Simulating the Wireless Sensor Networks Coverage area

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***Abstract*—Wireless Sensor Networks (WSNs) are being Applied in many real-life applications due to their efficiency and reliability in an economic manner. Coverage area is an essential performance metric in evaluating each WSN. It represents the capability of the network to cover and monitor certain areas of interest. The coverage area is mainly depending on the sensor sensing radius. In this work, Different simulation scenarios are proposed to model the coverage area according to the area size, number of deployed sensors, sensor sensing radius, and deployment type. Simulation scenarios are performed to analyze test and evaluate the relation between the coverage area and the other network parameters and metrics for different suggested cases. Analytic regression models are created for these different suggested cases. These models are suitable to be used accurately without any need to repeat, execute or re-run the simulation programs. The suggested analytical equations show accurate results during their training and testing examples. The coverage area is depending on the sensing radius, the number of deployed sensors, the deployment approach (random or predefined), and the deployed area. The effect of these parameters on the coverage area is simulated and tested in different scenarios. Different regression curves and their equations are created and tested. These equations can be accurately used to estimate the coverage values**.

***Keywords*—WSN, Coverage are, Sensing radius, Simulation, deployment, Regression.**

I. Introduction

In the current era, wireless sensor networks (WSNs) represents an active technology that has a positive impact on people's life [1]. A sensor node has unique characteristics, such as, reliability, supports large scale deployment, mobility, etc. [2]. It represents the smallest and essential part of the WSN. WSNs are used in different civil and military applications. These applications are not limited to the science, industrial and engineering [3]. A WSN is composed of a distinct collection of low cost sensor nodes deployed independently in a certain area. These sensor nodes can communicate with each other in a wireless manner based on certain frequency at low bandwidth, limited memory, and small computational power [4].

The essential WSN function is to sense, monitor or gather the needed data and transmit it to certain remote unit or to certain base station [5]. The collected raw data by sensors is then mined, processed or analyzed according to the wanted analysis at the base station or the remote server [6].

The most significant metrics considered in measuring the performance of the network in most of the WSN applications are the coverage, connectivity and the network lifetime [7][8].

II. Related works

There are different related works which concerning the coverage area in WSNs. Most recent of these are summarized in the following:

In [9] a bat algorithm (BA) as a nature-inspired algorithm (NIA) was utilized as an object function to address the sensor target coverage problem. They introduced the idea of the bat couple as a pair of bats. The first bat is used to activate the turned on sensing nodes, while the second bat relocates the node for relaying data from the activated sensing node to a sink node. They made use of the probabilistic sensing model. Energy saving represents the main emphasis of their study. They also ensured the network connectivity from the sensing node to the sink node. This study semulation results showed that the network lifetime is outperforms the other related works.

Authors in [10] provided a direct approach in implement the probabilistic sensing model to address the problem of the pre-defined deployment. Their study showed that more than 86% of the deployed sensors can be saved.

In [11] authors were suggested an algorithm to maximize the lifetime of the deployed WSNs to monitor a certain area. They used the minimal energy as an objective function, for their optimization approach by converting the continuous coverage area into the discrete coverage point using the differential evolution approach. The binary differential evolution was redeveloped to find a better nodes subset and satisfy the demand for coverage. Their simulation results showed that the coverage algorithm based on differential evolution has provided a coverage area of about 90%.

Authors in [12] studied the issue of how to completely cover the network without knowing the locations of the nodes. They utilized a probabilistic sensing model in creating their coverage control model for a randomly deployed sensors. Based on the size of the sensing region and the required performance, the sensing node and communicating node number were estimated. Their results showed that the coverage quality is higher than the coverage quality threshold.

In [13] they developed a probabilistic sensing model to address the issue of sensor placement for the line-of-sight sensors based on the coverage area. The membership functions for the sensing range and sensing angle in the probabilistic sensing model considers both the probability of the sensing and other environmental topography variables. They used Covariance Matrix Adaptation Evolution Strategy and simulated annealing as optimization techniques to

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optimize the sensors location. Their findings demonstrated a maximum in the coverage of a global sensor network.

Authors in [14] analyzed the WSN coverage algorithms and used the probabilistic sensing model to propose a network coverage algorithm. Their algorithm assisted in determining the existing of any node in the monitoring area with a sponsor set. The node must continue operating if the sponsor set does not exist; else, the algorithm will execute the subsequent steps. They decided when to sleep the node. According to their modeling results, the agreement minimizes the number of active nodes and successfully extends the network's life cycle to provide the preferred network coverage.

In [15], the authors took into their consideration the distributed dispatch issue and the k-coverage placement issue. They used both binary and probabilistic sensing models in their strategy based on the deployment problem. They proposed a relationship between the sensor's sensing radius and transmission radius. A competition-based and a pattern-based schemas were suggested. Their suggested schemas were distributed in nature and effective in terms of the number of the required sensors. Their simulation results outcomes were used to prove their network effectiveness.

Authors in [16] created a closed form expression for the k-coverage performance. They derived an analytical model based on a sensor failure. They considered the effects of the number of sensor nodes, the sensing range, and the sensor failure rate on the coverage area. Their proposed model results with a Root Mean Square Error of less than 0.03 and a decreasing the k-coverage probability with increasing in k.

III. PROPOSED SYSTEM

A square area has been considered with 310*310 m dimensions. Variable number of identical sensors (N=80, 100, 130 and 150) are deployed randomly inside that area. The sensor sensing range (r) is assumed to have the values (r = 0.8, 0.9, 1, 1.2, 1.4, 1.6, 1.8 and 2). The coverage area for each node is calculated as a circle area (πr^2) with diameter r. Any point within the deployed area is said to be covered if it lies within the coverage radius of at least one sensor. Furthermore, the area is said to be covered by the WSN if every point inside the area lies within the coverage radius of one sensor or more. The probabilistic sensing model is used.

IV. SIMULATION SETUP

Different simulation scenarios are implemented to model, analyze and test the effects of different WSN parameters on the coverage area. Table 1presents the suggested simulation setup.

Table1. WSN Environment

Parameter	Value
The simulator	Net Logo 6.1.1
Number of Nodes	Variable(80,100,130,150)
Algorithm	Random approach
Sensing Range	Variable(0.8,0.9,…..,2)
Area	Variable()

Different parameters affect the network coverage area such as the deployed area, number of nodes, deployment approach (random or predefined) and sensing ranges.

Figure 1 represents an environment sample.

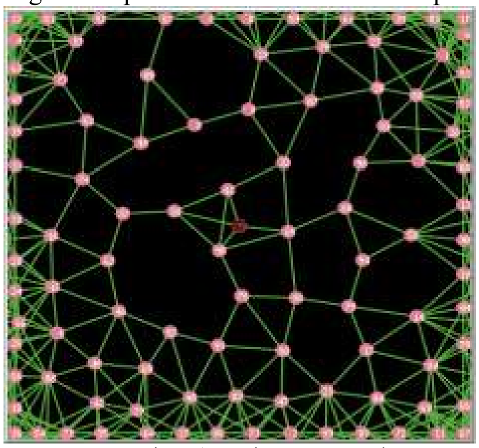

Figure1. Environment sample

Different scenarios are implemented to simulate the effect of each parameter on the coverage area.in this case the deployed area is selected as 310*310. Number of deployed nodes is varied (80,100,130 and 150) with different sensing ranges (0.8, 0.9, 1, 1.2, 1.4, 1.6, 1.8 and 2).

The following scenarios represent the simulation scenarios to show the effects of varying the number of nodes with different sensing ranges in a same area.

A. scenario 1

The first simulation scenario comprises of 80 nodes deployed randomly in a 310 x 310 m area with a sink node in a centre point. The sensing range for each sensor node is varied from (0.8, 0.9, 1, 1.2, 1.4, 1.6, 1.8 and 2). Table 2 specifies the resulted coverage area in each case.

Table2. Simulation Results for Scenario 1

Area	Number of Nodes	Sensing range	Coverage
310*310	80	0.8	0.36
		0.9	0.46
		1	0.57
		1.2	0.83
		1.4	%100
		1.6	%100
		1.8	%100
		2	%100

Table 2 represents certain estimated values for the coverage area based on certain sensing ranges. To generalize this case, a regression model is developed based on these measured values to estimate the coverage area for each sensing range value. Figure 2 represents the developed regression curve and its equation. This regression equation is tested with some of the tabular values to show its validity and then can be used to estimate the coverage area based on any sensing range value. The variable x in Eq. 1 represents the suggested sensing range and the variable y represents the resulted coverage area.

$$y = -12.102x^6 + 98.555x^5 - 325.52x^4 + 556.97x^3 - 520.54x^2 + 253.3x - 50.088 \quad \ldots\ldots (1).$$

Examples:

As a training phase:

- When the sensing range = 0.8 then y =0.36
- When the sensing range = 1 then y = 0. 57

These coverage areas are identical to the calculated values by the simulation program. So, equation 1 can be successfully used to estimate the coverage area for any sensing range as follows in a testing phase:

- When the sensing range = 0.95 then y = 0.517
- When the sensing range = 1.5 then y = 1

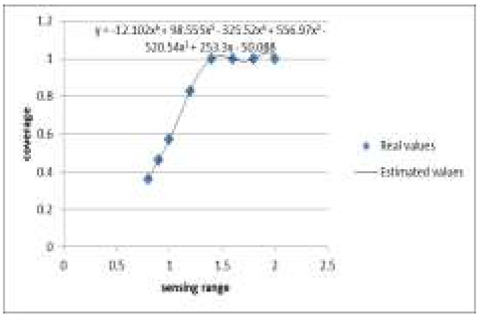

Figure2. The relationship between the sensing range and the coverage area

B. scenario 2

The second simulation scenario is composed of 100 randomly deployed sensors in a 310 x 310 m area with a sink node in a center point. The same sensing range values are suggested as in scenario 1. Table 3 specifies the estimated coverage area for each sensing range value.

Table3. Simulation Results for Scenario 2

Area	**Number of Nodes**	**Sensing range**	**Coverage**
310*310	100	0.8	0. 46
		0.9	0. 58
		1	0.71
		1.2	%100
		1.4	%100
		1.6	%100
		1.8	%100
		2	%100

Table 3 represents certain estimated values for the coverage area based on certain sensing ranges. To find a general formula to estimate any coverage area based on any selected sensing range, Figure 3 is proposed to represent the coverage area calculation. Equation 2 represents the resulted regression equation. The variable x in Eq. 2 represents the proposed sensing range and the variable y represents the resulted coverage area.

$y = 6.0495x^6 - 57.058x^5 + 219.07x^4 - 436.65x^3 + 474.07x^2 - 263.75x + 59.004$ …………………………….. (2)

Examples:

As a training phase;

- When the sensing range = 0.8 then y =0.46
- When the sensing range = 1.4 then y = 1

As a testing phase;

- When the sensing range = 0.95 then y = 0.64
- When the sensing range = 1.5 then y = 1

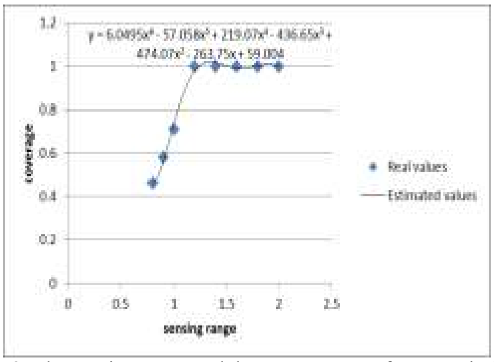

Figure3. The sensing range and the coverage area for scenario 2

C. Scenario 3

In the third simulation scenario, 130 nodes are deployed randomly in a 310 x 310 m area with a sink node in a center point. The same sensing range values are utilized. Table 4 shows the calculated coverage area for each sensing range value.

Table4. Simulation Results for Scenario 3

Area	**Number of Nodes**	**Sensing range**	**Coverage**
310*310	130	0.8	0. 59
		0.9	0.75
		1	0.93
		1.2	%100
		1.4	%100
		1.6	%100
		1.8	%100
		2	%100

Table 4 shows the calculated values for the coverage using certain sensing ranges. Figure 4 presents the graph and the equation for coverage area calculation.

$y = -0.9749x^5 + 5.4527x^4 - 9.8204x^3 + 3.7703x^2 + 5.9591x - 3.4835$ …………………….. (3)

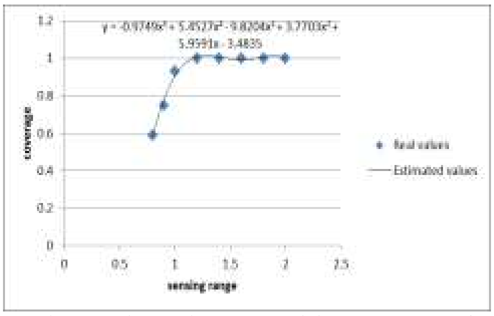

Figure4. The sensing range and the coverage area for scenario 3

Examples:

As a training phase;

- When the sensing range = 1.4 then y =1
- When the sensing range = 1.2 then y = 1

As a testing phase;

- When the sensing range = 0.95 then y = 0.84
- When the sensing range = 1.3 then y = 1

D. scenario 4

Finally, 150 nodes are deployed randomly in a 310 x 310 m area with a selected sink node placed at the center point. Table 5 shows the covered area while using different values for the sensing ranges.

Table5. Simulation Results for Scenario 4

Area	Number of Nodes	Sensing range	Coverage
310*310	150	0.8	0. 68
		0.9	0.87
		1	%100
		1.2	%100
		1.4	%100
		1.6	%100
		1.8	%100
		2	%100

Table 5 illustrates the calculated values for the coverage using specific values of sensing range. Figure 5 shows the equation for coverage calculation.

The variable x in Eq. 4 is used to represent the sensing range and the variable y used to represent the coverage area.

$$y = -2.1829x^4 + 13.329x^3 - 29.954x^2 + 29.323x - 9.5363 \text{ ……... (4)}$$

Examples:

As a training phase;

- When the sensing range = 0.9 then y =0.87
- When the sensing range = 1.2 then y = 1

As a testing phase;

- When the sensing range = 0.95 then y = 0.93
- When the sensing range = 1.5 then y = 1

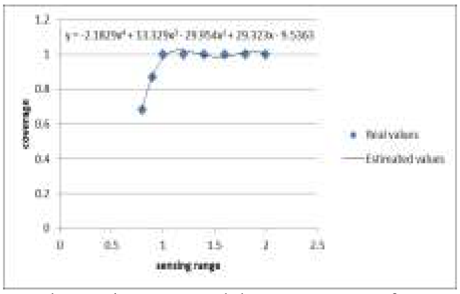

Figure5. The sensing range and the coverage area for scenario 4

V. CONCLUSION

In this paper, WSNs coverage area are analyzed and modeled to show their effects and relations with other network parameters and metrics. Different mathematical models are suggested based on the simulation results for each suggested scenario to estimate the network coverage area and other network metrics mathematically. The suggested models are tested. Their results showed an accurate result when compared with the simulation results for different simulated values. The sensor's sensing radius is significantly affecting the coverage area. The sensing rang, the number of deployed sensors and the deployed area are significant in planning for the network coverage area

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