Distance Based Deployment Approach to Improve the WSNs Coverage and Connectivity

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***Abstract*— A "wireless sensor network (WSN)" represents the gathering of certain number of sensors that are closely deployed in a recognizable area. The efficiency of any WSNs is heavily depending on the coverage delivered by the deployed sensors. This paper suggested the development of "deployment approach" to improve the WSN coverage, connectivity and reliability. This approach is based on the "distance between" each sensor node and its neighboring sensors. It aims to improve the nodes coverage in steps after a primary arbitrary deployment. In each step, a sensor node is appealed in the direction of its neighbors that have lower distance. This reaction maximizes the coverage of the detected area by forcing the sensor to change its position towards the area with a lower sensors density. The simulation results were compared with the GSO results. Our results showed that this deployment approach could provide high coverage, full connectivity and good reliability. Such results could be achieved with less number of iterations.**

***Index Terms*— Connectivity; Coverage; WSN; GSO; Sensors Deployment..**

I. Introduction

In the latest years, many researchers focus on the "wireless sensor networks (WSNs)" constructions and applications. WSNs have potential applications in different vital areas. Wireless Sensor networks represent systems that encompass certain numbers of wirelessly linked sensors that are spatially deployed in a certain region. Sensors can be deployed in large numbers due to its accepted cost and small size [1].

One of the key challenges facing the WSNs applications is how to determine the physical locations of the deployed sensor nodes. This problem represents an active research topic in the recent years. The supreme solution for such problem is to provide the sensor nodes by "Global Positioning System (GPS)". GPS is costly, power consuming and restricted for outdoor applications. To find the optimum sensors location, a set of nonlinear equations must be solved to reach the best prospect purpose in some cases. The effectiveness in this approach is how to investigate the sensors deployment by searching for the optimal or the near optimal solution [2].

II. Related work

In 2011, Wen-Hwa Liao et al. presented sensors deployment system based on "Glowworm Swarm Optimization (GSO)" to improve the nodes coverage after a process of random deployment. Each node was considered as "individual glowworms emitting". A "luminant substance" called "luciferin" and the strength of the "luciferin" rely on the distance between the sensor node and its neighboring sensors. A sensor node is appealed towards the lower intensity of "luciferin". The sensing field coverage is maximized when the sensor nodes move towards the lower sensor density area [3].

In 2012, Guo, et al. proposed a technique with goal coverage based on lattice scan. They divided the area into lattices. Then, the best lattice was selected as a position to the next sensor. This method used the smallest number of nodes to attain the coverage goal and to enhance the positions for the deployed sensor nodes [1].

In 2013, Yourim Yoon et al. proposed an effective "genetic algorithm" using a "novel normalization method". A "Monte Carlo method" was assumed in designing an effective assessment function. They showed that their computation time could be reduced without losing the quality of the solution. They selected a small number of random samples and steadily increased the number for the succeeding generations [4].

III. Sensors Deployment

The deployment approaches in WSN was divided into two groups as "sparse" and "dense deployments". In the given field of interest, the "sparse deployment" can be used with little number of nodes deployed, while the "dense deployment" can be used in high number of deployed sensors [5]. The "dense deployment" technique was used in the case of every event wanting to be noticed or the deployment of multiple sensors to cover the same area. The sparse deployment is suitable to achieve maximum sensing area with minimum number of sensors. The sensor nodes are either static or mobile; thus, they can change their positions with time [6].

Sensors are deployed in certain field either by locating them in "predetermined places" or randomly deployed. "Random sensors deployments" approach is one type of the "dense deployments". WSNs with mobile sensors are normally initiated with a "random deployment". They change their locations to the best suitable location due to their mobility [1] [6].

A. Static Deployment

In "static deployment", sensors are static and their locations must be selected due to certain "optimization strategy". Sensors locations will stay fixed and does not change during the operation of the network. "Static deployment" strategy can be achieved by deterministic steps and random deployments. This approach (the "deterministic deployment") starts by surveying the area of interests and continuing with the deployment process [6].

B. Dynamic Deployment

An important application of a "dynamic deployment" is its usage in robots. Mobility helps in attending the sensing goal by letting the sensor moves towards a maximum sensing performance. In "random deployment", most of the nodes are tossed in the first step, before a special utilization and reformation estimations is conducted to select the next movement [7]. Many developed algorithms have been built such as the "virtual force oriented particles algorithm" [8], "simulated annealing algorithm" [9], "particle swarm optimization algorithm" [10] and "simulated annealing genetic algorithm" [11].

IV. COVERAGE PROBLEM

The coverage represents the "quality of service (QoS)" for the sensing function of the WSN. Its main function is to answer the vital question: “How well do the sensors observe a physical space"? Therefore, the position of the sensor is the essential factor related to the "coverage problem"[4]. The sensor nodes must be located in an optimal position to ensure complete utilization and increase its sensing ability. Such process helps in maximizing the network sensing covered area.

Coverage value can be estimated as the fraction of dividing the covered area to the area of the "region of interest (ROI)". In many cases, the coverage problem is considered as a minimization problem. The stated objective function in this case is to minimize the area not covered by the sensors. These two approaches need hard calculations and computations in a longer time [1].

The "length measurement" is easier and needs smaller time than the "area computation". Thus, the "length measurement" is widely used in calculating the WSN coverage problem. A "point inside the ROI is covered by sensor i (si) if the distance between them is less than the si’s sensing radius". The area is considered as a covered area if all points are covered. Sampling techniques can be applied in the case of existing fixed number of points, which can be used in evaluating the coverage. Grid is one of the frequently used sampling techniques [12].

V. GSO APPROACH

Many approaches have been suggested and implemented to achieve certain coverage connectivity and reliability. Wen-Hwa, et al., for example suggested a sensor deployment system based on "glowworm swarm optimization" to improve the coverage after an "initial random deployment" of the sensors. They considered each sensor node as "individual glowworms emitting a luminant" body called "luciferin" and the strength of the "luciferin" depends on the space isolating the sensor node with its neighboring. A sensor node can be appealed to its adjacent with lower strength of "luciferin". The sensor that tends to move towards the area having lesser sensor concentration then the sensing coverage area will be maximized. Their simulation results showed that "GSO-based sensor deployment approach" can deliver great coverage with restricted number of the sensor movements [3]. They concluded the following GSO results:

When 50 sensors were deployed in a center of 100 X 100m area with sensing range of 5m & communication range of 10m, they found a coverage percentage of about 35.4 %. When 100 sensors were deployed at the same area and the same sensing and communication ranges, they found the coverage of 64.6 %. When they used 200 sensors with the same area, the same sensing and communication ranges satisfied the coverage of 92.2 %. This method failed to achieve connectivity and /or reliability with less numbers of sensors deployed randomly in such area.

VI. OPTIMUM NUMBER ESTIMATION

The optimum number of sensors required to cover all the areas of interest according to the grid distribution to achieve maximum coverage area, minimum overlapping coverage, full connectivity and good reliability can be estimated.

In this paper, a suggested approach was created to estimate the optimum required number of sensor nodes to achieve maximum coverage, minimum overlapping, 2-connectivity and certain limit of reliability with minimum number of sensors (minimum cost). The suggested approach in this paper aimed to find the required number of sensors in a simulation manner; 100 sensors were found to be suitable for the area of 100 X 100m with sensing range of 5m and communication range of 10m. Figure (1) shows the suitable deployment obtained.

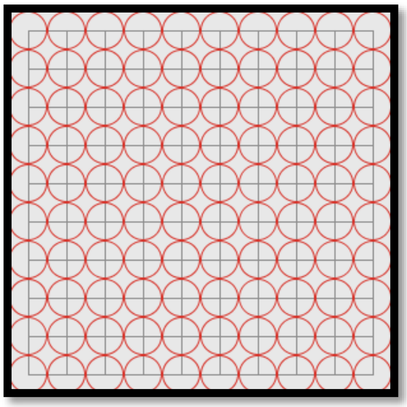


Figure 1: The minimum required sensors deployment

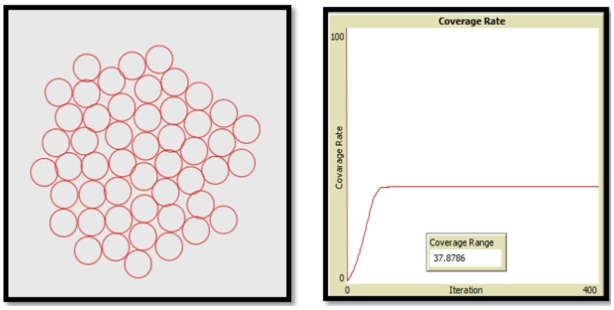
This algorithm estimates the resulted coverage area, which is 77.63 % and the full connectivity with minimum of 2 connections (2-connectivity).

VII. SUGGESTED DEPLOYMENT APPROACH

In this paper, a new developed deployment approach (in Net Logo simulator) has been suggested, implemented and evaluated using the same GSO approach parameters.

The suggested approach to "sensor deployment technique" was based on the space between the sensor node and its "neighboring sensors" to improve the coverage area after a random deployment. A sensor node was appealed towards its neighbors that have a large distance and transferred it towards one of them. In this way, the coverage area of the sensing area can be maximized as the sensor nodes move towards the region having "lower sensor density". We tested the algorithm with three cases as follows:

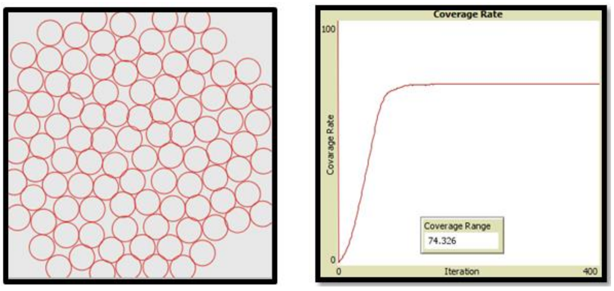
Case 1: Less than the optimum required number of sensors: In this case, 50 sensors were used to be deployed in 100 X 100m area with 5m for coverage area and 10m for communication range. These sensors were deployed randomly in the suggested area. The developed algorithm in this paper was applied to reach the best deployment. The wanted deployment aimed to ensure good connectivity, good coverage, less overlapping and good reliability. The final results were reached after 135 iterations. Figure (2, a) shows the resulted deployment positions and (2, b) shows the coverage value steps with the iteration numbers.



(a) (b)

Figure 2: Deployment positions of case 1

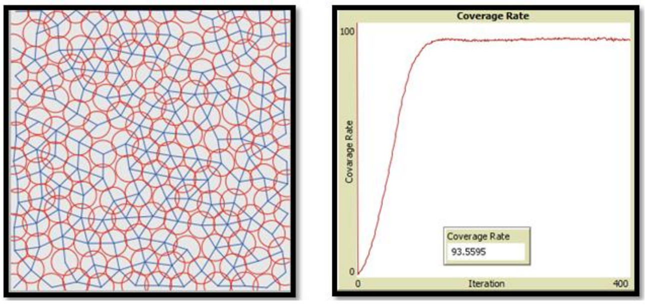
Case 2: Equal optimum required number of sensors: In this case 100 sensors were used to be deployed in 100 X 100m area with 5m for coverage area and 10m for connectivity. These sensors were deployed randomly in the suggested area. The final results were reached after 182 iterations. Figure (3, a) shows the resulted deployment positions and (3, b) shows the coverage value steps with the iteration numbers.



(a) (b)

Figure 3: Deployment positions of case 2

Case 3: Greater than the optimum required number of sensors: In this case 150 sensors were used to be deployed in 100 X 100m area with 5m for coverage area and 10m for connectivity. These sensors were deployed randomly in the suggested area. Figure (4, a) shows the resulted deployment positions and (4, b) shows the coverage value steps with the iteration numbers. The final results were reached after (220) iterations. Table (1) summarizes the results of the above three cases. Figure (5) shows a clear comparison between the results of this paper and the GSO (developed by Wen-Hwa et al.). From the results, it is clear that the developed approach provides a good results compared with the GSO. The number of iterations used in our approach is too less than the number of iterations used to reach the GSO results. For example, the final deployment achieved in case 2 is 135 iterations, while they reached their results in 400 iterations using the same parameters.



(a) (b)

Figure 4: Deployment positions of case 3

Table 1
The results of the suggested cases.

Cases	No. of Sensors	Field area	Sensing Range	Communication Range	Total coverage area
Case 1	50	100 X 100	5	10	37.8786 %
Case 2	100	100 X 100	5	10	74.326 %
Case 3	150	100 X 100	5	10	95.5595 %

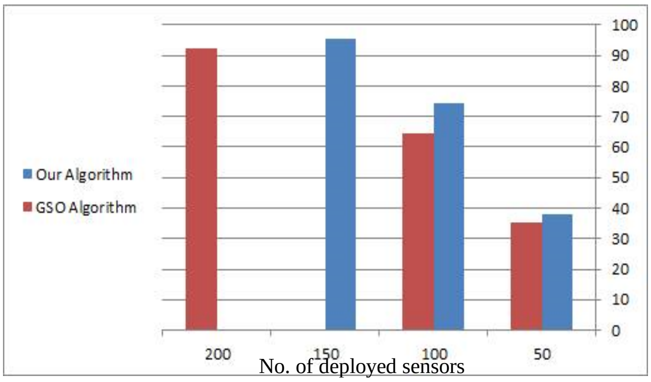


Figure 5: The developed approach and the GSO results.

VIII. Conclusions

In this paper, the developed sensor deployment approach based on spaces (distances) can maximize the coverage; minimize the overlapping, ensure full connectivity and achieve good reliability level. These factors can be achieved in little movement numbers after an "initial random deployment".

The developed approach in this study helps in increasing the network ability to perform its sensing function. The probability that the sensor nodes will continue to achieve their communication functions without failure for certain period will be increased due to the two connections for each sensor node with neighbors.

The developed approach has an advantage that it does not need "centralized control" of the "deployed nodes" so; it is easily scalable for large "sensor networks". The developed approach results dominate the GSO results in all the used metrics in addition to the reduction in the number of the sensors positions movements.

REFERENCES

[1] X. M. Guo, C. J. Zhao and X. T. Yang, “A Deterministic Sensor Node Deployment Method with Target Coverage Based on Grid Scan”, Chinese Journal of Sensors and Actuators, vol.25, no.1, 2012, pp.104-109.

[2] K. S. Low, H. A. Nguyen, and H. Guo. "A particle swarm optimization approach for the localization of a wireless sensor network." Industrial Electronics, 2008. ISIE 2008. *IEEE International Symposium on*. *IEEE*, 2008.

[3] Liao, Wen-Hwa, Yucheng Kao, and Ying-Shan Li. "A sensor deployment approach using glowworm swarm optimization algorithm in wireless sensor networks." Expert Systems with Applications 38.10 (2011): 12180-12188.

[4] Y. Yoon and Y. H. Kim, “An efficient genetic algorithm for maximum coverage deployment in wireless sensor networks,” IEEE Transactions on Cybernetics, 2013.

[5] Noureddine Boudriga; "AWSN-Based system for country boarder surveillance and target tracking", advances in remote sensing, 5, 2016. (http://www.scrip.org/gurnal/ars).

[6] Hasson, S. Talib, and A. N. Reyadh, "A Modified Virtual Approach to Deploy Border Line Sensors." *Asian Journal of Information Technology*. Pp. 2750-2755. 2016.

[7] Luo, Qiang, and Zhongming PAN. "An algorithm of deployment in small-scale underwater wireless sensor networks." Chinese Journal of Sensors and Actuators 24.7 (2011): 1043-1047.

[8] Wang, Xue, Sheng Wang, and Jun-jie Ma. "Dynamic sensor deployment strategy based on virtual force-directed particle swarm optimization in wireless sensor networks." Acta Electronica Sinica 35.11 (2007): 2038.

[9] Lin, Y. S. Frank and P. L. Chiu, "A near-optimal sensor placement algorithm to achieve complete coverage-discrimination in sensor networks." *IEEE Communications Letters 9.1* (2005): 43-45.

[10] L. Yi, "Wireless sensor network deployment based on genetic algorithm and simulated annealing algorithm." *Computer simulation*. Pp. 171-174..2011

[11] Liao, W. Hwa, Y. Kao, and Y. S. Li, "A sensor deployment approach using glowworm swarm optimization algorithm in wireless sensor networks." *Expert Systems with Applications*. 12180-12188. 2011.

[12] A. Aziz, N. Azlina, A. W. Mohemmed, and B.S. D. Sagar, "Particle swarm optimization and Voronoi diagram for wireless sensor networks coverage optimization." *Intelligent and Advanced Systems*, ICIAS 2007. International Conference on. IEEE, 2007.

[13] W.-K. Chen, “*Linear Networks and Systems”* (Book style). Belmont,CA: Wadsworth, 1993, pp. 123–135.
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