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The design of an optimal and secure routing model in wireless sensor networks by using PSO algorithm

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Abstract

Wireless sensor networks (WSNs) are consisted of tens, hundreds or even thousands of self-directed sensors which are embedded in an environment wirelessly at a distance from each other to communicate with each other, and their task is discovering and aggregation of environmental information and transmitting it to a monitoring center. Continuous movement of sensor nodes and their limited battery power causes routing problems for these types of networks. Thus, providing a reliable and secure protocol in wireless sensor networks seems crucial. Our main emphasis in this paper is on utilizing artificial intelligence techniques such as clustering and Particle Swarm Optimization (PSO) algorithm for finding a safe and efficient routing in wireless sensor networks.

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Keywords: Wireless Sensor Network, Security, Particle Swarm Optimization (PSO) algorithm, Clustering.

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1. Intruduction

Computer systems were initially mainframe, but they were pushed towards the computer networks due to the increased efficiency and productivity of these networks. In addition, only simply connecting computers as a network doesn’t increase the processing power, but another concept called distributed systems has been involved [5,8]. As an example of distributed systems, wireless sensor networks can be mentioned.

Wireless sensor networks are composed of hundreds and even thousands of sensor nodes i.e. a set of self-directed sensors which are embedded in the environment wirelessly at a distance from each other in a connected way and their task is discovering events, collecting data and environmental information and transferring them to a monitoring center. In fact, sensors have been equipped with processors and communication facilities. They have different types to measure some physical quantities or environmental conditions such as temperature, light, humidity, sound, motion of the pollutant, etc. Sensors were initially used by the military, but they got wider application over time. Sensor networks were developed by different application motivation for different places such as impassable areas, disaster areas, and they also have monitoring applications in battlefield in military. The applications of sensor networks are increasing day by day, and soon they are going to play a wider role in everyday life of human being. Nowadays, wireless sensor networks are one of the most debated topics of research in computer science, communications, industry, and many non-military fields. Some of these huge applications include monitoring and controlling industrial processes, monitoring health condition of systems, environment monitoring of firms, centers, and houses, health care, smart homes, traffic control, and so on [2-4,6,7,9].

Wireless sensor networks have significantly advanced architectural wireless sensor networks by introducing powerful and even moving activators. Although activators work by nodes or sensor nodes, they can carry out practical and special activities. For the accurate and valid performance of these activators, the design of a reliable and useful report for the sensors to inform the activators about environmental events seems vital. Activators are powerful and even moving elements which have progressed wireless sensor networks. Activators are much more powerful than sensors in terms of computing capacity. A moving activator like a robot can change its position each moment to have the desired performance [7]. An activator processes information and data received from the sensors and according to the data interact with the environment. For an activator to react accurately and reliably to the environment, a reliable framework of sensors to report facts and events to activators is obligatory.

Among the main disadvantages of wireless sensor networks, limited battery power can be mentioned. Since most batteries are irreplaceable, improper energy use may cause problems such as destructive attack, and hardware and sensor nodes downtime [9]. In section 2 of this paper, the clustering algorithm and PSO algorithm will be explored. In Section 3, using the idea of intelligent techniques such as clustering and PSO algorithm, we provide a secure and efficient model for collecting and reporting events in WSNs. Finally, in section 4 the research conclusion will be dealt with.

2. Investigation of the intelligent algorithms

In this section, some of the intelligent algorithms used in this research has been investigated and analyzed. The term artificial intelligence as a new knowledge was coined in 1965, though work on this field of science had begun in 1960. Most early research on artificial intelligence was concerned about game machines and substantiating math theorems by the help of computers. At the beginning, it seemed that computers will be able to do such things by only utilizing lots of discoveries and searches for selecting the best solution. The term artificial intelligence was first used by John McCarthy who is remembered as "the father of science and knowledge of intelligent machines production" [5].

2.1. Clustering:

In clustering is a method to estimate density. It is counted as unsupervised learning, because the data are not labeled at first. The goal of unsupervised learning is clustering the samples and not connecting input and output. In this type of learning, the labels are not specified from the beginning. The reason for the importance of this learning is that in real world system faces inputs with no pre-specified labels. In this situation, the system itself clusters the data. This procedure has been shown in Fig. 1. In unsupervised learning, the data is divided into clusters in which there is the most similarity among the data and minimum similarity exists among the data in different clusters [1].

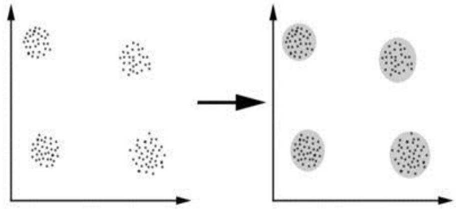

Fig. 1. An example of applying clustering on a set of data by using standard distance among the data [5].

2.2. particle swarm optimization (PSO) algorithm

Particle Swarm Optimization (PSO) algorithm is a subset of collective intelligence that has been established based on collective behavior in decentralized and self-organized systems. These systems usually consist of a population of simple agents that interact locally with each other and with their environment. Although, usually no concentrated control forces the actors how to behave, their local interactions lead to the emergence of public behavior. Some examples of such systems can be observed in the nature such as groups of ants, flocks, herds of animals, bacteria gatherings and groups of fish.

PSO algorithm was first proposed in 1995 by Eberhart and Kennedy. The formulation of this method has been inspired from mass flight of birds, swim team of fish and their social life which has been formulated by using a series of simple relations. Like all other evolutionary algorithms, particle swarm optimization algorithm starts by creating a random population of individuals that is called a group of particles here. The features of the particles in each group is determined based on a set of parameters and their optimal values need to be specified. In this method, each particle shows a point of the problem resolving space. Each particle also possesses a memory by which they remember the best situation reached in the search space. Therefore, each particle moves in two directions: (a)Towards the best position they have taken individually so far, (b) Towards the best position that all particles have selected. In this method, the position change of each particle in the search space is influenced by its own experience and knowledge and also their neighbors.

Suppose that in a particular issue, we have D-dimension space and that the i-th particle of the group can be displayed by a velocity vector and a position vector. The position change of each particle is possible by a change in the structure of the position and its previous velocity. Every particle includes data consisting of the best value ever reached (personal optimum) and X^t position. This data is the result of a comparison of efforts of the specific particle to find the best answer. In addition, every particle knows its best answer ever achieved in the whole group by a comparison between the optimum values of different particles (universal optimum). Thus, in order to reach to the best answer each particle attempts to change its own position by using the following information: A: Current position (X^t), B: Current velocity (V^t), C: the distance between the current position and the personal optimum, D: the distance between the current position and the comprehensive optimum. Thus, the velocity of each particle and as a result its new position will change as follows:

$$V_i^{t+1} = wV_i^t + c_1\ rand(0,1)(pbest_i\ - X_i^t\ ) + c_2\ rand(0,1)(gbest_t\ - X_i^t\ ) \quad (1)$$

$$X_i^{t+1} = X_i^t\ +\ V_i^{t+1} \quad (2)$$

Where V_i^{t+1} is the velocity of particle (i) in the new iteration, V_i^t is the velocity of particle (i) in the current iteration, X_i^t is the current position of the particle, X_i^{t+1} is the position of article in the new iteration, $pbest_i$ is the best taken position of the particle (i), $gbest_t$ is the best position of the best particle (the best position that all the particles have taken so far). Rand (0,1) is a random number between zero and 1 which is used to maintain the diversity of group. C_1 and C_2 are cognitive and social parameters respectively. Selecting the appropriate values for these parameters accelerates the convergence of the algorithm and prevents premature convergence in local optimums. Recent research shows that choosing a larger value for cognitive parameter of C_1 is more appropriate than social parameter of C_2, but the condition $C_1 + C_2 \leq 4$, must always be met. Parameter W is called the inertial weight which is used to ensure convergence of the particles set. It is also used to control the impact of previous velocities records on the current velocities. Research shows that a value between 0.4 and 0.7 is suitable for W.

3. The proposed model based on the intelligent techniques

In this part of our study we attempt to offer a reliable method for wireless sensor networks by using the intelligent techniques. In this method sensors will be able to collect the environmental data in the best way possible and report it to the destination. The proposed algorithm is shown in Fig. 2 and acts according to the following steps:

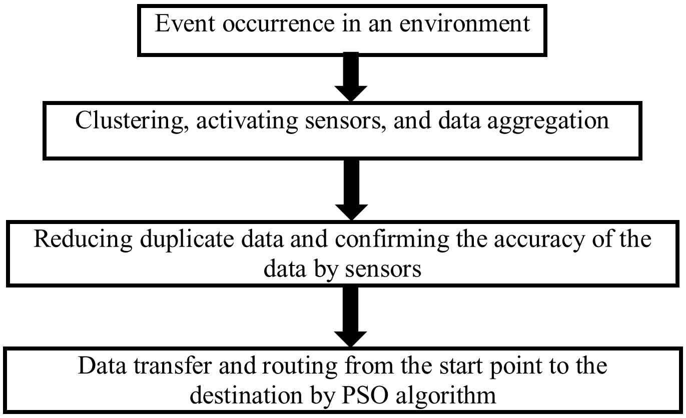

Fig. 2. The proposed model for the aggregation and routing of the data in wireless sensor networks

3.1. The clustering and data aggregation phase

This phase happens in an environment when different sensors may receive data which might include wrong or duplicate data or even it happens when a large number of sensors tend to transfer the data which in turn leads to routing traffic and failure of some part of the data. Therefore, it's preferred that the data before getting to the activators be organized and their accuracy be checked. Clustering algorithm and dividing the environment into network cells is the first idea that we have applied in order to reduce duplicate and failure data. Using clustering algorithm and dividing the workplace into network cells is an efficient design to reduce duplicate and invalid data. Thus, reducing duplicate and invalid data greatly increases efficiency, and reduces congestion and routing traffic. While selecting smaller network cells helps to increase accuracy to a great extent, bigger network cells make less data reduction and optimize the network performance. Therefore, the size of network cells must be balanced and optimized. After clustering the sensors in the environment, in all clusters a node called "cluster head" node is chosen to manage the sensors inside its own cluster. This is shown in Fig. 3. This node in each cell is responsible for several tasks including data gathering of its own network cell sensors and managing the data, averaging that data, validation assessment of sensors, and distinguishing valid from invalid sensors. The main idea that can be highlighted here is that "cluster head" in each cell detect defective sensors with an approach and remove theses sensors' data from the accurate data. The new approach that we have proposed has two important advantages. Considering the major challenges that the sensors may either have limited battery power on one hand or that the data transmitted among sensors may be corrupted or lost on the way on the other hand, we proposed a new approach to solve the two fundamental problems which is specified as follows: At the first place, the "cluster head" node in each cluster requests all sensors among its own cluster to send their data volume and battery power to "cluster head". Next, "cluster head" by checking these two parameters removes both nodes with low battery power and also defected nodes with failure data. Then, it calculates the average of the remaining sensors' data. Now the data of all environmental sensors have reached to the "cluster head" to forwarding this data to activators. Since there are several "cluster heads" and forwarding the data by all "cluster heads" cause highly heavy routing traffic, at this stage of our proposed method, we select among all “cluster heads”, four “cluster heads” with the highest battery level on four sides of the incident to receive the closest remaining “cluster heads” data. Finally, these four nodes transfer the data to the nearest activator.

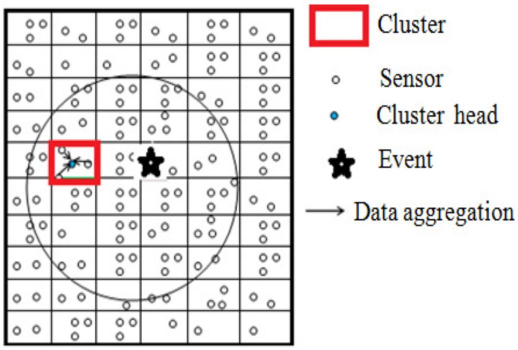

Fig. 3. Application of clustering for management and data aggregation

3.2. Data transfer phase

In this stage, it's time for the four selected cluster heads on four sides of the incident to forward their data through a path to the activator which in turn performs the reactions needed to neutralize environmental event. Routing in these four selected cluster heads is done as follows: First, the four cluster heads find the best position and path by using PSO algorithm. Fig. 4. shows the performance of particle swarm optimization (PSO) algorithm. It is clear from this Figure that the orange arrow is the best sensor node that should be selected for routing and forwarding information. Next step for routing is that after each source node selected the next node by using the PSO algorithm, this node undergoes an evaluation of battery level and in case of low battery level is removed and another node is selected based on the above mentioned discussed method. This procedure is repeated so many times until the data gets to the activators or main destinations through the most secure and optimal path.

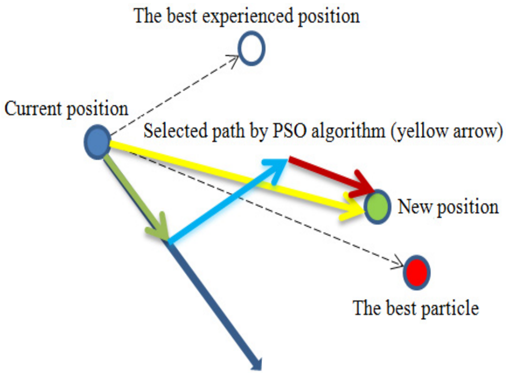

Fig. 4. The routing procedure by PSO algorithm

4. Conclusion

Wireless sensor networks are one type of distributed systems that have been of interest for different researchers in recent years. They are consisted of tens, hundreds or even thousands of self-directed sensors which are embedded in the environment wirelessly at a distance from each other so as to communicate with each other, and their task is discovering and aggregation of environmental information and transmitting it to a monitoring center. In this paper, by utilizing artificial intelligence techniques such as clustering and PSO algorithm, a secure and optimal method for reporting events in wireless sensor networks have been offered which is able to optimally aggregate received data from the environment and report it to the activators.

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