Optimizing the Routing of Wireless Sensor Networks for Obstacles-avoidance

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ABSTRACT
In the recent years, wireless sensor networks (WSNs), have become essential part in a huge number of the modern applications. Researchers have developed a lot of work to improve their performance. But, practically WSNs still face with different kinds of obstacles those cause main challenges for their reliability. Therefore, finding an optimum obstacle-avoiding route path for the WSNs is considered an important research problem. The present work introduces a new optimum routing algorithm based on the cluster-based method for the WSNs with obstacles. The proposed system uses the cluster-based method and the mobile sink to decrease the power consumptions and increase the lifetime of the WSNs. Besides, it uses the genetic algorithm to optimize the avoiding-obstacles routing path. Suggested system has been applied for a WSN used to communicate between a discovery-radiation robot and its operating system as a case of study. Simulation results for the tested WSN and their comparison with three other route algorithms have proved the effectiveness of the proposed novel method.

Keywords
Wireless sensor networks, obstacles, energy-efficient routing, cluster-based, genetic algorithm.

1. INTRODUCTION
Wireless sensor networks (WSNs) have advanced abilities in sensing and communicating the modern technology fields. A WSN is a large collection of self-directed wireless nodes those spread in an area of interest [1]. It integrates wireless communications, micro sensors and computer networks. WSNs have a great suitability for several application areas like military, medical, environmental, industrial, and many others [2-5]. Researchers of WSNs have interested in the routing methods that affect on the performance of the WSNs. The efficiency of any WSN has a great dependent on its routing algorithm.

It is found that, there are many parameters affect the routing process of the WSNs such as environment variation, sensor energy consumptions and the holes of coverage. Sometimes, these holes caused by different types of obstacles appeared practically in the real-time observed areas [6].

The obstacles can be classified into static and dynamic ones. They are found as walls, buildings, blockhouses, pillboxes, cars, trains, etc. in the outdoor environments. Obstacles can exclude the network connectivity and fail its operation [7].

However, using the optimization techniques for achieving free avoidance-obstacles routing path is considered one of the most important keys for improving the WSNs' performance.

The suggested work has introduced a novel algorithm that optimizes the routing process to have a shortage, avoiding-obstacles, low power consumption and longest network lifetime routing algorithm by using the Genetic Algorithm Approach.

The reminder in this paper can be organized as follows: Section 2 gives a brief overview of the genetic algorithm optimization approach. Section 3 introduces the related work. Section 4 deals with the proposed system. Section 5 represents the applicability of the proposed system and its results. While, section 6 discusses the conclusion.

2. GENETIC ALGORITHM OPTIMIZATION APPROACH: AN OVERVIEW
Genetic algorithm (GA) is an optimization meta-heuristic that imitates the process of natural evolution. Its main idea derived from Darwin's theory of evolution and survival of the fittest.

GA is an adaptive and efficient method of feature selection. It is a population-based and algorithmic search heuristic method. GA generates a random initial population of solutions for the problem at hand. Each solution is represented as a chromosome [8].

The operation of the genetic algorithm begins by creating an initial population randomly. This population consists of a set of possible solutions to the problem. Each individual in the population is evaluated using a fitness function. It is found that, the most difficult issue in using GA referred to how to find a suitable fitness function which evaluates the fitness value of the individuals. After this evaluation process, selection is applied to choice the highest fitness values of the chromosomes that will produce the new generation. The selected chromosomes are called parents [9]. Crossover and mutation operators are applied to change the chromosomes to construct the new population in the next generation. This process continues until the best solution is reached [10].

Termination is the last step in the genetic algorithm. Usually, the iteration of the GA is stopped when a certain criterion is met. The most widely used stopping criterion is achieving a certain predefined number of iterations at which GA is terminated [11].

3. RELATED WORK
A considerable work is developed to overcome the limitations of the routing algorithms to handle some obstacles in real-time situations. Researchers have developed many systems to solve this problem.

In the last years, researchers have used the analytical optimization techniques for WSNs. But, these approaches need complex tasks that grow exponentially as the problem size increases. Besides, they have not produced good results or suitability for real-time applications especially with obstacles [12].

This drives to use the bio-inspired optimization methods that are computationally efficient alternative to analytical methods.

A number of solutions have been developed to overcome the obstacle limitations using these optimization methods.

Stojmenovic and Lin have used the Greedy Face Greed (GFG) technique for a data routing process with obstacle-avoidance. The GFG routing technique reduces the routing path length with the help of nearest neighbor node selection. However, this technique is unable to detect the concave region of an obstacle [13].

Karp and Kung have proposed the Greedy Perimeter Stateless Routing (GPSR) technique for obstacle avoidance data transmission. The GPSR technique can avoid static obstacles based on right hand forwarding node selection mechanism. Both GFG and GPSR algorithms can detect the obstacles that are present in the WSN and then successfully transmit sensed data to the BS. But, they cannot find the energy efficient shortest data routing path due to the lack of global obstacle information [14].

Zou, et. al., proposed a distributed algorithm called Partial–partition–Avoidance GEographic Routing (PAGER). This system establishes a shadow region for any concave obstacles. It avoids the processes for this shadow region. Then, PAGER determines the transmission cost of the neighbor nodes and forwards the data to its lowest cost one. In this technique, the cost maintaining process of nodes increases control overhead within the network. Besides, PAGER cannot detect multiple obstacles within the monitoring region [15].

Chang, et. al., proposed two route guiding protocols, S-RGP and M-RGP that could detect large size obstacles appeared in the monitoring area. The S-RGP technique detects obstacle border nodes and constructs the shortest data routing path. While, M-RGP is used for multiple obstacles detection. The main drawback of these two techniques is that they need a significant control overhead and time for detecting a minimum number of boundary nodes and constructing the obstacle avoidance path [16].

Choi, et. al., proposed a sensor network based localization algorithm for an indoor service robot to improve localization of them for the fusion sensor agent [17].

Amulya, et. al., suggested a surveillance robot for home security in the presence of obstacles. They used mobile video sensor nodes and ZigBee based wireless communication to design a home control network [18].

More recently, genetic algorithm techniques have also proved their success to solve the optimal node deployment problems. In random deployment, genetic algorithms are applied to determine near optimal positions for additional mobile nodes needed to have maximum coverage. Besides, a force-based genetic algorithm was introduced to utilize the sum of the forces used by the neighbors to choose the direction of the mobile nodes [19]. Also, a multi-objective genetic algorithm running on a base station to determine where the mobile nodes can move to maximize the coverage and minimize the travelled distance [20]. While, a cluster-based WSN has used the genetic algorithm to find the best positions for the cluster heads that cover maximum number of nodes and so maximizing the area coverage [21]. Also, Voronoi diagrams (that were used to divide the field into cells) used the genetic algorithm. They have applied it to determine the best positions for k additional mobile nodes that maximize the area coverage inside each cell [22].

Although, the previous systems have succeeded to achieve free-obstacles paths, they suffer from complexity and time losses.

Therefore, the proposed system has introduced the genetic algorithm to optimize the avoidance-obstacles routing path for a cluster-based WSNs. It can improve the performance of WSNs' applications in real-time situations.

4. PROPOSED SYSTEM

Different approaches have been developed to improve the performance of the WSNs and extend their lifetime. It is found that, in the practical situations the WSN's route algorithm usually face some obstacles. This causes misconnection, delay time of communicating and increasing the power consumptions of the network. On the other hand, there is still a little work has been handled this important challenge. However, the proposed system has introduced a novel cluster-based routing algorithm to solve this problem. It uses the genetic algorithm (GA) optimization methodology to optimize the routing process for obstacle-avoiding shortest path. Besides, it can decrease the power consumptions and increase the lifetime of the WSNs.

However, the suggested system can achieve these previous tasks by three ways. They are:

1- using the mobile sink.
2- using the cluster heads to minimize the overload traffic and power consumptions.
3- optimizing the routing path for avoiding the obstacles and selecting the shortest path by using the GA.

Firstly, using the mobile sink can reduce the power consumption of WSNs. So, it will increase the lifetime of WSNs. Compared with static nodes, mobile sink have more energy and more powerful capabilities.

The proposed system uses the mobile nodes as the mobile sink which moves across the sensing field to collect the data.

In the recent years, the mobile sink based data collection technique has become an attractive research area in WSNs' design. It improves the networks' performance and lifetime. Distributed robotics and WSN co-operatory working in mobile sink based WSNs [23]. The proposed mobile sink moves randomly along different paths to collect data from head clusters. Then, it transmits the data to the base station through either single-hop or multi-hop communication.

Presence of obstacles within the monitoring area causes a challenging issue for the system to find the optimal routing path. Therefore, the proposed system has used the genetic algorithm to overcome this limitation. It can reduce the communication overhead for sensor nodes located near the base station or the sink. At the same time, the mobile sink concerns the energy consumption balance among nodes while moving across the sensing field. However, the uniform energy consumption is achieved. Besides by moving the sink, the routing algorithm can avoid the disconnected and sparse network.

Secondly, the suggested system divides the nodes of the WSN into two categories: cluster heads and cluster members. It uses the cluster heads internally to collect the data inside their cluster members (nodes) which collect the environment information and then pass data externally to the mobile sink. By using the cluster-based routing algorithm, the suggested system can decrease the power consumptions and increase the lifetime of the WSN.

Thirdly, the obstacle avoidance sink movement problem is an NP-hard problem. So, the proposed system can use the genetic algorithm optimization methodology to optimize the routing algorithm that can avoid various obstacles appeared in the practical situations. Thus, the suggested system enables the mobile sink to move through the network with obstacles having a shortest route path.

The operation of the proposed system can be explained as follows:

1- The suggested system determines the cluster heads and their members.
2- The mobile sink begins collecting all the sensing data from cluster heads as a periodical movement from starting site and finally returns.
3- During its movement, the mobile sink can move near the cluster heads consuming less power. So, the network lifetime can be extended significantly. In the proposed system, the network lifetime is defined as the time interval from sensor nodes start working until the death of all static sensors.
4- The mobile sink can move to any site except those contain obstacles. This makes the routing task for the mobile sink more complex.
5- To overcome this challenge, the proposed system determines the locations of the obstacles. It has used the grid-based method to divide the sensing region into equal size grid cells as the communication radius of static sensors. So, the obstacles in the sensing area will be appeared at some grid cells. Edges of obstacles can intersect grid cells or they may contain part of some grid cells. In this case, the grid cell is considered as obstacles. This regularization shape of obstacles can simplify the routing process of the mobile sink.
6- Assume that *Ni* static sensor nodes are deployed randomly over a sensing field. All the static sensor nodes have the same sensing range represented as a circle with radius *r*. The proposed system gathers the information about the locations of the static sensor nodes.
7- Then, the suggested system has used the genetic algorithm optimization methodology to efficiently find an optimum obstacle-avoiding route for the mobile sink in the presence of obstacles.

To implement the proposed system, it is assumed that the sensor nodes are randomly deployed, and the base station node position is stationary. Also, the mobile sink moves at a fixed speed along the optimal obstacle avoidance path and collects data from each static sensor node before transmitting data to the Base Station.

Also, the suggested system has considered the deployed sensor nodes set, S, and its corresponding data collection points $P_{Sensors}=\{p_1, p_2,..., p_n\}$, and $U_{Sensors}$ contains the set of all remaining uncovered sensor nodes at each step. The data collected points are connected to each other such that any sensor nodes directly communicate to at least one other node. However, the proposed shortest avoiding-obstacles path algorithm can be represented as:

Shortest avoidance-obstacles Path algorithm

1. Create an empty set $P_{Sensors}$

2. Create a set $U_{Sensors}$ containing all sensors

3. Set S contains all deployed sensor nodes

While

5. Find obstacle free path between the neighbor nodes through IR signal transmission

6. Find a data collection point pi between n1(si) for $si \in S$ which minimizes

$\theta = cost\{ n_1(s_1)/(n_1(s_1) \cap U_{Sensors}$ and check at least one connection exist between $m_1(s_i)$ and p_i

7. Cover all sensor nodes under $n_1(s_i)$

8. Add the corresponding data collection point pi of $n_1(s_i)$ in $P_{Sensors}$

9. Remove sensors in n_1(si) from $U_{Sensors}$

End while

10. Find an approximate shortest path on data collection points in $P_{Sensors}$

The genetic algorithm can be implemented as shown in the following steps:

a. Chromosomes Representation

The chromosomes of the proposed Genetic Algorithm (GA) are represented in a binary digit form. They encode the locations of each mobile sensor node in the sensing area as (X, Y) point. It represents the value of the location on the X and Y axises. The size of the proposed population is 30 chromosomes.

b. Selection methodology

The proposed genetic algorithm has used the tournament selection scheme to select the most suitable chromosomes for continuing to the next generation.

c. Crossover

Proposed GA uses a single point crossover. Its rate=0.5.

d. Mutation

The suggested system has applied the inversion mutation for the offsprings. The mutation rate is: 0.02.

e. Fitness function

The fitness function is the core part of the genetic algorithm operation. It evaluates the fitness of each chromosome (solution) in the population to determine its ability to be included in the next generation of the GA.

In the proposed system, the fitness function optimizes the number and locations of the clusters and obstacles in the observed area. The proposed system concerns also the decreases of the consumption power, the cost, and the shortage free-obstacles route path. This can avoid the overlapping redundancy among the coverage areas of the deployed mobile nodes. Also, each mobile node can cover only a distinct region. The fitness function is given by:

$$F = Minimize \sum_{(i,j)\epsilon A} cx_{ij} + \sum_{i\epsilon P} ny_i \quad (1)$$

where,

$x_{ij} \in \{1,0\}$

$y_i \in \{1,0\}$

$x_{ij} = \begin{cases} 1, & if\ s_j\ can\ cover\ node\ s_i\ through\ obstacle\ free\ path \\ 0 & otherwise \end{cases}$

$y_i = \begin{cases} 1, & if\ node\ s_i\ is\ on\ the\ tour \\ 0 & otherwise \end{cases}$

c, n = constant

Where, eq. (1) represents the objective function that minimizes the total cost and length of the obstacle free data collection path.

f. Termination

The GA can be terminated in two ways either by achieving the optimum solution or by having 100 iterations.

However, the proposed system can optimize the number and the locations of the cluster and avoiding the obstacles appeared in the communication process.

5. APPLICABILITY OF THE PROPOSED SYSTEM AND ITS RESULTS

The proposed system is applied for a simulated wireless sensor network that communicates between a robot having a dosimeter used for discovering the radiation sites and its operating system. Then, the results achieved by the proposed system are compared with the corresponding ones for three other systems. The first system is a traditional route algorithm for WSN that having no optimization [24], the second system uses an analytical optimization for WSNs having obstacles [25]. The third one uses particle swarm optimization technique [26].

Table (1) represents the used parameters for the problem at hand. While, table (2) deals with the obtained results from the four systems. Figure (1) shows a comparison between the results obtained from the tested systems.

Table (1): the used parameters tested WSN at hand

Parameters	Values
Grid Size	10 m
Dimension of sensing field	50m x 50m
The number of nodes	200
Initial Energy	0.5J
Data aggregation	7J/bit/report

Table (2) : A comparison between the obtained results from the proposed system and other three systems

System	Number of Nodes	Lifetime	Power Consumption
Proposed System	325	87.5 H.	65 W
No Optimization System	583	42.3 H	273 W
Analytical Optimization System	494	53.5 H.	214 W
PSO System	425	67.4 H.	186 W

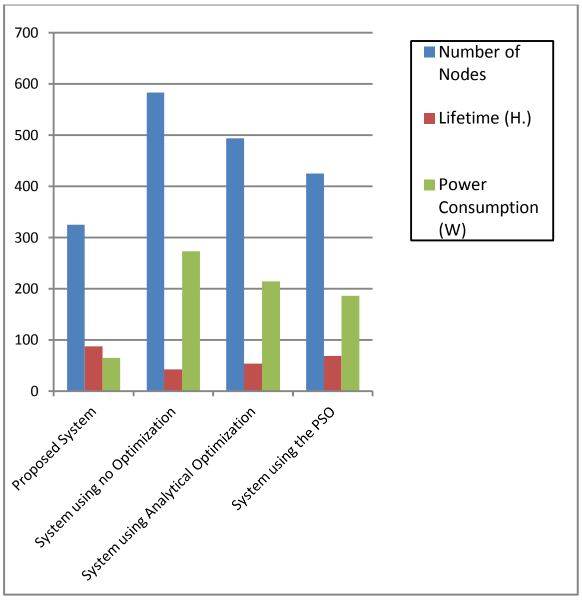

Figure (1): A Comparison between the results achieved by the proposed system, and the other three systems

It is found that, the proposed system has proved its goodness by increasing the lifetime of a WSN used in detecting the radiation sites. Also, the proposed system decreases its power consumption. Therefore, the suggested system can improve the performance of Wireless Sensor Networks those are applied in real time applications.

6. CONCLUSION

Although the great wide spread of the wireless sensor networks in our daily life, there still some challenges faces them to be applied in many other real-time applications. It is found that, appearing the obstacles in real time sites can fail the operation of the network. Besides, power consumptions of the WSNs. These two limitations still cause important issues for the networks till now.

Proposed system has suggested new algorithm that uses a genetic algorithm for a cluster-based WSNs. The cluster-based technique has been used to simplify the data gathering process and decrease its power consumptions. While, the genetic algorithm is used to optimize the avoiding- obstacle route and its shortage path.

Proposed system has been applied to evaluate a simulated wireless sensor network used in discovering the radiation sites. It has compared for three other optimized systems have applied for the same simulated WSN. The proposed system has proved a significant decreasing in the energy consumption and the number of used nodes for maximizing the coverage area. On the other side it has increased the WSN's lifetime. Its obtained results have proved its goodness to be applied for real time WSN applications.

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