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Research Article

A Deployment Strategy of Nodes in WSN Based on "X" Partition

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In order to reduce the energy consumption and the cost of wireless sensor networks (WSNs) deployed in linear areas and prolong the life of the network, a deployment strategy of nodes in WSNs based on "X" partition was proposed in this paper. The monitored area was partitioned based on "X" shape, and the sensor nodes were deployed, so as to make the whole area be covered and the number of nodes deployed be reduced. At the same time, the monitoring units are divided and compressed to balance and save energy of the network and prolong life of the network. Through experiment verification, compared with traditional partition deployment strategy, the deployment cost of network can be reduced effectively by the proposed strategy. In terms of the life of the network, the proposed strategy is longer than the diamond partition strategy more than 50%.

1. Introduction

At present, wireless sensor networks are widely used in various scenes. Many sensor nodes are deployed in the area to be monitored according to the established strategy and cooperated with each other to complete the task of collecting, processing, and transmitting [1]. Sensor nodes are usually deployed in complex environments and cannot be reused. Therefore, when a node is unavailable due to its own energy depletion or other factors, the whole wireless sensor network will be seriously affected.

When wireless sensor networks are used for monitoring in tunnels, mines, rivers, or large bridges, the sensor nodes are also distributed linearly because of the linear shape of these areas. Moreover, in this kind of environment, the base station is often set at one end of the area to be monitored. When the information collected by sensor nodes is sent to the base station in the form of multihops, more data forwarding tasks and greater energy consumption need to be undertaken by sensor nodes closer to the base station, while few data forwarding tasks and low energy consumption are on sensor nodes farther away from the base station, which leads to an "energy hole" in the whole wireless sensor network [2, 3], and the life of the network is ended prematurely. In addition, the similarity of data collected by close nodes in the network is high, which makes the data redundancy of the whole network larger; the energy of sensor nodes is wasted; and the life of network is greatly shortened.

Aiming at the problem of network deployment and optimization, many efforts were made and a series of results were achieved by researchers. The node deployment density function under linear network was proposed in reference [4, 5]; the sensor nodes were arranged according to the density formula. By arranging sensor nodes in this way, the ratio of total energy and energy consumption speed in each region can be balanced, so as to effectively prolong the life of the system. However, in many practical application scenarios, its density cannot be accurately controlled. Yen et al. [6] adopted isosceles triangle partition to realize K-coverage of monitoring region, and sensor nodes were grouped to balance the overall energy consumption of the network, but the coverage rate is not high. Liu and Wu [7] proposed a hierarchical wireless sensor network routing protocol for mine roadway environment, which can cluster in large scale in areas with large data forwarding volume. However, the existence of cluster heads necessarily becomes a network bottleneck that restricts the performance of the networks. Muthusenthil and Kim [8] proposed a hierarchical wireless sensor network model for underground working environment. The topology control method based on static node controllable deployment is adopted, and the nodes are arranged on one side of the roadway in a straight line; thus, the double coverage of the roadway was realized. Rejinaparvin and Vasanthanayaki [9] proposed the cluster node competition algorithm; the network was divided into several clusters with different sizes and combined with inter-cluster routing to save network energy. This protocol considers the influence of the remaining power, so it is able to balance the node power. Regular triangle partition, rectangular partition [10], and diamond partition [11] are included in common deployment strategies of wireless sensor network nodes. There are some problems in existing node deployment methods and strategies, such as high node deployment density, high network deployment cost, and large data redundancy. The data compression in wireless sensor networks [12–14] can make the transmission energy consumption be effectively reduced and the life of the network be prolonged. Aiming at the problems of uneven distribution of directed sensing nodes scattered in the designated monitoring area by random deployment in the monitoring task of directed wireless sensor networks in a two-dimensional environment, the characteristics of directed sensor nodes, probabilistic sensing model, and cooperative sensing model of multiple sensor nodes for monitoring target points are analysed. In this paper, a deployment strategy of nodes in WSN based on “X” partition is proposed; the area to be monitored can be divided by “X” partition; then, the number of sensor nodes in the network and network deployment cost can be reduced on the premise of realizing full network coverage. At the same time, the data of the monitoring unit is compressed to balance the network energy consumption and prolong the network life. The proposed method can guide the direction adjustment and perception optimization of two-dimensional oriented sensor nodes, so as to improve the perception ability of network nodes.

The main contributions of this study are summarized as follows:

(1) We propose a new a deployment strategy of nodes in WSN based on “X” partition, which can improve the coverage of the region to be monitored and the perceived quality of service and reduce the overall energy consumption of the network

(2) The proposed deployment strategy can adjust and optimize the location distribution of wireless sensor nodes according to the demand characteristics of the area to be monitored, meet the sensing needs of different areas, and improve the energy efficiency of the network and nodes

The rest of this paper is organized as follows. The energy consumption model is introduced in Section 2. Node deployment strategy is presented in Section 3. Simulation results and analysis are given in Section 4. Finally, conclusions are given in Section 5.

2. Energy Consumption Model

The requirements of node connectivity in wireless sensor networks are roughly the same as those in ad hoc networks: (1) the information must have one or enough paths to forward from the information source to the destination node; (2) the delay of information forwarding shall be as small as possible. The more information forwarding paths, the more reliable the system is. However, due to the need for multiple intermediate nodes to work at the same time, the node energy consumption increases and the system life decreases. The energy consumption of wireless transmitting devices increases exponentially with the increase of transmitting and receiving distance. Using multihop information forwarding instead of point-to-point communication can save a lot of energy. However, too many hops will increase the number of information receiving and forwarding and will also bring additional energy consumption. Therefore, the key to reduce energy consumption is to compromise the above two contradictory factors and appropriately control the number of forwarding nodes. The following definitions are given:

Definition 1. Connectivity between sensor nodes. If in the deployment area of wireless sensor network, nodes can always transmit information to each other in some way, it is said that nodes are connected in the network coverage area.

Definition 2. Connectivity of wireless sensor networks. If in the wireless sensor network deployment area, for a large subset of all nodes, the base station can always transmit relevant control information to any node in the node set by some routing method and any node in the node set is also connected, the wireless sensor network composed of this large node set in the network coverage area is connected.

The set composed of all sensor nodes is divided into $\{h_1, \ldots, h_m\}$, $s_i \in \cup_{1\leq j\leq m} h_j$, and $h_i \cap h_j = \varnothing$, where h_i represents a set of sensor nodes that make up the backbone connection network and s_i is a sensor node. Each nonbackbone node in the sensing state can communicate with at least one backbone to save power. There must be one and at least one direct or indirect path between the backbone nodes to connect the two.

In wireless sensor networks, the energy of sensor nodes is mainly spent on the conversion and processing of external signals and the overhead of data communication. The wireless communication energy consumption model in the data transmission stage and the data compression algorithm in the data processing stage are adopted by the deployment strategy of nodes in wireless sensor network based on “X” partition.

When $l-$bit data is sent by the sensor node, its energy consumption formula is

$$E_{Tx}(l,d)=\begin{cases} l\left(E_{\text{elec}}+\xi_{fs}d^2\right), & d<d_0, \\ l\left(E_{\text{elec}}+\xi_{mp}d^4\right), & d\geq d_0, \end{cases} \tag{1}$$

where $E_{Tx}(l,d)$ is the node energy consumption, which is generated in the transmission circuit and signal amplifier.

E_{elec} is the energy consumption of transmitting unit data by transmitting circuit or receiving circuit. ξ_{fs} and ξ_{mp} are amplifier coefficients, d_0 is the distance threshold, and the corresponding channel model is selected by the node according to the relationship between data transmission distances d and d_0.

When $l-$bit data is received by the sensor node, the receiving circuit is the only source of its energy consumption, so the energy consumption E_{Rx} of the receiving node is

$$E_{Rx}(l) = lE_{elec}. \tag{2}$$

In the data processing stage, data compressing is processed by sensor nodes to filter out the repeated useless data. In the data compression algorithm, the energy consumed by each node for compressing unit data is E_{DA}.

$$E_p = lE_{DA}. \tag{3}$$

3. Node Deployment Strategy

Sensor node deployment strategies are mainly divided into two categories: random deployment strategy and fixed deployment strategy. In the random deployment strategy, the sensor nodes are randomly deployed in the area to be monitored, and then, the optimization of the network is studied. In the fixed deployment strategy, the sensor nodes are deployed in the designated position of the area to be monitored according to the established strategy, and the optimization of the network is studied. In the actual environment, roads, rivers, mines, and other shapes can be regarded as linear areas. Considering the rules of linear region morphology comparison, fixed deployment strategy is adopted in this paper.

In order to facilitate subsequent research and analysis, the following assumptions are made here:

(1) Many sensor nodes and one basic sensor are contained in the network. The initial energy, sensing radius, communication radius, transceiver power, and data processing energy consumption of sensor nodes are all the same

(2) The sensing rate of sensor nodes for data within the sensing radius is 100%, and the sensing rate for data outside the sensing radius is 0%

(3) The energy consumption of sensor nodes mainly occurs in the data processing and transmission stage, without considering the energy consumption of nodes in sensing data

The monitored area is equally divided into a plurality of "X" partitions, as shown in Figure 1. The distance of each "X" partition is the same, and sensor nodes are deployed at the vertices and intersections of "X." The full coverage of the region can be realized by this step.

3.1. "X" Partition Coverage Strategy. The linear area which is monitored is partitioned based on the "X" shape, sensor nodes are deployed at boundary vertices, and intersections of "X" make the node position as the center of the circle and the sensing distance as the radius; the coverage area is the sensing area of each sensor node. The sensor nodes of four vertices at the boundary of the region and the center crossing position are included in each partition. As shown in Figure 2, A, B, D, and E are common sensor nodes, which are responsible for sensing surrounding data. In addition to sensing data, the sensor node at position C is also responsible for processing and transmitting data, which is called the master node.

The area sensed by the master node in the "X" partition and its ordinary node far away from the base station is divided into a monitoring unit; as shown in Figure 2, the area covered by circles A, B, and C is a monitoring unit, which ensures that the nodes transmit data towards the base station and redundant energy consumption can be avoided. The perceived information is transmitted to the master node by ordinary nodes in the monitoring unit, and then, the information is received by the master node, which obtains the data of the whole monitoring unit.

The length and width of the linear region are a, and the sensing radius of sensor nodes is r; the region is divided into "X" shape according to the value L, which can realize the full coverage of the network and minimize the number of nodes.

$$L = 2\left(r + \sqrt{r^2 - \left(\frac{b}{2}\right)^2}\right). \tag{4}$$

As shown in Figure 3, it is an "X" partition according to the distance L, with A, B, C, D, and E as five sensor nodes; A, B, D, and E are all located on the boundary of the region; and C is located on the center of "X." At this time, the intersection point H of circle A and circle C is located on one boundary of region, and the intersection point N of circle B and circle C is located on another boundary of region, and the circles A, B, and C just intersect at point M. Circle D and circle E are the same as circle A and circle B. Any point in the whole "X" partition can be sensed by sensor nodes. If $L > 2(r + \sqrt{r^2 - (b/2)^2})$, the intersection points of H and N are located within the boundary of the region, which leads to some regions not being sensed by any sensor nodes; that is, the full coverage of the network cannot be realized. If $L < 2(r + \sqrt{r^2 - (b/2)^2})$, although the network can achieve complete coverage, the deployment number of sensor nodes cannot reach the optimal value. Therefore, $L = 2(r + \sqrt{r^2 - (b/2)^2})$ is the best partition distance.

According to the previous definition of monitoring units, monitoring units are corresponded to "X" partition one by one, so when the network is fully covered, the number of monitoring units in the network is equal to the number of "X" partitions. The number of monitoring units in the network is $N_d = N_X = (a/L) = (a/(2(r + \sqrt{r^2 - (b/2)^2}))2(r$

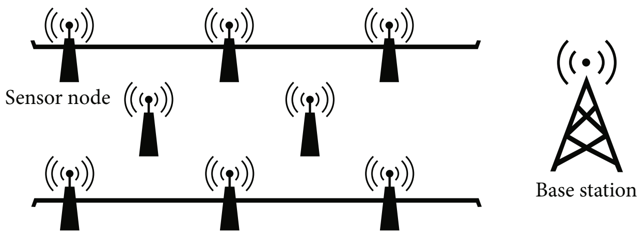

Figure 1: Node deployment model of linear area.

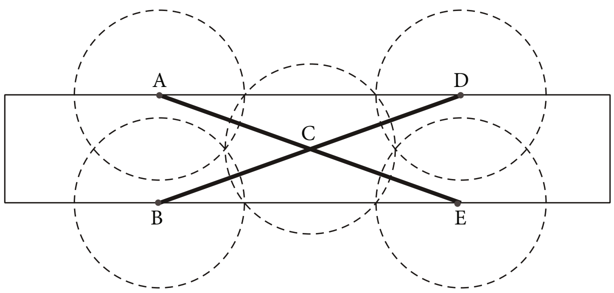

Figure 2: The deployment strategy of nodes based on "X" partition.

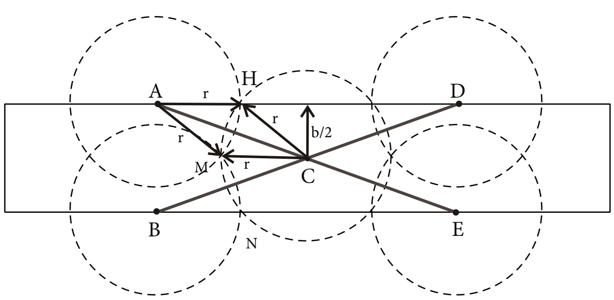

Figure 3: Node coverage effect diagram.

$+\sqrt{r^2-(b/2)^2}))$, the number of basic nodes needed to achieve full coverage of the network is $3a/L = (3a/(2(r+\sqrt{r^2-(b/2)^2}))2(r+\sqrt{r^2-(b/2)^2}))(a/L)$, the number of master nodes is a/L, and the master nodes are numbered $i = 1, 2, 3, \cdots, a/L$.

The dimensions of the wireless sensor network can be reduced by division of monitoring units from a two-dimensional plane area to a one-dimensional straight line. Based on the "X" partition, the size of all monitoring units is the same and all monitoring units are arranged in sequence. The data of the whole monitoring unit is stored in the master nodes, and the relative positions and distances of the master nodes in monitoring units are the same; that is, they are evenly distributed on a straight line. According to the distance from the base station, the monitoring units and master nodes are numbered. Data is transmitted to the base station through other master nodes in a multihop manner, and the problem of data return caused by the traditional clustering method is solved.

3.2. Data Compression. Sensing, processing, and transmitting are the functions of sensor nodes. And the energy consumption of data processing is much smaller than that of data transmission. Therefore, the energy consumption of the network can be balanced and the life of the network can be prolonged by processing the data before transmitting the data. Data compression is the main work of data processing; that is, sensor nodes compare and analyze the data they sense and receive, filter redundant data, and integrate main data. However, data compression is at the expense of the accuracy of data transmission to reduce the energy consumption of data transmission. Moreover, the more the data compression times, the greater the network delay. In the deployment strategy of nodes in WSN based on the "X" partition, each monitoring unit has a master node, and the number of sensor nodes is small. Data compression can be performed only inside the monitoring unit: after the data sent by the sensor nodes in the unit is received by the master node, it is integrated and compressed with the data sensed by the master node and then transmitted by multihop. Because the monitoring range of each monitoring unit is small and the sensing areas of each sensor node overlap, the principal component analysis method [15] is adopted in this paper to reduce data redundancy and compress data. The main process is as follows: in the monitoring unit, the data sensed by the nodes are sent to the master node and then received by the master node to generate corresponding data matrices. After analyzing and comparing these matrices, the principal components in the matrices are extracted and transmitted.

According to the energy consumption formula of the data compression, the compression energy consumption of each master node in the network is

$$E_p = 3lE_{DA}. \tag{5}$$

3.3. Network Energy Consumption Optimization. After the size of the monitoring unit and the number of the main node were determined, the network energy consumption is further optimized. In wireless sensor networks, the biggest energy consumption of nodes is in the data transmission stage. In a linear area, data is transmitted in multihops; there is a great relationship between energy consumption of nodes and the transmission step. By comparing the energy consumption under different transmission distances, the optimal value is selected to optimize the network energy consumption.

The distance d between two adjacent master nodes is taken as the basic step length for data transmission, and the step length is written as $D = nd(n = 1, 2, 3)$. Since the data has been compressed by each master node in the monitoring unit before data transmission, the energy consumption of each master node when transmitting data to the base station is the same under each step length, so it is only necessary to calculate the energy consumption E_i of the master node i acting as a relay node and the energy consumption ${E_k}^n$ of the whole network when $l-$bit data is transmitted to the base station by the No. 1 master node under different

Table 1: Sensor node parameter settings.

Parameter name	Numerical
Sense radius r	20 m
Initial energy E_0	0.5 J
Energy consumption per unit data transmission E_{elec}	50 nJ
Amount of data l	1200 bits
ξ_{fs}	$10\ \mathrm{pJ}\cdot\mathrm{bit}^{-4}\cdot\mathrm{m}^{-2}$
ξ_{mp}	$0.0013\ \mathrm{pJ}\cdot\mathrm{bit}^{-4}\cdot\mathrm{m}^{-2}$
E_{DA}	50 pJ

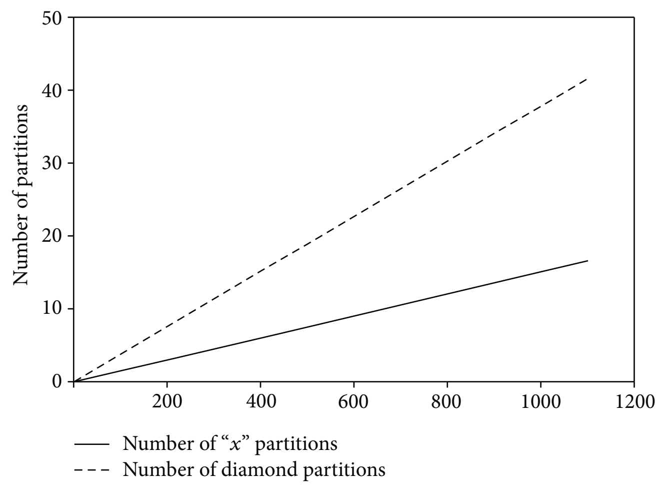

Figure 4: Relationship between the number of nodes and the length of regions.

step values n, and then, the optimal step value can be selected.

$$n=1, E_i = E_{RX}(l) + E_{TX}(l,d), E_k{}^1 = (m-1)\left(2lE_{\mathrm{elec}} + l\xi D^{t\cdot}\right),$$
$$n=2, E_i = E_{RX}(l) + E_{TX}(l,2d), E_k{}^2 = \left\lfloor \frac{(m-1)}{2} \right\rfloor \left[2lE_{\mathrm{elec}} + l\xi D^{t}\right],$$
$$n=3, E_i = E_{RX}(l) + E_{TX}(l,3d), E_k{}^3 = \left\lfloor \frac{(m-1)}{3} \right\rfloor \left[2lE_{\mathrm{elec}} + l\xi D^{t}\right]. \tag{6}$$

Derive the formula for selecting the available step length:

$$n = \{n \mid \min \mathrm{E}_k{}^n\},$$
$$E_k{}^n = \left\lfloor \frac{\left(\left(a/2\left(r+\sqrt{r^2-(b/2)^2}\right)\right)-1\right)}{n} \right\rfloor \left[2lE_{\mathrm{elec}} + l\xi (nd)^t\right], \tag{7}$$

where the value t depends on ξ and ξ is related to the value n .

After the transmission step is determined, when the data of the i-th master node is transmitted to the base station for each round of data transmission, the energy consumption of the network is

$$E_k{}^n(i) = \left\lfloor \frac{\left(\left(a/\left(2\left(r+\sqrt{r^2-(b/2)^2}\right)\right)2\left(r+\sqrt{r^2-(b/2)^2}\right)\right)-i\right)}{n} \right\rfloor \cdot \left[2lE_{\mathrm{elec}} + l\xi (nd)^t\right]. \tag{8}$$

The sum of transmission energy consumption of each master node in the network is the total energy consumption $E_{\mathrm{total}}{}'$ of transmission in the network; then,

$$E_{\mathrm{total}}{}' = \sum_{i=1}^{a/\left(2\left(r+\sqrt{r^2-(b/2)^2}\right)\right)} E_k{}^n(i). \tag{9}$$

For comprehensive data compression and data transmission, the total energy consumption E_{total} of the network is

$$E_{\mathrm{total}} = E_{\mathrm{total}}{}' + \frac{a}{2\left(r+\sqrt{r^2-(b/2)^2}\right)} E_p. \tag{10}$$

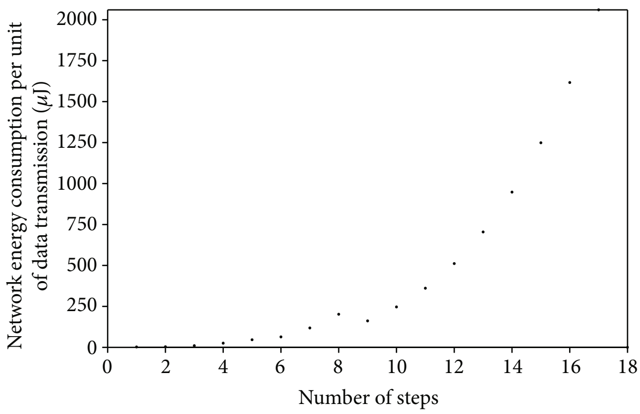

Figure 5: Relationship between energy consumption per unit data transmission and step length.

Table 2: Partition effect based on "X" partition deployment strategy and diamond partition deployment strategy.

Deployment strategy	Number/number of network partitions (clusters)	Number of network nodes	Partition distance d (m)
X-shaped partition	18	54	66
Diamond partition	20	60	60

3.4. Deployment of Spare Nodes. In order to ensure the life and performance of the network, spare nodes are properly deployed for each master node according to its energy consumption. Because the energy consumption of the master node in the network is related to the hop count j, $j = i/n$, the later the hop count, the greater its energy consumption. Under a certain step length, the life of the whole network is equal to that of the master node in the last hop [9]. The energy consumption E_i of each master node in the network is

$$E_i = E_{RX}(l) + E_{TX}(l, d) = (i-1)lE_{\text{elec}} + ilE_{\text{elec}} + il\,\xi d^t. \quad (11)$$

Therefore, the closer the energy consumption of the master node that initially transmits information is to that of the master node in the last hop, the more balanced the network energy consumption is. That is, the smaller the value of$|E_1 - E_{a/L}|$, the more balance the network energy consumption and the longer its life. The formula for calculating the number of spare nodes of each master node is [9]

$$\text{Num}_i = \frac{E_i}{E_1}. \quad (12)$$

3.5. Steps of Node Deployment. Assuming that the base station is on the right side of the linear area, the specific steps of the deployment strategy of nodes in WSN based on the "X" partition are as follows:

Table 3: The number of spare nodes of each master node.

Node number	Number of spare nodes	Node number	Number of spare nodes
1	0	10	5
2	1	11	6
3	1	12	6
4	2	13	7
5	2	14	8
6	3	15	8
7	4	16	9
8	4	17	9
9	5	18	10

(1) The linear area to be monitored is initialized, and its length is a, width is b, and node perception radius is r

(2) The linear area is divided into "X" partitions by length $L = 2(r + \sqrt{r^2 - (b/2)^2})$, so as to realize the full coverage of the network

(3) The divided "X" partitions are divided into monitoring units, and the master nodes in each monitoring unit are numbered $1, 2, 3, 4 \cdots \cdots, i$ from left to right

(4) The optimal step size n of data transmission and network energy consumption E_{total} are calculated

(5) The position j of each master node in the transmission path is calculated

(6) Sensor nodes and spare nodes are deployed in the linear area to be monitored based on the "X" partition strategy

(7) Run the network; when the energy of the master node is unavailable, replace it with a spare node

4. Experiment and Analysis

4.1. Experiment Environment and Parameter Setting. In order to verify the rationality of this method, *Python 3.7* is used for simulation experiment, ignoring packet loss and other problems in the process of data forwarding, comparing with diamond partition strategy. All experimental environments assume that the signal transmission range of sensor nodes is a regular circle. In order to ensure the accuracy of the experiment, all data adopt the average value of 20 rounds of experimental data. The nodes are initially randomly distributed in the monitoring area, and the number of nodes is 70. The parameters of the sensors used in the experiment are shown in Table 1. Transmission threshold $d_0 = 87$.

4.2. Analysis of Network Cost. In practice, the number of network partitions is directly affected by the length of the area to be monitored. The width of the area to be monitored and the sensing radius of the sensor nodes are set as fixed values. According to formula (4), the number of partitions

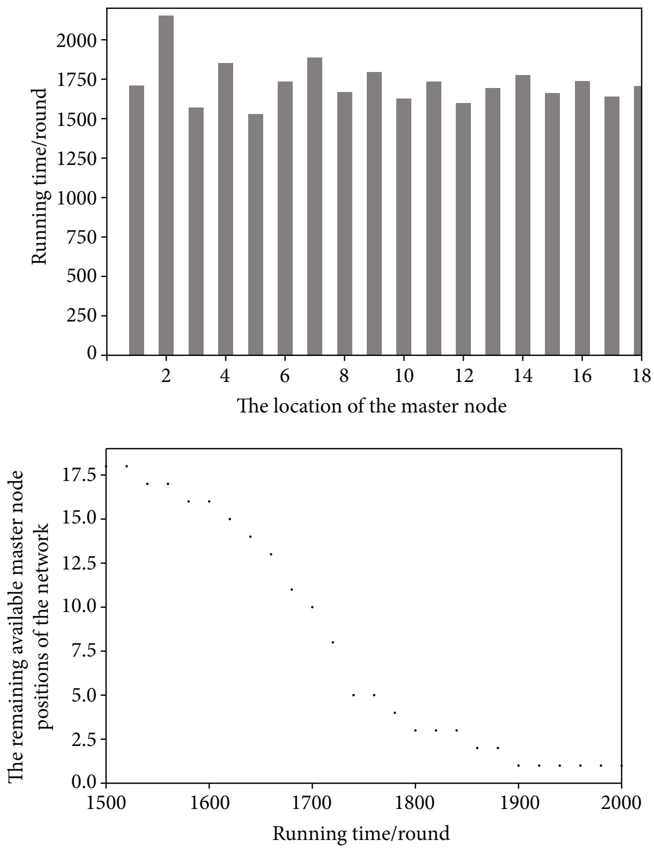

Figure 6: The life of master nodes in network.

obtained by the "X" partition deployment strategy and the diamond partition strategy is compared under different region lengths. As shown in Figure 4, the number of partitions based on the "X" partition deployment strategy is significantly less than the diamond partition, and the difference between the two strategies is more significant with the increase of the length of the area to be monitored. When the length of the area to be monitored is long, it is more suitable to choose the "X" partition deployment strategy for network deployment. At this time, the number of basic sensor nodes needed to achieve complete network coverage is less than that of the diamond partition deployment strategy; that is, the cost of network deployment is lower.

In the traditional diamond partition deployment strategy, after partitioning the area to be monitored, it is necessary to calculate the optimal cluster spacing and the location of cluster nodes, so that sensor nodes are often deployed according to the approximate value of the optimal solution instead of the optimal solution. However, in the "X" partition deployment strategy, the nodes can be only deployed according to the partition location and then filter out the master nodes.

4.3. Analysis of Network Energy Consumption. In the experiments, the length and width of the area to be monitored are set as 1200 m and 30 m, respectively, and the number of basic sensor nodes needed under the "X" partition deployment strategy and diamond partition strategy is shown in Table 2.

Based on the "X" partition deployment strategy, 18 monitoring units are divided in the area to be monitored, and the master nodes are numbered as $i = 1, 2, 3, \cdots, 18$. Then, the optimal step length of data transmission is calculated according to the selected function of transmission step length. The network energy consumed of the No. 1 master node in transmitting data under different step lengths is shown in Figure 5, so the optimal transmission distance is 66 m, that is, $n = 1$.

According to the experiment in reference [2], the data transmission effect is best when the area to be monitored is divided into 20 clusters in the experimental environment set in this paper; that is, the optimal distance of data transmission in the network is 60 m.

The energy consumption of the network can be directly reflected by the energy consumed by each round of data transmission in the network. According to the selected optimal data transmission distance, the energy consumed by the network for one round of data transmission under different deployment strategies is calculated. In the "X" partition deployment strategy, the data in the monitoring unit is firstly compressed by the master node. According to the energy consumption formula of data compression, 324 nJ energy will be consumed by the master node for each round of network operation. According to the energy consumption

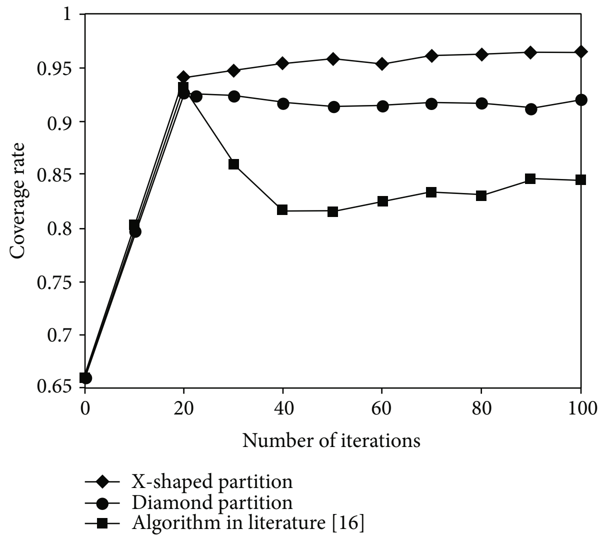

Figure 7: The coverage rate comparison results of different algorithms.

formula of data transmission, the energy consumed by the network for data transmission is 26357616 nJ. In the "X" partition deployment strategy, the total energy consumption of the network is 26360856 nJ. In the diamond partition deployment strategy, the energy consumption of each round of network processing is 8252400000 nJ, which is much higher than the "X" partition deployment strategy.

4.4. Life of Network. The life of network is another important basis for measuring network performance. The number of spare nodes required by the network is calculated according to Equation (12). At first, the energy consumption of the No. 1 master node in the basic network is calculated to be 1710.74 nJ per round, and then, the number of spare nodes to be deployed near each master node is obtained, as shown in Table 3.

Based on the "X" partition deployment strategy, nodes are deployed in the area to be monitored to form a network. And the life of nodes is calculated in the network, as shown in Figure 6. When more than one-third of the nodes in the network run out of energy, the network performance will decrease sharply; that is, the life of the network is exhausted. It can be seen from Figure 6 that under this deployment strategy, the life of each master node in the network can reach 1500 rounds. On the premise of ensuring the network performance, the network can run more than 1650 rounds at most; that is, the life of the network exceeds 1650 rounds. Under the same experimental environment, the network composed of diamond partition deployment strategy can run for 1000 rounds. Therefore, the network life of the strategy proposed in this paper is superior to the diamond partition strategy.

4.5. Connectivity Rate and Coverage Rate. Wireless sensor network coverage must consider multiple performance indicators in order to make network coverage more reliable and effective, including coverage rate, connectivity rate, energy consumption, signal strength, fault tolerance, scalability, and reliability.

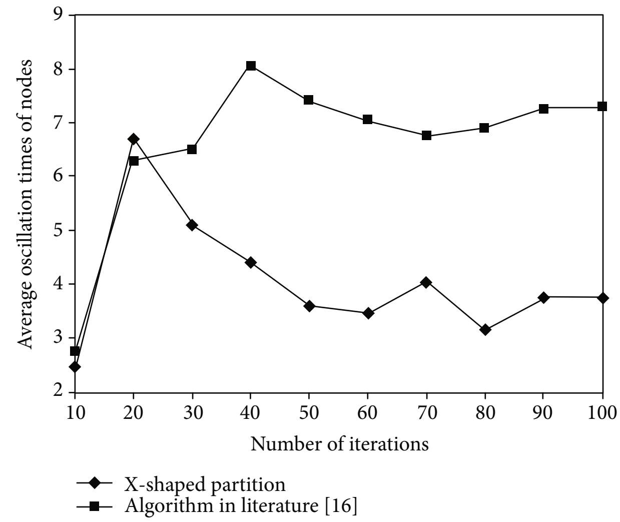

Figure 8: Average oscillation times of nodes.

Table 4: Partition effect based on the "X" partition deployment strategy and diamond partition deployment strategy.

	$t = 20$	$t = 40$	$t = 60$	$t = 80$	$t = 100$
X-shaped partition	1.37%	3.76%	9.54%	4.66%	4.51%
Diamond partition	7.72%	13.38%	13.68%	13.18%	11.77%

During the experiment, Monte Carlo method is used to calculate the area coverage to measure the coverage ability of three algorithms (X-shaped partition, diamond partition, and the algorithm in literature [16]). The comparison results are shown in Figure 7.

When the number of iterations is $t < 20$, it can be seen from Figure 7 that the coverage rate of the X-shaped partition in this paper is similar to that in the diamond partition and literature [16]. When the number of iterations is $20 \leq t \leq 40$, many nodes of the algorithm in literature [16] oscillate back and forth. The number of node oscillations is shown in Figure 8.

The algorithm in literature [16] did not analyze and deal with the problem of continuous oscillation of nodes in detail, resulting in slow and unstable convergence speed of the algorithm, and the regional coverage decreased.

Table 4 shows the change of coverage growth rate of the X-shaped partition in this paper compared with the diamond partition with the number of iterations.

When the number of iterations of the algorithm is $20 \leq t \leq 60$, most nodes are in the optimization state. The growth rate of the coverage of the X-shaped partition in this paper is larger than that of the diamond partition. When the number of iterations $t > 60$, the coverage algorithm basically tends to be stable. Therefore, the growth coverage rate of the X-shaped partition is slower than that of the Diamond partition.

The focus of this paper is how to balance the network load and improve the network lifetime through the deployment strategy of nodes. However, this paper does not use the previous method of calculating the distance according to the received signal strength but only determines the angle of nodes in different center coordinate systems according to the signal strength, which will lead to low positioning accuracy and complex mobile path and positioning methods.

5. Conclusions

In this paper, a deployment strategy of nodes in WSN based on the "X" partition is proposed, the linear area is equally divided into some "X" partitions, and the sensor nodes are deployed at fixed positions to achieve full coverage of the area to be monitored. According to the position of the node and base station, the monitoring unit is divided, the master node is determined, and the data is compressed by the master nodes in the monitoring unit; then, the data is transmitted, so as to balance the network load and improve the utilization of the network. According to the difference of node energy consumption, spare nodes are deployed to prolong the life of the network. Through theoretical analysis and experimental verification, the deployment cost of the network can be effectively reduced in the "X" partition deployment strategy and the life of the network can be prolonged. The aim of subsequent research is reducing the network delay and transmission accuracy caused by data compression in this deployment strategy.

Data Availability

The basic data used in this paper can be downloaded from https://gitee.com/hwang_zc/asdasd/blob/master/dataset.csv.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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