Sinks in Multi-hop Wireless Sensor Networks, in: Proceedings of the International Conference on Pervasive Services, IEEE, Istanbul, July 2007.

[17]. H. Kim, Y. Seok, N. Choi, Y. Choi, T. Kwon, "Optimal Multi-sink Positioning and Energy- efficient Routing in Wireless Sensor Networks", in: *Proceedings of the ICOIN, Lecture Notes in Computer Science (LNCS)* 3391, Korea, 2005, pp. 264–274.

[18]. E. I. Oyman, C. Ersoy, "Multiple Sink Network Design Problem in Large Scale Wireless Sensor Networks", in: *Proceedings of the International Conference on Communications* (ICC 2004), Paris, France, June 2004.

[19]. Debasree Das, Zeenat Rehena, Sarbani Roy, Nandini Mukherjee, "Multiple-Sink Placement Strategies in Wireless Sensor Networks", In. *Proceeding s of the IEEE International Conference*, 2013.

[20]. W. Yi Poe, J.B. Schmitt, "Self-Organized Sink Placement in Large- Scale Wireless Sensor Networks", in: *Proceedings of the 17th Annual Meeting of the IEEE International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems* (MASCOTS 2009), London, September 2009.

[21]. J. J. F. Hair, R. E. Anderson, R. L. Tatham and W. C. Black, *Multivariate Data Analysis with Readings*, Prentice-Hall, Inc., 1995.

[22]. K. Langendoen and N. Reijers, "Distributed localization in wireless sensor networks: a quantitative comparison,"

Journal of Theoretical and Applied Information Technology
31st May 2014. Vol. 63 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Computer Networks, vol. 43, no. 4, pp. 499–518, 2003.

[23]. A.Nasipuri and K. Li, "A directionality based location discovery scheme for wireless sensor networks," in *Proceedings of the 1st ACM International Workshop on Wireless Sensor Networks and Applications (WSNA '02)*, pp. 105–111, September 2002.

[24]. L. Doherty, K. S. J. Pister, and L. El Ghaoui, "Convex position estimation in wireless sensor networks," in *Proceedings of the 20th Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM '01)*, pp. 1655–1663, April 2001.

[25]. A. Youssef and M. Youssef, "Ataxonomy of localization schemes for wireless sensor networks," in *Proceedings of the International Conference onWireless Networks (ICWN '07)*, pp. 444–450, Las Vegas, Nev, USA, 2007.

[26]. J. Bachrach and C. Taylor, *Localization in Sensor Networks*, Massachusetts Institute of Technology, Cambridge,Mass, USA, 2004.

[27]. R. Manzoor, *Energy efficient localization in wireless sensor networks using noisy measurements*, 2010.