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An Approach to Find Optimal Locations for Base Station to Achieve Energy Efficiency in Wireless Sensors Network

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Abstract – Due to the difficulty of recharging the batteries of Sensor Nodes (SNs), which have a finite amount of energy resources, energy efficiency is one of the crucial factors to take into account in Wireless Sensor Networks (WSNs). Base Station (BS) location in WSN plays a significant role as it is one of the deciding factor on network performance. By placing the BS at optimal location, it can increase the WSN's energy efficiency and network coverage. Placement of the BS at optimal location is complex problem and it requires balance between coverage of the network and energy efficiency. In this work we have used Low Energy Adaptive Clustering Hierarchy (LEACH) protocol as routing algorithm. We placed BS at the center of each of the quadrant of square shaped deployment area as well as at the center of entire deployment area. We evaluated network longevity as a measure of performance, and we observed how much energy was used for each round. Results indicate that location of the BS is optimal if the placement of BS connects the farthest SN with shorter distance until First Node Dies (FND), stays near where there are more number of SNs situated until Half Node Dies (HND) and at the center of the deployment area in our case until Last Node Dies (LND) compared with other locations.

Index Terms – Cluster, Multiple Base Stations, Network Life- time, Relocation, Uneven Distribution, Wireless Sensors

I. INTRODUCTION

In WSN, the gateway between the network and outer world is BS or Sink. Information from all the SNs will be gathered at BS. BS then forward that data to the outer world. There can be a single BS or

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multiple BSs. The BS may be mobile in nature or it may be static. Where to place the BS in WSN is crucial. Because the location of BS impacts on performance of WSN. BS may have assumed to have infinite energy but SNs have limited energy stored in their batteries. Once the energy in the SN drains out, it is difficult to replace the battery. So it is essential to save energy as much as possible. Energy consumption is directly affected by the distance between two points which are in communication. If the distance between two points which are in communication is small then the energy consumption is lesser compared to those two pointsare located at longer distance between them.

The same rule applies here. As the distance between all the SNs to the BSin the deployment area is lesser then the energy consumption to transfer data between SNs and BS is also lesser. But SNs are generally deployed in random fashion. By positioning BS at a certain location, some nodes are close by, while othersare far away. Then it is crucial to find the optimal location of BS. If the BS is set up in the center of the deployment areaand the SNs are distributed evenly throughout the network, thenetwork will perform better. But it is not the case always as SNs are deployed randomly in the deployment area. There maybe possibility of more number of SNs are located at particular area than the rest of the area. With this case of deployment, location of the BS at center will not give optimal result. Finding the ideal BS location for SNs, which are dispersed randomly and unevenly throughout the deployment area, is therefore necessary. SNs can be deployed uniformly as shown in Fig. 1 or unevenly as shown in Fig. 2. Total 8 SNs are deployed in both the cases and the BS is located at centerof the deployment area. Placing the BS at the center of the deployment area is the optimal location for the 1st case as all SNs are located at uniform distance from BS. But it is not truealways because of deployment of SNs itself may be uneven or after few rounds of operation, some of the SNs might have died.

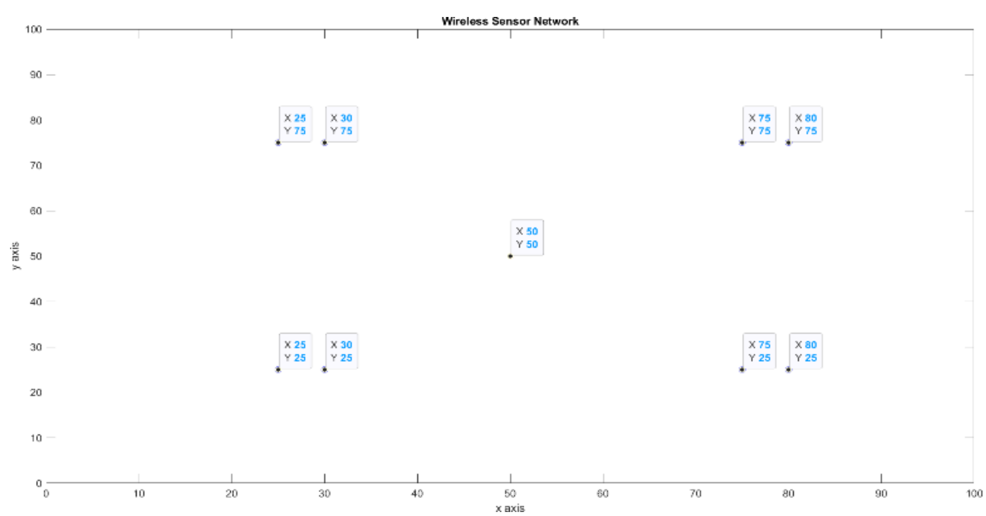

Fig. 1: Uniform distribution of SNs

In the second case also same number of SNs are deployed but most of the SNs are located in 3rd quadrant while BSis located at center of the deployment area. As more numberof SNs are situated at particular area, it is not a good ideato place BS at the center of the deployment area. Considera case

International Journal of
Human Computations & Intelligence
Vol. 03, Issue. 01, Jan/Feb 2024

where SNs located at (75, 75), (25, 75) and (75, 25)are out of energy then it is required to move the BS towards 3rd quadrant as less energy is consumed during transmission between SNs and BS if the distance between SNs and BS is small. In our analysis we have used clustering approach, where there will be Cluster Heads (CHs) and its MNs. Data gathered from MNs will be received by CH, which will then send the data to BS as illustrated in Fig. 3. The routing protocol wehave used is LEACH [1]. In order to assess network performance, we have placed BS in various locations. To measure network performance we have found when FND, HND and LND occurred. These parameters are used for analysis of network performance.

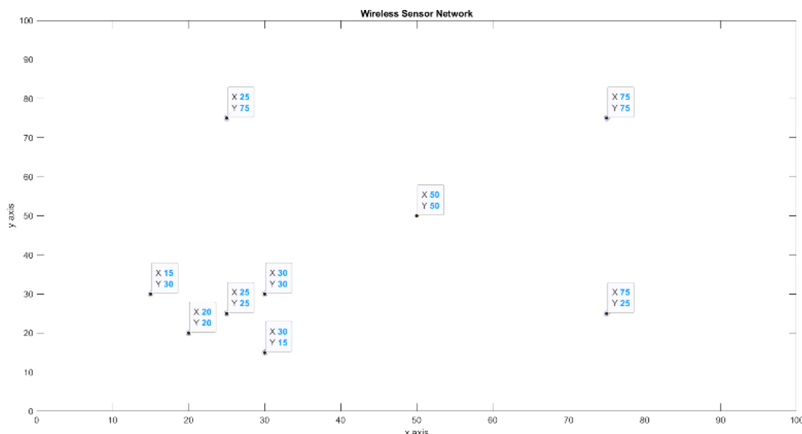

Fig. 2: Uneven distribution of SNs

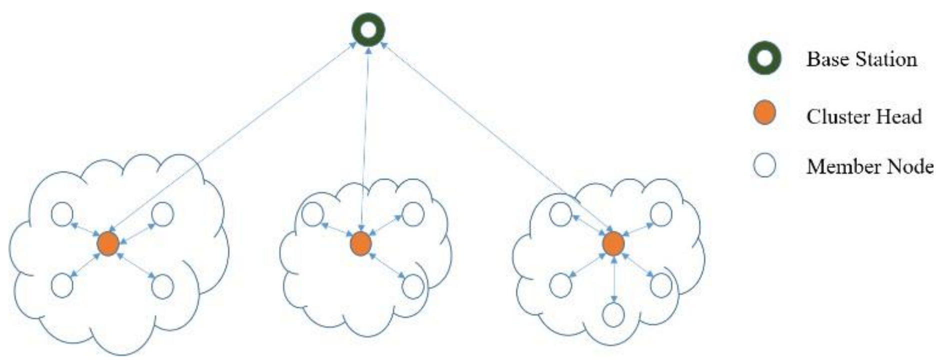

Fig. 3: Illustrates clustering in WSN

II. LITERATURE REVIEW

The static and dynamic approaches to positioning the BS in the optimal location are discussed in [2]. Static BS placement can be used to optimize network performance objectives, but dynamic schemes that involve repositioning during operation provide greater flexibility and adaptability when dealing with changes in the environment/network resources. Limitations of the static methods for placing BS optimally include their focus on structural quality metrics and use of a fixed topology for analysis. Because dynamic positioning of the BS is NP- complete, it is difficult to find optimal solutions. It is possible to develop algorithms more efficiently while taking multiple BS positions into account in a distributed manner. Application Nodes (ANs) and BSs topology control is the main concern of[3].

It proposes algorithmic methods to find the best BSs, even when the average bit-stream rate is not proportional to their initial energy provisioning, in order to maximize the network lifetime of WSNs deterministically. Various definitions based on the mission criticality of WSNs determine the optimal locations for BSs. To create upper and lower bounds for the feasibility and necessity of energy provisioning and topology control, respectively, intrinsic properties have been studied in order to establish them. Finding the ideal BS locations canbe difficult and time-consuming using the brute force method. More efficient algorithms can also be developed to find the best BS, which will speed up computation and make the process simpler. Based on computation geometry, an algorithm for BS placement is proposed in [4]. This algorithm determines the best location for a BS. Additionally, it guarantees the least number of relays and overall energy consumption while transferring data to the BSs in WSNs.

This algorithm can be improved further by taking into account additional factors that may have an impact on the amount of energy used by WSNs, such as environmental conditions, external interference, etc. It is suggested in [5] to use the Location Aware Routing for Controlled Mobile Sinks (LARCMS) technique to reduce reporting delays, lengthen network lifetimes, and provide uniform energy consumption. In order to avoid a hot spot region close to the sink node, it collects data using two mobile sinks on a predetermined trajectory. Due to the use of two mobile sinks in this method, the use of controlled mobile sinks restricts its applicability and drives up the cost of implementation, which is the biggest drawback. Another drawback is that it necessitates homogeneous, static, and location-aware SNs that might not always be feasible in the absence of GPS or localization methods. In [6] a network model that uses the Harmony Search Algorithm to dynamically reposition a mobile BS within such a cluster-based infrastructure is proposed. In order to uniformly distribute the responsibilities amongst sensors, the model distributes the SNs into optimal clusters and selects optimal CHs. It determines where the moveable BS should be positioned in relation to the CHs and the BS in orderto shorten the communication paths for transmission of data from each node to its associated CH.

Future work, including the inclusion of realistic models, may take this network model into account for more complex scenarios. Additional study may concentrate on multiple BSs to increase WSN lifetime by relocating them to various sites while accounting for factors like free space loss and the knife-edge effect of energy loss. Furthermore, future research may investigate methods to optimize CH choice based not only on residual energy but also on other factors that favorably impact network lifetime. In [7], the fundamental problem of base-station positioning optimization in WSN is explored. It considers a scenario where sensors only transmit data once, either directly or through another node. This scenario offers two advantages: low duty cycling and low end-to-end delay because there are fewer hops on the routes. The computation of transmission schemes with fixed BSs as well as their simultaneous localization and exploration have both been accomplished using algorithms. A setting with multiple BSs will be taken into account in future research. Contributed in [8] is a solution to the primary design problem of energy conservation in sensor networks.

It suggestssetting up a number of mobile BSs and combining a flow- based routing protocol with an integer linear programme for effective routing during each round. Within such a framework, it is possible to investigate using graph partitioning algorithms, especially those for locating balanced partitions. Additional research is required to determine the best way to apply the strategy described in this paper to the very large sensor fields and independently optimize energy usage across sub-networks. The position of sink nodes using a heuristic approach is studied in [9]. In order to maximize link connectivity between various SNs, reduce propagation latency/delay, and increase energy efficiency, the smallest number of sink nodes must be placed in an unweighted topology. The location of SNs and data transfer patterns must be determined using an effective and scalable optimization algorithm, as this paper has shown. It is necessary to explore alternative strategies and conduct additional research on how to decrease energy consumption while maintaining maximum network performance.

In [10], the issue of clustering-based hierarchical routing is covered. In order to reduce the cost of energy for data communication, this involves clustering the nodes first then choosing CHs, and then figuring out where to put the BS. A method that determines the best location for the mobile BS has been proposed in order to avoid data overflow when sending information from all CHs tothe BS in a single hop. In order to increase energy efficiency and network lifetime in WSNs, this paper has identified the need for a reliable clustering-based routing technique. The development of a more resilient algorithm, however, that can manage dynamic changes in CHs in each round and maintain optimal data communication with low energy consumption, calls for more study. In order to reduce the total distances from all the SNs to the sink node, an ideal location for the sink node is investigated in [11]. The sink's placement at this location increases energy efficiency in comparison to other potential locations within the field but slightly decreases throughput when especially in comparison to the center, according to a performance evaluation.

In order to maximize throughput when attempting to place at the center, more research is required. It is suggested in [12] to restructure the network and connect only those nodes to a sink that reduce the total energy of the sink below a predetermined threshold in order to optimize energy usage in WSNs. It also sheds light on how multiple-sink WSNs can be more effective than single- sink WSNs because they require fewer hops to transfer data from node to sink, which uses less energy overall. Additional research is also necessary to determine how various factors, such as node density and transmission distance, can impact a WSN's overall performance. Furthermore, more research is required to create effective algorithms that can efficiently balance energy between nodes while reorganizing the network.

III. APPROACH ADAPTED

We have placed the BS at various locations and analyzed the network performance in order to determine the BS's optimal location. The clustering method has been applied in our work. LEACH is used as the routing protocol. BS is positioned at a fixed location in LEACH. CHs send the BS the data they have gathered from their MNs. It is assumed that SNs are homogeneous. Each round of LEACH consists of three phases: the advertisement phase, the setup phase, and the steady state phase. Nodes will participate to become CH during the advertisement phase using a threshold formula.

International Journal of
Human Computations & Intelligence
Vol. 03, Issue. 01, Jan/Feb 2024

$$Th(n) = \begin{cases} \frac{M}{1-M*(c \bmod \frac{1}{M})} & if\ n \in S \\ 0 & otherwise \end{cases} \quad \text{Eq. (1)}$$

Where

M - Preferred percentage of CHsC - Current round

S - Set of nodes that were not CHs in rounds 1/PTh(n) – Threshold value of nth node

CH will be selected by comparing the random number (be- tween 0 and 1) generated by each SNs with the threshold value. If the value is lesser than threshold value then that node will become CH. The CH status is broadcast to nearby nodes. Non-CHs are required to tune into medium and select membership on the basis of signal quality. Nodes broadcast their membership status using Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) during setup. CHs are required to listen to the medium. A Time Division Multiple Access (TDMA) schedule will now be formed, with a variable number of time slots. When transmitting data, nodes sleep until their scheduled time. CHs must hear to every slot, aggregate/compress the data they receive, and then send it to BS. We place the BS at different location w.r.t deployment area of SNs i.e., at center of each quadrant as well as at the center of deployment area. Following parameters are considered while simulating in MATLAB R2022b

Table I: Network Parameters

Operation	**Energy Dissipation**
Required energy to run circuitry Eelec ETx ERx	50 nJ/bit
Energy for amplification (Eamp)	100 pJ/bit/ m^2
Energy for data aggregation (EDA)	5 nJ/bit
Size of Data Packet (N)	4000
CH Percentage (P)	5
Initial node energy	0.5 J

SNs are deployed randomly throughout the deployment area but in non-uniform fashion. Area of deployment is 100×100 m^2. Total number of SNs deployed initially are 100. Deployment area is divided into 4 quadrants. From the center of the deployment area; 1st, 2nd, 3rd and 4th quadrants lies between 0° to 90°, 90° to 180°, 180° to 270° and 270° to 360° respectively. As shown in Fig. 3, 3rd quadrant consisting of 75% of the entire SNs deployed and rest of 25% of the nodes are deployed in all 4 quadrants. BS is placed at center of each quadrants as well as at center of the deployment area. Deployment of SNs are as shown in Fig. 4.

International Journal of
Human Computations & Intelligence
Vol. 03, Issue. 01, Jan/Feb 2024

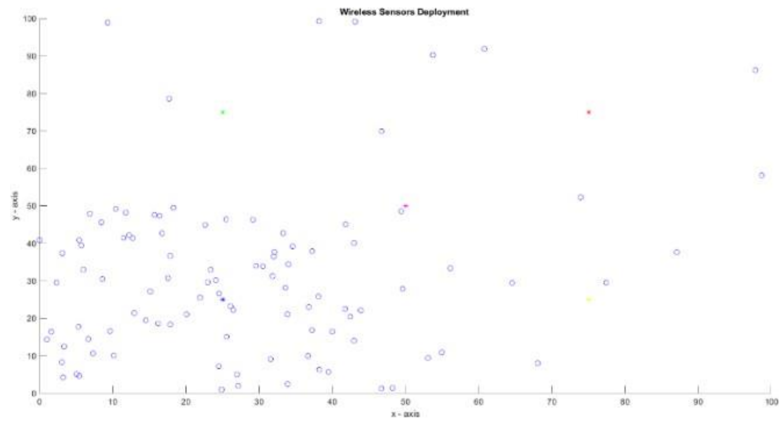

Fig. 4: Illustrate the deployment of Wireless Sensors

IV. RESULTS AND DISCUSSION

Network performance is measured in terms of FND, HND and LND as shown in Figure 5 and Table 2. As we observe in Table 2, FND is largest of all if we place BS at the center of the 2nd quadrant. This is because in this placement of BS the farthest SN distance to BS is least among all other placement. Placement of BS at the center of 3rd quadrant gives better result compared to all if we consider the parameter HND. Because most of the SNs are present in 3rd quadrant only. Hence energy consumption is lesser as distance is less. Placement of BS at center of the deployment area gives better result in our case if we consider the parameter LND. Because the placement is such that it is the location which has shorter distance between alive SNs after HND to the location of BS. Energy left per round with all the nodes is shown in Fig. 6 and it also support our argument.

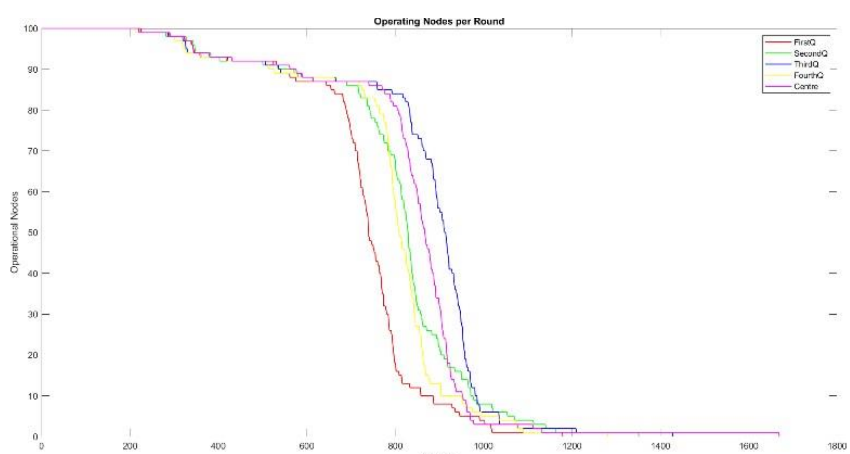

Fig. 5: Illustrate the operating nodes left per round

To find the optimal location of BS, it is necessary to decide which is important to consider among FND, HND, and LND and place BS in accordance with that. It applies for static SNs and BS. If we employ the dynamic BS then there is a possibility to move the location of BS according to

International Journal of
Human Computations & Intelligence
Vol. 03, Issue. 01, Jan/Feb 2024

requirement. As in our case BS can be placed at 2nd quadrant till FND, relocate the BS to 3rd quadrant till HND then to the center until LND. Mobile BS can yield better result but with change in topology complexity. We have not considered LEACH for comparison because the BS is located away from sensors deployment area, so the lifetime of that setup is less compared to the BS which is situated within deployment area. Limitation of our approach is, it is required to know the location of all the SNs and need to find the distance between SN and BS. But it is one time process, after that BS can store the information about distance and location.

Table II: Illustrate the Network Performance

	Location	FND	HND	LND
First Q	(75, 75)	339	746	1179
Second Q	(25, 75)	343	830	1351
Third Q	(25, 25)	325	916	1428
Fourt Q	(75, 25)	318	815	1281
Center	(50, 50)	338	869	1669

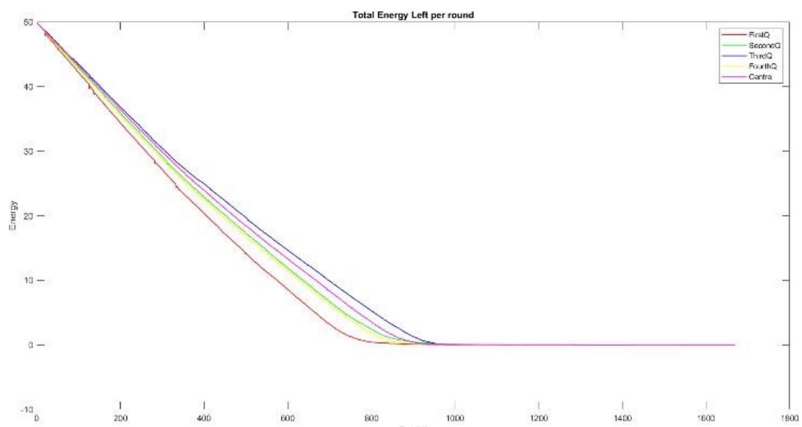

Fig. 6: Illustrate the total energy left per round

V. CONCLUSION

Placing the BS at different location gives the varied results. If the application used by WSN is critical then we need to check the distance of farthest SN from BS to be shorter compared to all other possibility of placement. If we measure network lifetime with HND, then placement of BS at the location where more number of nodes are situated is optimal. If the application demands more longevity even until LND then optimal location for BS can be decided based on location of alive SNs after HND. In our case it is at the center of the deployment area. Static single BS deployment compromise with the network performance in terms of network lifetime. By using multiple BSs or mobile BS we can achieve better results with additional complexity of topological changes. Position of BS in our work is based on the static location of SNs but considering CHs to position the BS will further enhance the network lifetime but there is additional overhead of finding CHs in each round and relocating BS accordingly.

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