An Optimal Approach for Deployment Sensors in WSN

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Abstract —Wireless Sensor Networks (WSNs) is considered the basis of all architectures of IoT applications. Those networks are deployed according to the needs of each domain. The goals of the proposed approaches of deployment are the lifetime maximization of each device. The major challenge is to find a tradeoff between desired requirements for the lifetime, coverage and cost with limited available resources. In this paper, we present a new method for the deployment of WSN that tries to increase the lifetime of the network. A set of optimum position are presented after their calculation using a GPS. The objective is to locate our sensors in these optimum positions. We try to minimize the energy consumption by decreasing the distance travelled by the sensors to reach their optimum positions.

Index Terms— WSNs, IoT applications, deployment problems, lifetime, energy consumption

I. Introduction

Actually, the supervision of all objects in the world is based on IoT applications. Those applications concern many types of supervision. The need to observe and control physical phenomena such as temperature, pressure is essential for industrial and scientific applications. This task is delegated to sensor whose function is to acquire information about the observed phenomena and execute the processes attached to it. WSNs are considered a special type of ad hoc networks. They bring an interesting perspective: those networks can self-configure and manage themselves without need of human intervention. The nodes are typically deployed randomly throughout a geographical area, called area of interest. The collected data is routed through wireless communications to a base station whose role is to aggregate and to exploit the data collected [1].

In WSN, sensors have limited resources, energy resources and generally the compute capacity and storage capacity. Therefore, most studies and research on WSNs have focused on optimizing resources to improve performance and meet Quality of Service (QoS) requirements. The researchers are working on the determination of the sensor field topologies because it has a great influence on the performance of the WSN. It affects also QoS metrics, such as energy consumption, sensor lifetime, and sensing coverage [2]. In the literature, several works proposed approaches for locating a WSN. The Evolutionary Algorithms (EAs) are well suited for adapting the behavior of many adaptive systems because of their simplicity [1]. EAs require only a fitness function to provide a measure of the system behavior. Many different variations of EAs for adapting system behavior have been extensively explored. The paper is organized as follows. The next section gives a number of deployment approaches applied in various kinds of applications. In the second section, we present our proposed approach for sensors deployment. The simulation results and discussion are given in section three. We conclude the paper in the last section.

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II. Related Work

The process of deploying nodes affects directly the performance of WSNs. The problem of deploying or positioning sensors is a strategy used to define the network topology, number and position of sensor nodes. The researchers aim to achieve an optimal deployment that increases the coverage rate and the network lifetime with a minimization in energy consumption. In this context, many approaches were proposed in the literature.

A. Particle Swarm Optimization

Particle swarm optimization is used by several researchers in deployment of sensor networks. The authors in [3] proposed a mixture of stationary and mobile nodes and they used Particle Swarm Genetic Optimization (PSGO) as a solution to cover holes. PSGO is used to determine the redeployment positions of the mobile nodes in order to improve the average density of the nodes. PSGO maximizes the quality of service, defined as the ratio of the covered area and the total area. In [4], the researchers propose a new method to optimize the coverage rate using the ‘Voronoi diagram’ and the PSO. PSO is used to find the optimal positions of sensors in order to maximize the coverage and the ‘Voronoi diagram’ is used to evaluate the objective function value of the solution. The execution time depends on the number of sensors in the network.

B. Genetic Algorithm

Several research works has focused on the problem of deploying nodes to get maximum coverage in WSN. Genetic algorithms have also been used to solve the problem of optimal node deployment. While most of the proposed solutions have focused on the deterministic deployment of nodes, little work has been done in case of random node deployment [5]. The researchers used ‘Voronoi diagrams’ to devise the field into cells. Then, AGs were applied to determine the best positions for k additional mobile nodes that maximize area coverage within each cell. Some research used the AG to search for an optimal number of sensor nodes that can be added after the node's initial deployment (random deployment) to maximize coverage [6].

C. *Flower Pollination Optimization*

The main challenge of WSNs is to optimize the performance of sensor nodes to save energy and thus extend the network lifetime. In order to achieve this objective, the researchers proposed to apply a "clustering" algorithm based on FPA [7] [8]. In [9], the authors propose an approach based on FPA. The goal of MOFPA is to find optimal sensor positions in an area taking into account coverage rate, energy consumption and connectivity. FPCOA is the approach presented in [10]. It based on FPA. Authors aim to find a better network topology whose main objective is to maximize coverage of the area. Authors in [11] try to find an optimal trade-off between maximize coverage, reduce energy consumption, improving network lifetime and maintaining connectivity.

III. PROPOSEDAPPROACH

In WSN applications, the great challenge is to guarantee a long lifetime of the sensor nodes [8]. This leads us to discover new horizons to reduce the energy consumption. Consuming less energy is a primary objective in designing WSN applications, as each sensor node is usually supported by batteries which could be difficult to replace [12]. The initial phase includes starting the network. A set of mobile sensors are placed randomly in the area of interest. These sensors have the same initial energy (homogenous network). On the other side, the optimal positions, found in the given area, are given from the beginning. They are calculated in function of coverage so, they achieve a maximum coverage. A satellite is used to determine these optimum positions [13].

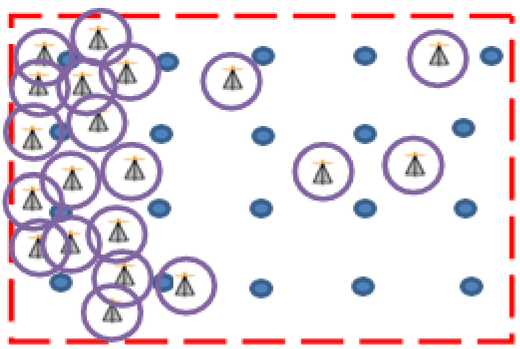

Fig. 1. Initialization phase.

The initial phase of our algorithm involves the following steps:

- Random deployment of sensors
- The base station collects the locations of all sensors. These can perform a self-localization and send their locations to the base station.
- The base station uses this information to affect sensors to optimum positions using our approach that will be explained after. To determine the position of each sensor, the process illustrated in figure 2 is followed.
- The base station sends the new topology to the sensors and these will moved according to it.

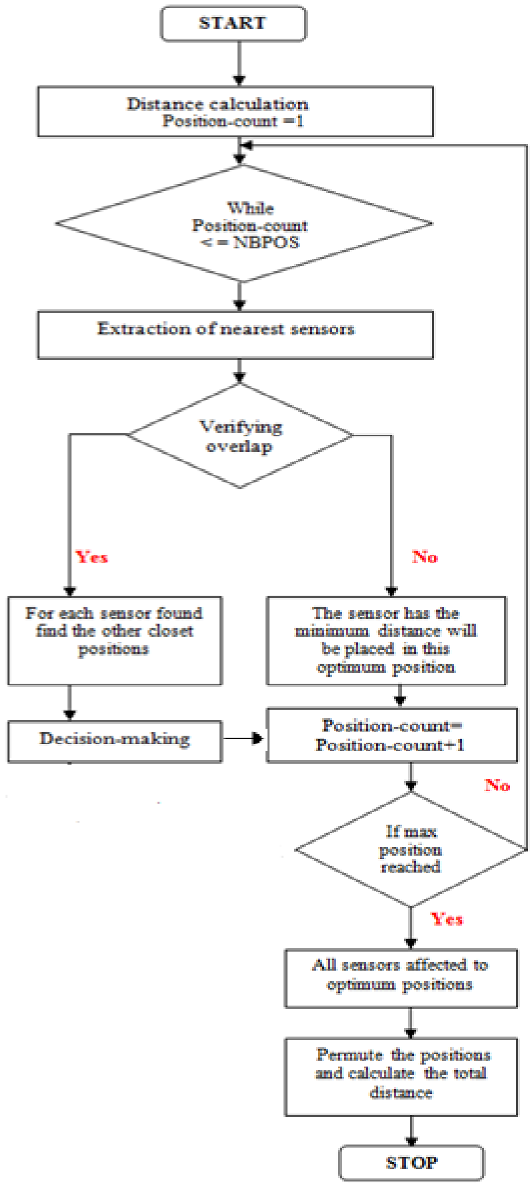

Fig. 2. Flowchart of proposed approach.

To make sensors in their optimum positions, a set of steps presented in the below flowchart will be followed. The optimal positions ensure a maximum coverage, that's why placing all the sensors in these positions guarantees coverage equal to 100%. The objective is affecting sensors in these positions with reducing the energy consumption to extend the network lifetime.

The flowchart of the proposed approach is given in Fig. 2

- The first step consists to calculate the distance between each position and sensor (Euclidian distance). Then, for each position, we will extract the nearest sensor (who has the minimum distance).
- To verify the overlap we look for the other sensors with the same minimum distance: two cases may be found. The first is when there are no other sensors with the same minimum distance so the nearest sensor will be affected to this current position. The second case when we found other sensors having the same minimum distance. We look for each sensor found if there is another position closer than the current position.
- In the decision-making step, we will affect to the current position, the nearest sensor that has not another position closer than the current position. If all the sensors found have other positions closer than the current position, we select a sensor randomly to assign it to this position.
- If all the sensors are assigned, the positions of the sensors will be swapped and the total distance traveled by the whole network will be calculated each time. The topology which gives the shortest distance is that which will be followed.

IV. Results and Discussion

We evaluate our approach using parameters presented in the following table:

TABLE I: INITIALIZATION PARAMETERS

Width of area	100 meters
Height of area	100 meters
Number of deployed sensors	15 sensors
Number of optimum positions	15 positions
Rs	15 meters
Rc	15 meters

As mentioned previously, a set of optimal positions are initially determined. The figure shows the location of the optimal positions in the area of interest.

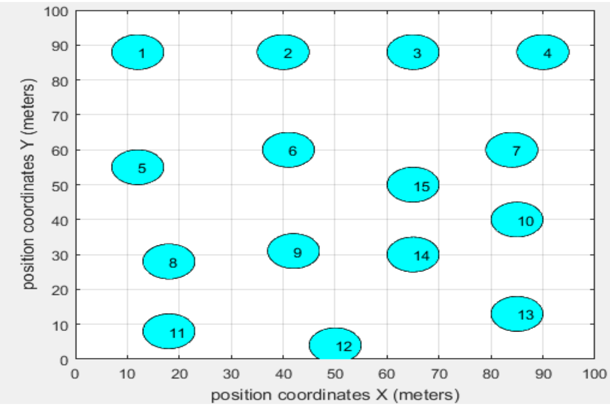

Fig. 3. Locations of optimum positions

Initially, the sensors are deployed in the area randomly. This causes cover holes. As shown in Fig. 4, the random distribution of the sensors does not guarantee the coverage of the entire area.

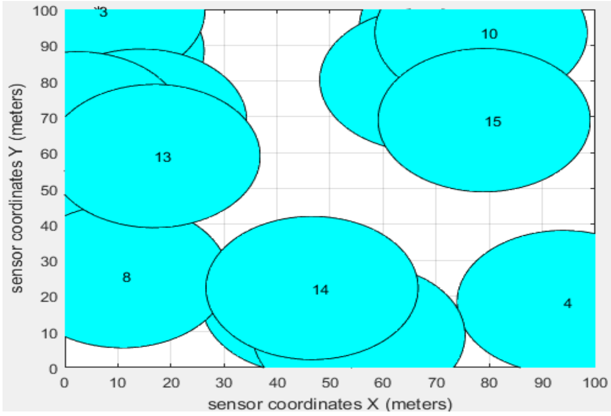

Fig. 4. Randomly sensors distribution

The application of our deployment approach give the following topology with the distances traveled by the sensors to reach their positions.

The topology obtained is presented in Table II with the distance traveled by the sensors. Using this distribution we aim to balance the distances traveled by the various sensors. Therefore, the energy dissipated will be equitable for all sensors. Before placing a sensor in an optimal position, we have taken into account the current positions of all the sensors. Fig. 5 shows the deployment of the sensors in the zone of interest by following the obtained topology.

TABLE II: DEPLOYMENT RESULTS OF PROPOSED APPROACH

Optimum positions	**Affected sensors**	**Distance (position, sensor)**
Position 1	sensor 3	4.0158
Position 2	sensor 10	18.0938
Position 3	sensor 6	10.8652
Position 4	sensor 15	29.3200
Position 5	sensor 13	12.2550
Position 6	sensor 11	16.8478
Position 7	sensor 7	15.2106
Position 8	sensor 8	2.4234
Position 9	sensor 1	15.0067
Position 10	sensor 4	46.9296
Position 11	sensor 5	9.6338
Position 12	sensor 9	20.9829
Position 13	sensor 12	12.1744
Position 14	sensor 2	13.0349
Position 15	sensor 14	15.2277
Total distance travelled by all	**242.0215**	

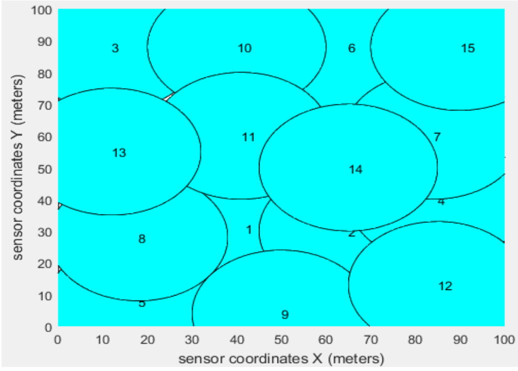

Fig. 5. New sensors distribution using the proposed approach

We compared the coverage of the area of interest after the new distribution with that of the initial distribution (the random distribution) (Table III).

TABLE III: INFLUENCE OF OUR APPROACH ON THE COVERAGE OF AREA

Initial distribution	67 %
Proposed approach	100 %

We note that after the random sensors deployment, the area is not fully covered. The coverage rate reaches 100% by applying our proposed approach. We concentrate now on the comparison of the new approach with some existing algorithms in the literature (Fig. 6).

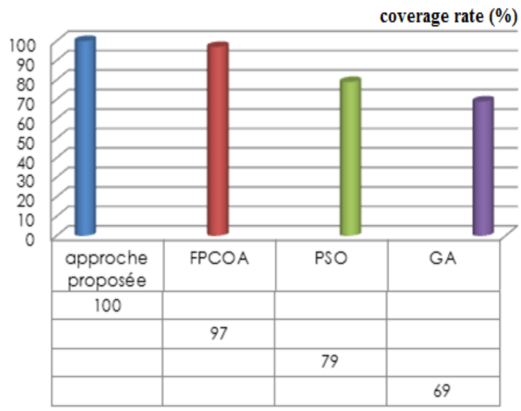

Fig. 6. Performance of proposed approach

By comparing our approach with some existing algorithms [6], we assume that it is efficient, in term of coverage. Since we have determined the optimal positions from the beginning, the location of the sensors at these positions is considered the best.

The minimization of deployment cost is also considered one of localization algorithms objectives in WSNs. The aim is to achieve a maximum coverage rate with a small number of sensors. As long as the number of sensors decreases, the deployment cost will also be minimal. We compare our approach with some existing approach [5]. The following flowchart shows the variation in coverage rate in function of the number of sensors deployed in the area (Fig. 7).

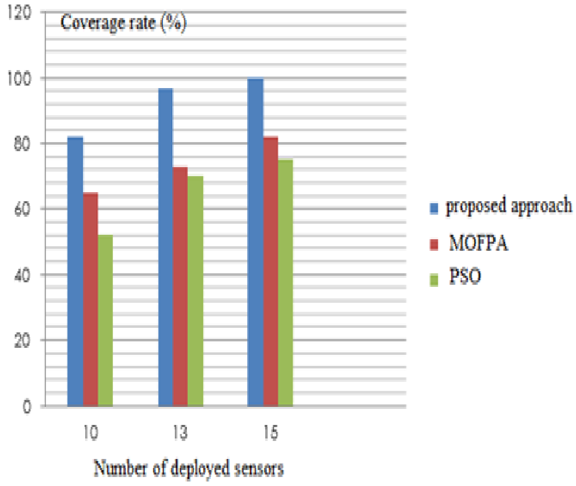

Fig. 7. Variation of coverage rate in function of number of deployed sensors

From the graph above, we find that our approach gives good performances by varying the number of sensors deployed. By comparing it with MOFPA and PSO, the area of interest is more covered when we apply our approach.

V. CONCLUSION

The paper proposes a method to optimize the deployment of Wireless Sensor Networks (WSNs) by finding a tradeoff between desired requirements for the lifetime, coverage and cost with limited available resources. The approach proposed tries to increase the lifetime of the network. We try to minimize the energy consumption by minimizing the distance travelled by the sensors. In a future work, we will apply our approach in a heterogeneous network with an inequality between the number of sensors to affect and the optimum positions.

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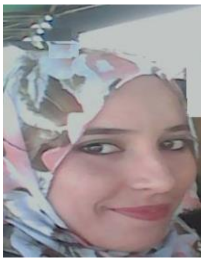

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