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Node Deployment of WSN Based on Drones

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ABSTRACT

In order to solve the problem of WSN node deployment being unable to achieve relatively orderly and efficient deployment in some specific scenarios, this study refers to the specific development of WSN coverage technology at home and abroad, and hopes to create a basic and universal coverage system based on existing technology, in order to face various emergency situations in reality.

KEYWORDS

WSN node deployment; Basic; Universal

1. INTRODUCTION

With the continuous development of technology, people's demand for signal coverage is increasing. The development of wireless sensor network technology has entered a new stage, gradually integrating with other industries and continuing to develop deeper. For example, the development of swarm intelligence has driven research on WSN coverage optimization based on swarm intelligence algorithms [1]. Many scholars are committed to improving the coverage efficiency of wireless sensor networks. Improved the coverage of WSN [2]. The required number of nodes will decrease, but the survival rate of nodes will decrease due to the increase in usage. In this article, the author discusses in detail the balanced and efficient results of energy consumption and node survival rate in wireless sensor networks, as demonstrated by Guo Jin's research [3] on energy balance algorithms in wireless sensor networks.

The drone industry has developed rapidly in recent years, so the direction of using drones to participate in WSN node deployment has attracted many scholars' thinking. Flood disasters have always been a seasonal disaster that troubles southern China, especially in the summer each year. Search and rescue missions after floods are of utmost importance during this period. In some low-lying areas, the accumulation of floods has damaged ground base stations, cut off communication signal coverage, and prevented trapped residents in the disaster area from communicating with the outside world. At this time, unmanned aerial vehicles carrying nodes can provide communication signals to fully solve the communication problems in the disaster area. Similarly, in some exploration missions, communication base stations need to be deployed at specific locations. In areas where power systems cannot be controlled, drones can be used to expand the radiation range of base station signals. In the military application of wireless sensor network technology [4], the author discusses that the coverage of wireless sensor networks can be used to monitor and determine the location of targets. However, the deployment of fixed nodes is not very helpful for mobile forces because they cannot guarantee complete coverage of every path to monitor the enemy's movement line. However, the deployment of unmanned aerial vehicles carrying nodes can achieve complete coverage of target locations by adjusting their positions and cooperating with each other. Therefore, the deployment of unmanned aerial vehicles carrying nodes can meet the needs of mobile forces with strong mobility. Overall, utilizing drones to deploy WSN nodes is a worthwhile research topic.

1.1. The Composition Structure of WSN

Wireless Sensor Network, WSN, it mainly consists of three parts: sensor nodes, sensor networks, and users, among which sensor nodes and sensor networks are relatively important. Sensor nodes are micro embedded devices that require low prices and low power consumption. These limitations inevitably result in weaker processor capabilities and smaller memory capacities carried by them. In order to complete various tasks, sensor nodes need to complete various tasks such as collecting and converting monitoring data, managing and processing data, responding to task requests from aggregation nodes, and node control. How to utilize limited computing and storage resources to complete various collaborative tasks has become one of the challenges in sensor network design [5]. The sensor nodes include ordinary nodes, sink nodes, and management nodes [6]. A sensor network is a computer network composed of many automated devices distributed in space, which use sensors to collaboratively monitor physical or environmental conditions at different locations.

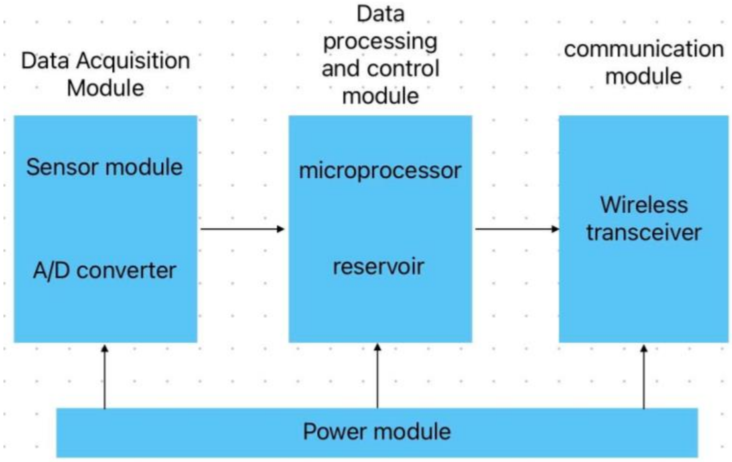

Figure 1. Basic composition modules and internal connections of sensor nodes

1.2. Working Principle of WSN Single Node System

According to Figure 1, we can roughly identify the basic components of the sensor node, which are the sensing unit, processing unit, communication unit, and power supply [7]. is the core of sensor nodes, responsible for device control, task allocation and scheduling, data integration, and data transmission of the entire node.

The node conducts preliminary data processing and information fusion on the collected information and the information forwarded to it by other nodes, and then transmits it to the base station in the form of relay transmission by adjacent nodes, and then transmits it to the user port through the base station in the form of Internet, satellite, etc. Sensor nodes are the basic functional units of wireless sensor networks [8].

In sensor nodes, the power module provides energy to the nodes and is the fundamental module of the entire wireless sensor node. Due to the limitation of node volume, the energy of sensor nodes is very limited. Therefore, in the entire node design, low power consumption and high precision are the main requirements, and a series of effective measures are taken to save energy. In addition, medical sensor nodes cannot frequently replace batteries, which affects people's normal lives. Therefore, the designed medical nodes should have a longer lifecycle [9].

1.3. Wireless Sensor Network Coverage

Wireless sensor network coverage is a distributed sensor network coverage, with sensors that can communicate with the outside world at its end. The overall coverage of the network is the most important and fundamental issue for WSN monitoring effectiveness, which reflects the monitoring and communication status of the entire monitoring area. The coverage control of wireless sensor network is to optimize the allocation of various resources in the wireless sensor network through the placement of network sensor nodes and routing selection, in the case where resources such as energy, wireless network communication bandwidth, and network computing processing capacity are generally limited. This ultimately improves the quality of services such as perception, monitoring, sensing, and communication Choosing a wireless sensor network coverage control strategy helps to effectively control the energy of network nodes, improve perceived service quality, and extend overall survival time [10].

1.4. WSN's Drone Deployment

According to different situations, people usually use two schemes: random drone deployment and fixed-point deployment. There are many benefits to instant coverage. Firstly, it does not require a large amount of computation from people and can greatly meet the signal coverage requirements. Secondly, it requires less resources and only requires drones for deployment, without the need for hovering operations. And fixed-point deployment is also an indispensable deployment method. In some specific environments, random deployment is easily affected by unstable factors and reduces the service area covered by signals. However, fixed-point deployment can overcome the problems caused by environmental changes, and at the same time, it can achieve more accuracy and maximize coverage, improving operational efficiency. One of the deployment methods for fixed-point deployment requires a large amount of data simulation to obtain a rough coverage plan, in order to cover the relevant areas. For the simulation of coverage, the first consideration is the altitude issue, which determines the horizontal distribution of the task. Many deployment methods involve raising the drone to a fixed altitude and then adjusting the orientation of the same horizontal plane. Therefore, it is crucial to prioritize determining the altitude issue.

1.4.1. Impact of drone distance from the ground

The transmission energy of signals is the same, and they will diverge with the increase of propagation distance. Therefore, the primary consideration when drones participate in node deployment is whether the distance is suitable for the signal transmission of each node. At the end of the 1.4WSN drone deployment, we mentioned that the first problem that needs to be solved is the height of the horizontal plane where the drone works. Therefore, our first foothold is the optimal hovering point of the drone. Because it is a plane analysis, we assume that the drone is analyzing an absolutely flat surface.

Theorem: The nearest point to H on a convex curved edge is at its nearest vertex to H, or on the curved edge connected to the nearest vertex [11]. This theorem is proved using the inverse method, and the final calculation method is obtained: given a vertex set V of a convex regular curved edge shape, the hovering point is determined by calculating the intersection product of its line segments [12].

2. SIMULATION EXPERIMENT

2.1. WSN Coverage Algorithm

WSN has multiple coverage methods, and the perspective we are studying is based on it. Some deeper coverage methods have evolved from the basic coverage methods

2.1.1. Barrier coverage with wireless sensors [13]

Fence covering is a relatively low difficulty simulation experiment among several experiments, which is conducted on a given straight line. We divide a line segment into n segments on average, so there is a total of n-1 nodes. Assuming that the error distance of the drone's random point deployment is r and the signal coverage radius of each node is R for simulation experiments (drone fixed-point deployment is actually the most ideal, but overall, the overall efficiency of point deployment is the best, which can save a lot of computing power and drone resources). We conducted a simulation experiment of fence coverage in MATLAB, and only needed to ensure that 2R+2R is less than or equal to the distance d between adjacent points for random point placement. This is equivalent to randomly scattering nodes in a specific large area, which can have a very high success rate. (We excluded a special case where the coverage area is connected into a fence to monitor whether objects pass through, but we cannot guarantee that this line is completely included in the two detection ranges. If there is a need for this, we only need to establish a right angle coordinate system with this line as the x-axis, so that the intersection point y1 * y2 of adjacent circles is less than or equal to). Figure 2 is a schematic diagram of fence coverage on non branch lines, which is more universal and more in line with the actual needs of fence coverage. When encountering more irregular curves in reality, the segmentation method can be chosen to divide the entire irregular curve into multiple small segments for local analysis, similar to the mathematical method of differentiation for segment analysis.

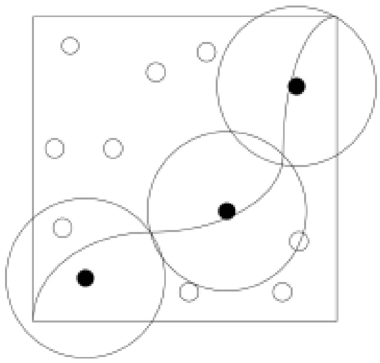

Figure 2. Schematic diagram of universal fence coverage

2.1.2. Regional coverage[14]

Regional coverage is the most common way of coverage in people's daily lives, which is divided into random point coverage and fixed-point area coverage. Random scatter coverage [15] [Wang B, Chua K C, Srinivasan V, et al. Information coverage in randomly deployed wireless sensor networks] IEEE Transactions on Wireless Communications, 2007, 6 (8): 2994-3004. The application scope of Randomly scatter coverage points is relatively small, while fixed-point area coverage [16] (Targeted area coverage) is used in many scenarios. Therefore, we mainly explored the coverage of fixed-point areas. And vertex area coverage is divided into regular shape area coverage and irregular shape area coverage according to the type of covered area. In our opinion, the coverage of irregular graphic areas is more worthy of attention, as almost all special situations encountered in reality are composed of irregular graphics as the main body. In the previous text we mainly analyzed the basic types of regional coverage and newer models, providing us with some ideas.

As shown in Figure 3, these are three work points deployed randomly. We found that although it saves computing power, there is a waste of resources to some extent. For example, two coverage areas overlap, which affects coverage efficiency. In addition, one area is not connected to the other two areas, which means that under certain special conditions, communication can only be carried out within its own work area and cannot be carried out across areas.

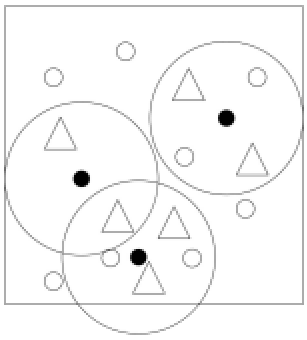

Figure 3. Random Dot Coverage

As shown in Figure 4, for a more regular area coverage method, we can see that for the rectangle in the legend, the coverage service range of the drone is regarded as an ideal circle, with four adjacent circles sharing a common intersection point. This layout can achieve an objective ideal value for coverage and communication efficiency.

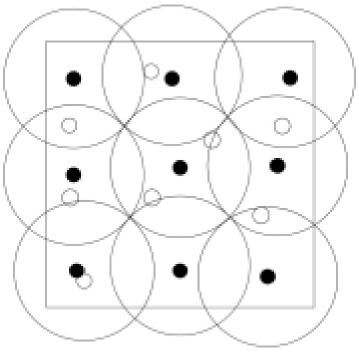

Figure 4. Fixed point deployment in regular areas

As shown in Figure 5, under the condition of irregular areas, we can embed irregular patterns into regular grids (the smaller the area of the individual cells in the grid, the more accurate the measurement values). This is combined with the coverage method in Figure 4, which can combine the edge length d of the small grid with the working range R of the drone and arrange them in an orderly manner. It can also be seen as rounding up each grid occupied by the irregular model (fully occupied and partially occupied), simplifying the algorithm while increasing the WSN coverage of the drone. For example, in the following figure, we can connect the diagonals of a square as the unique common focal point of four circles (given that the drone's operating range is root 2).

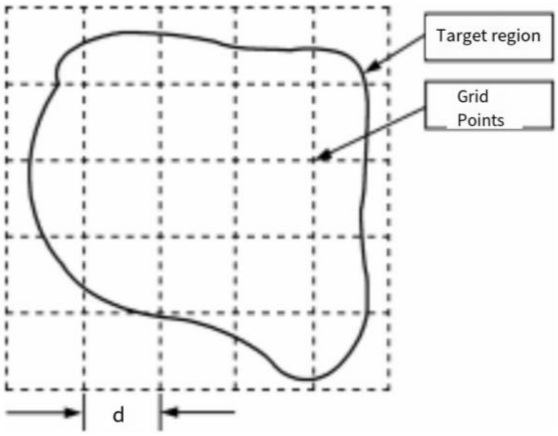

Figure 5. Grid method for solving irregular area coverage

3. CONCLUSION

This article aims to solve the problem of WSN node deployment being unable to achieve relatively orderly and efficient deployment in certain specific scenarios. It proposes a basic and universal WSN coverage system for certain situations, such as flood rescue, earthquake communication, etc., in order to face various emergency situations in reality. In further research, we will continue to introduce more precise coverage arrangements in the theme of drone based WSN deployment, which can use multiple models of drones for coverage (i.e. the working radius R may vary), in order to maximize overall work efficiency.

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