The Maximum Coverage Set Calculated Algorithm for WSN Area Coverage

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***Abstract*—The Coverage Control Technology is one of the basic technologies of wireless sensor network, and is mainly concerned about how to prolong the network lifetime on the basis of meeting users' perception demand. Among this, in the study of area coverage, the set K-cover algorithm is broadly accepted because that it can prolong network lifetime rather well. However, maximum set covers problem is proved to be NP-Complete. At the same time, the existing set K-cover algorithms are centralized, and can not adapt to the large-scale sensor network applications and expansion. So, how to get the maximum coverage set number and realize node set division by distributed algorithm is becoming the problem of people attention. Thus, this paper firstly utilizes node minimum layer overlapping subfield to find out area minimum coverage value, as the upper limit of coverage node set's number. On the basis of this maximum, it put forward to way of dividing node set. Secondly, the maximum coverage set number calculated algorithm is proposed. Simulation result shows the distributed algorithm MCNCA is very effective.**

***Index Terms*—Wireless Sensor Network, Area Coverage, Set K-Cover algorithm, Maximum coverage set, Node minimum layer overlapping subfields**

I. INTRODUCTION

In wireless sensor networks, due to single sensor node's limited perception ability, the technology, which effectively and reasonably organizes node collaboration and realizes expected perception demands, is called coverage control technology. It is the basic technology of wireless sensor networks, directly reflecting quality of service of wireless sensor network's sense service to the environment. Because of limited energy of single sensor node, how to save energy and prolong the network lifetime at the same time of meeting user sense demand is the key point of the design of wireless sensor networks coverage control technology [1, 2, 3, 6]. For the wild scenes, special environment like desert or battlefield, way of randomly spreading redundant nodes in designated area is often applied to initial deployment [4, 5, 7, 8]. Therefore, when area coverage algorithm is being designed, both of the realization of full area coverage by wireless sensor networks, which avoids appearance of coverage holes to ensure sense service quality, and the extension of network lifetime by energy-saving mechanism such as sleep schedule, making use of redundancy characteristic of sensor nodes, are expected.

In order to satisfy the demand mentioned above, set K-Cover algorithm is broadly accepted because it can prolong network lifetime rather good. It divides all the nodes into K different coverage node set and every coverage node sets can cover the whole area. These coverage node sets work alternately and implement area monitoring. Because lifetime of one coverage set is the same as lifetime of the original network, K coverage sets can prolong network lifetime for K times. Thus, not only user sense demand can be satisfied to realize overall coverage, but also network lifetime can be prolonged. However, maximum set covers problem is proved to be NP-Complete. At the same time, the existing set K-Cover algorithms are centralized, not suitable for the application and the expansion of large-scale wireless sensor network [6-8]. Furthermore, in area coverage problem, existing set K-cover algorithm concerned about how to divide the coverage set based on the maximum coverage set number known. They ignore to how to calculate the maximum coverage set number. But, in area coverage, the calculation of maximum coverage set number is very difficult and it is the base of coverage set division. Therefore, how to calculate the maximum coverage set number and realize node set division by distributed

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algorithm based on localized information is becoming focus of attention.

According to the analysis mentioned above, this paper firstly utilizes node minimum layer overlapping subfield to find out area minimum coverage value, as the upper limit of coverage node set's number. On the basis of this maximum, it put forward to way of dividing node set. At the same time, the distributed algorithm MCNCA is proposed to calculate the maximum coverage set number

In this paper, the application of existing set K-Cover algorithms in wireless sensor network is introduced in section 2; in section 3, a way of computing the maximum number of K-Cover set number and the method of dividing node sets is presented; in section 4, one maximum coverage set number calculated algorithm (MCNCA) is proposed. In section 5, performance of the algorithm is analyzed by simulation experiment; in the last section, conclusion of this paper is given.

II. Related Work

Cardel et al address the target coverage problem in wireless sensors [9]. They propose a method to extend the sensor network life time by organizing the sensors into a maximal number of set covers that are activated successively. Only the sensors from the current active set are responsively for monitoring all targets and for transmitting the collected data, while all other nodes are in a low-energy sleep mode. They model the solution as maximum set covers problem and design two heuristics that compute the sets, using linear programming and a greedy approach. Further, they address the target coverage with adjustable sensing range [10]. Communication and sensing consume energy, therefore, efficient power management can extend network lifetime. They consider a large number of sensors with adjustable sensing range that are randomly deployed to monitor a number of targets. Since targets are redundantly covered by more sensors, in order to conserve energy resources, sensors can be organized in sets, activated successively. They address the Adjustable Range Set Covers (AR-SC) problem that has as its objective finding a maximum number of set covers and the ranges associated with each sensor, such that each sensor set covers all the targets. A sensor can participate in multiple sensor sets, but sum of the energy spent in each set is constrained by the initial energy resources. They mathematically model solutions to this problem and design heuristics that efficiently compute the sets.

The algorithms mentioned above are solution to disperse target coverage problem. In area coverage problem, Slijepcevic et al formally give definition of K-Cover problem and point out that K-Cover set division is a NP problem [11]. In their paper, a centralized heuristic algorithm is applied to divide the coverage set. Honghai Zhang et al propose a-lifetime concept [12]. They give the time duration during which at least a portion of the surveillance area is covered, and use centralized algorithm to find minimum a-coverage node set among remained nodes, which can satisfy maximum of a-lifetime upper limit. All the algorithms mentioned above maximize the number of coverage node set and prolong network lifetime as far as possible on the basis of ensuring area overall coverage.

Abrams et al try to maximize the coverage subject to a lifetime requirement K, called set K-cover problem [13]. Set K-cover problem is also proved to be NP-complete. The authors provide three algorithms to solve this problem: (1) random algorithm, (2) distributed greedy algorithm, (3) global greedy algorithm. In the random algorithm, each node randomly chooses a cover set. This simple algorithm is very robust. However, the coverage performance is not very good. In the distributed algorithm, each node makes its decision sequentially, according to their ID numbers. A node chooses the cover in which it can maximally increase the total coverage, based on the decisions of previous nodes. This algorithm is also very simple and can provide fairly good coverage performance. However, it has several problems. First, each node only makes a decision once. This decision depends on prior decisions already made by nodes with smaller IDs. Therefore, the performance of the solution depends on what order the nodes execute the algorithm. This can result in very poor performance in low density networks. Second, since the running time is linear in N, the algorithm can take a long time to run in large scale networks. Third, the algorithm is not really based on local information, since each node needs to wait for the decisions made by all other nodes prior to it. Finally, the algorithm requires synchronization for its execution.

Xin Ai et al firstly use game theory to solve problem of K-Cover set, take maximization of network lifetime as node's rational favor, propose distribution algorithm, which maximizes node set coverage area in the situation of knowing lifetime and test algorithm coverage performance in different K-Cover set [14, 15]. However, this algorithm has many limitations. Firstly, network lifetime is related to number of coverage node sets. Number of coverage node set must be decided through other methods and the algorithm can't decided by itself, which won't be applied to reality. Secondly, the algorithm aims at enlarging network lifetime, and in the situation of knowing number of coverage sets, enlarging coverage area as far as possible and can't realize area overall coverage, which runs counter to user sense demand of overall coverage in the real area's monitor application. Besides, the algorithm is only to easily set node parameters and can't keep a balance between network node density and coverage sets number to optimize network coverage area. At last, this algorithm uses node's exposed area as payment function. The calculation in the real application is complicated with low precision and is hard to be realized.

Through analysis mentioned above, in area coverage problem, existing set K-cover algorithm concerned about how to divide the coverage set based on the maximum coverage set number known. They ignore to how to calculate the maximum coverage set number. But, in area coverage, the maximum coverage set number is difficult to calculate and it is the base of coverage set division. So, this paper uses the concept of node minimum layer overlapping subfield to find the minimum coverage layer number as the maximum number of coverage node sets.

III. Division of K-Cover Set

Network lifetime is related to node set number and K coverage sets can prolong network lifetime for K times. The bigger node set number is, the longer network lifetime is. However, network lifetime must be based on meeting user's sense demand. In area coverage, user sense demand is area overall coverage. Therefore, this paper realizes division of node set on the basis of ensuring area overall coverage. Thus, this section introduces the concept of minimum layer overlapping subfields (MLOF); then provides the way to compute maximum of cover set number and divide coverage set.

A. Minimum layer overlapping Subfield (MLOF)

This paper uses concept of minimum layer overlapping subfields (MLOF) to implement calculation of area minimum coverage layer number (AMCLN) and division of coverage node sets. At the same time, searching and calculating method of MLOF is provided, which is easier and more exact compared with circle exposed area provided by Xin Ai et al.

Definition1. Node sense circle, namely, circle with node as its center, and node sense radius as its radius is called node sense circle, which represents node sense range.

Definition2. Node overlapping fields, namely, if two or more nodes sense circles are intersected, the overlapping range is called node overlapping field.

As is shown in Fig. 1, the overlapping field of node1 and node3 is the area consisting of subfields 1, 2, and 3 in area A.

Definition3. Minimum layer overlapping subfields (MLOF): overlapping field of two nodes may be covered or cut into different subfields by other node sense circles. Every subfield is covered by different number of nodes, which is countered as this subfield's coverage layer number. Take the subfield with the minimum coverage layer number as two nodes' minimum layer overlapping subfield (MLOF).

As is shown in Fig. 1, the overlapping field of node1 and node3 in area A is separately cut into subfield 1, 2, 3 by node2 and node5's sense circles. Among them, subfield 1 is covered by node 1, 2, 3 and its coverage layer number is three; in the same way, subfield 2's coverage layer number is four and subfield 3's coverage layer number is three. Therefore, subfield 1 and subfield 3 are node1 and node3's MLOF. It also can be seen from this that, two nodes' MLOF is not unique.

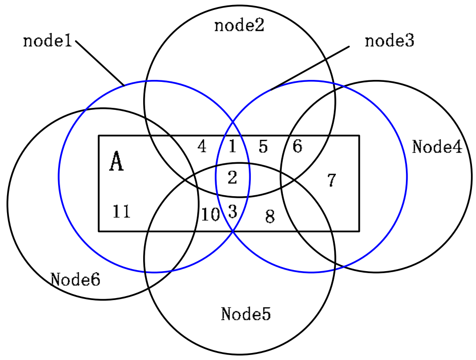

Figure 1. Node deployment in area A

The calculation method of coverage layer number of node i and node j's MLOF is as follows:

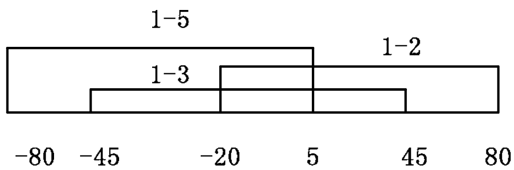

Figure 2. MLOF of node1 and node3

(1) According to neighbor node's state information and sense radius, node can find out two intersections with neighbor node sense circle, then calculate clockwise angle of the line connecting intersection and circle center and the horizontal line, namely, α,β;$0<=\alpha,\beta<=180^0$. Fig. 2 shows node1 and neighbor nodes 2, 3, 5's angle. For example, 1-3 shows node1 and node3's two angles, α β, are separately $-45^0$and 45^0.

(2) In all of node i's neighbors, conserve angles between two angles of node i and node j. For example, the angles of node1 and node5 and of node1 and node2 between angles of node1 and node3 are $-20^0$and 5^0. Then arrange these angles from the smallest to the biggest. The sequence is as shown in Fig. 2, which is [-45^0,-20^0, 5^0,45^0], and the range between -45^0 and 45^0 is cut into many small ranges.

(3) Aiming at each small range, set a counter. For any of node i's neighbors, if its two angles cover the range, then add 1 to the counter. As is shown in Fig. 2, counting value between [-45^0,-20^0] is 2.

(4) Find out the minimum counting value and add 1 to it among all the ranges and that is converge layer number of node i and node j's MLOF. For example, counting value of [-45^0,-20^0] and [5^0,45^0] are the minimum and equal 2. Then, coverage layer number of node 1 and node2's MLOF is 3.

B. Maximum number of K-Cover sets

In this section, on the basis of MLOF, maximum of K-Cover set number is calculated.

Definition4. Area minimum overlapping subfields: monitored area is cut into different subfields by sense circles of sensor nodes deployed on it. Among them, MLOF with the minimum coverage layer number is called area minimum overlapping subfields.

As is shown in Fig. 1, area A is cut into many small subfields by nodes deployed on it and these subfields also belong to node's overlapping fields. Layer number of node1 and node3's MLOF whose id are 1,3 is 3, layer number of node1 and node6's MLOF whose id is 11 is 2, layer number of node3 and node4's MLOF whose id is 7 is 2,etc. It can be known by comparison that smallest layer number of all nodes' MLOF in the area is 2. So, all the subfields with 2 layers, as subfields 4, 5,7,8,10,11 etc, are called area A's area minimum overlapping subfields.

Definition5. Area minimum coverage layer number (AMCLN): the coverage layer number of area minimum overlapping subfields is called Area minimum coverage layer number.

As is shown in Fig. 1, layer number of area A's minimum overlapping subfield is 2, then AMCLN is 2.

In area coverage control technique, if AMCLN is bigger than 1, then sensor nodes deployed on area can be divided into different independent coverage node sets and each coverage node set can cover overall area. These coverage node sets are not crossed, namely, don't contain the same node. Each coverage node set works independently and runs alternately, leading to the result of prolonging overall network lifetime. Number of maximum coverage node set that can be divided is decided by theorem1.

Theorem1. Maximum of K-Cover set number theorem: If an area is multi-layer covered by sensor nodes deployed on it and sensor nodes can be divided into different coverage node sets, there exists at least one division of coverage node sets, which makes each coverage node set can cover the overall area and number of divided coverage node sets must be smaller or equal to coverage layer number of area minimum overlapping subfields.

[Proof] If all the sensor nodes deployed in the area are divided into different node sets, and each node set can cover the overall area, then in order to avoid appearance of coverage holes, it is asked that any point in the area must be covered by at least one node in each node set. As to AMCLN, it reflects number of sensor nodes, which can cover any point in the area. If coverage set number is not over AMCLN, then sensor nodes corresponding to any point can be evenly distributed to each coverage set. Thus, each coverage set can cover all the points in the area, realizing area overall coverage. AMCLN is decided by area minimum overlapping subfields. Thus, as long as number of divided coverage node sets does not over the coverage layer number of area minimum overlapping subfields, then it can be ensured that every coverage node set can cover the whole area.

Application of apagoge can prove that number of divided coverage node sets must not be bigger than the coverage layer number of area minimum overlapping subfields and its proof is as follows:

Suppose there exists a division, which makes coverage node set number bigger than coverage layer number of minimum overlapping subfields in the area, and each coverage node set can still realize overall coverage. It can be known from definition 4 that, coverage layer number of area minimum overlapping subfields reflects number of sensor nodes, which cover this subfield. If the number is smaller than number of divided coverage node sets, then it shows that at least in more than one coverage set there doesn't exist node that covers the subfield, leading to coverage holes will be led. It is in contradiction to the assumption.

From this, correctness of the theorem is proved. [The proof is over]

For example, according to theorem1, in Fig. 1, the maximum of coverage sets that all the sensor nodes can be divided is 2 in area A.

C. Way of Dividing Node Set

When maximum of node set number is known, how to according to known set number divide nodes into each node set is proved to be a NP problem [7]. This paper can through lemma1 seek an optimal way of dividing node sets.

Lemma1. If an area is multi-layer covered by sensor nodes deployed on it and coverage layer number of area minimum overlapping subfields is taken as maximum of node coverage set number, then division of nodes covering all nodes MLOF into each node set can ensure each node set cover the overall area.

[Proof] It can be known from definition4 that, the coverage layer number of area minimum overlapping subfields is minimum value of all nodes MLOF. Therefore, aiming at each node MLOF, numbers of nodes covering on it are all not smaller than number of divided coverage node sets. If these nodes are evenly distributed in each node set, then node MLOF can be covered by each node set. According to definition3, node MLOF is node overlapping field covered by the fewest nodes, that is, node set covering on node MLOF is subset of node set covering on node overlapping fields. Thus, each node overlapped fields can also be covered by each node set. The area consists of overlapping fields of all nodes, so, the area can be covered by each node set. [The proof is over]

Maximum Coverage Set Number Calculated Algorithm (MCNCA). According to theorem1, calculating AMCLN and getting maximum coverage node set number in the situation where area overall coverage is ensured, so as to determine maximum network lifetime.

IV. Maximum Coverage Set Calculated Algorithm

This algorithm uses node local information which is already known to seek MLOF formed by node and its all neighbor nodes. Through exchange of information with neighbor nodes, seeking AMCLN in the way of distribution, and takes it as maximum coverage node set number based on area overall coverage. Theorem1 ensures correctness of this algorithm.

The algorithm is proposed in two solutions: centralized solution and distributed solution.

The centralized solution is executed at the Base station. Base station computes and broadcasts back the sensor schedules. This solution is as follows.

Algorithm Centralized Maximum Coverage Set Number Calculated Algorithm

```
Begin
    1: Get neighbor node set to each node;
    2: Set up MLOF set to each node;
    3: Seeking minimum coverage layer number to each
       node;
    4: Seeking minimum value in all nodes.
End
```

The minimum value is maximum coverage set number. This solution is simply, but, it can not adapt to the large-scale sensor network applications and expansion. So, we propose a distributed solution MCNCA. The performance analysis in section V is also aiming to MCNCA. In this distributed and localized algorithm, each sensor node determines its schedule based on communication with one-hop neighbors. This solution is as follows.

Algorithm Maximum Coverage Set Number Calculated Algorithm (MCNCA)

```
Begin
  1 set up neighbor node set N
    1) Broadcasting Hello message；
    /* this message contains <node identifiers, position> */
    2) Receiving neighbor nodes state messages；
    /* this message contains <neighbor node identifiers, position> */
    3) set up neighbor node set N;
  2 set up MLOF set M
    For ( p ∈ N ) Do
      1) Seeking MLOF formed by this node and neighbor
         node p;
      2) add coverage layer number and coverage node set
         corresponding MLOF into M;
    EndFor;
  3 Seeking minimum coverage layer number and store it
    into variable Cmin;
  4 Broadcasting Cmin value；
  5 set timer counter Tr；
  6 Get AMCLN
    while (Tr is not expire) Do
      1) receiving neighbor minimum coverage layer
         number and store it into variable Cmin'；
      2) IF If Cmin' < Cmin Then
           Cmin= Cmin';
           broadcasting Cmin value;
         EndIf;
    EndWhile;
End.
```

The algorithm uses distributed method to make every node get area minimum coverage layer number by constant exchange of minimum value information. Among it, setting of receiving time period Tr is decided by the number of network node message iterations. It is seen in section VI. Besides, if network scale is rather small, centralized algorithm can also be considered. All nodes will send their own minimum values to sink node through route algorithm, let sink node calculate minimum value of them and broadcast it to all nodes. We only discuss the distributed algorithm MCNCA in next section.

V. Performance Analysis

This section carries out performance analysis for the algorithm by simulation. Suppose node sensing radius r_s is 10m, radio radius is 20m. Thus network node connectivity can be ensured based on area overall coverage. In order to eliminate marginal effect, randomly deploy n nodes in the area $(50+2r_s)*(50+2r_s)m^2$. When analyzing performance, only consider the central 50m*50m area. Node number n are separately 98、147、196、245、294.

A．Maximum Coverage Node Set Number

Firstly, we analyze the max coverage set number in different network node densities. So, Separately in the situation where node number n is 98、147、196、245、294, carry out algorithm MCNCA. Node sensing radius r_s is 10m. Seek maximum node set number that can be divided in different network node densities based on area overall coverage.

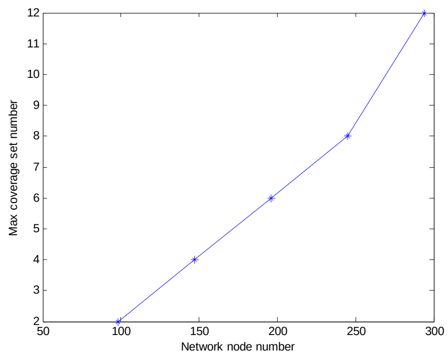

Figure 3. Maximum node set number divided n different network density

Simulation result is shown in Fig. 3, this result is the same as that of centralized algorithm, it can be known from the figure that, number of nodes in the network is in turn 98、147、196、245、294, corresponding maximum node set number are 2、3、6、8、12. Therefore, with the constant increase of network node density, in the situation of containing area overall coverage, maximum node set number that can be divided is multiplied. That is, if network node density becomes bigger, it's overlapping layer number in the area also increase quickly.

Secondly, we analyze the max coverage set number in different node sensing radius. So, Separately in the situation where node sensing radius r_s is 10m、15m、20m、25m、30m, carry out algorithm MCNCA. The number of nodes in the network is 98.Seek maximum node set number that can be divided in different node sensing radius based on area overall coverage.

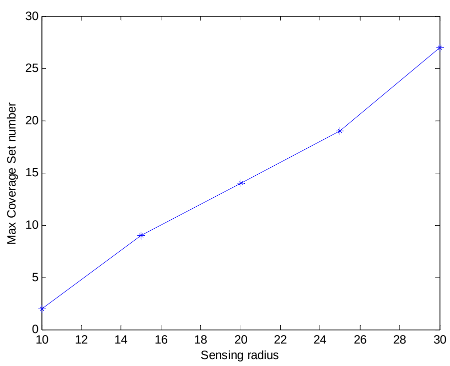

Figure 4. Maximum node set number divided in different node sensing radius

Simulation result is shown in Fig. 4, it can be known from the figure that, node sensing radius is in turn 10m、15m、20m、25m、30m, corresponding maximum node set number are 2、9、14、19、27. Therefore, with the increase of node sensing radius, in the situation of containing area overall coverage, maximum node set number that can be divided is multiplied. That is, if node sensing radius becomes bigger, it's overlapping layer number in the area also increase quickly.

Because node set number is directly proportional to network lifetime. Suppose initiate network lifetime is T, then each coverage node set lifetime is also T., These coverage node sets work alternately and K coverage node sets prolong network lifetime for K times.

B．Iterations for distributed algorithm MCNCA

For algorithm MCNCA, Tr is decided by the number of network node message iterations. We analyze the impact on iterations for network node densities and node sensing radius.

Firstly, we analyze the number of network node message iterations in different network node densities. So, Separately in the situation where node number n is 98、147、196、245、294, carry out algorithm MCNCA. Node sensing radius r_s is 10m. Seek the number of network node message iterations in different network node densities based on area overall coverage.

TABLE I.
THE NUMBER OF NETWORK NODE MESSAGE ITERATIONS IN DIFFERENT NETWORK NODE DENSITIES

N	98	147	196	245	294
Iterations	2	1	2	1	2

Simulation result is shown in Table1, it can be known from the table that, number of nodes in the network is in turn 98、147、196、245、294, corresponding the number of network node message iterations are 2、1、2、1、2. That is, the number of iteration is small. So, the impact on iterations for network node densities is less.

Secondly, we analyze the number of network node message iterations in different node sensing radius. So, Separately in the situation where node sensing radius r_s is 10m、15m、20m、25m、30m, carry out algorithm MCNCA. The number of nodes in the network is 98.Seek the number of network node message iterations in different node sensing radius based on area overall coverage.

TABLE II.
THE NUMBER OF NETWORK NODE MESSAGE ITERATIONS IN DIFFERENT NODE SENSING RADIUS

Radius	10	15	20	25	30
Iterations	1	2	2	1	1

Simulation result is shown in Table2, it can be known from the table that, node sensing radius is in turn 10m、15m、20m、25m、30m, corresponding the number of network node message iterations are 1、2、2、1、1. That is, the number of iteration is small. So, the impact on iterations for node sensing radius is less.

Finally, for node random deployment, we analyze the number of network node message iterations to different network node deployment situation. The number of nodes in the network is 98, and node sensing radius r_s is 10m.

TABLE III.
THE NUMBER OF NETWORK NODE MESSAGE ITERATIONS BY REPEAT OPERATION

Operation Times	1	2	3	4	5
Iterations	1	3	2	2	1
Operation Times	6	7	8	9	10
Iterations	2	2	2	3	2

Simulation result is shown in Table3, it can be known from the table that, for node random deployment, the number of network node message iterations is different to different network node deployment situation. So, the situation of network node deployment has an effect on iterations.

So, network node densities, node sensing radius and the situation of network node deployment have an effect on iterations. But, the impact is less. The number of network node message iterations is small. That is, the distributed algorithm MCNCA is effective.

VI. CONCLUSION

K-Cover algorithm is broadly accepted because it can prolong network lifetime rather good. It divides all the nodes into K different coverage node set and every coverage node sets can cover the whole area. These coverage node sets work alternately and implement area monitoring. Because lifetime of one coverage set is the same as lifetime of the original network, K coverage sets can prolong network lifetime for K times. Thus, not only user sense demand can be satisfied to realize overall coverage, but also network lifetime can be prolonged. In area coverage problem, existing set K-cover algorithm concerned about how to divide the coverage set based on the maximum coverage set number known. They ignore to calculate the maximum coverage set number. But, in area coverage, the maximum coverage set number is difficult to calculate and it is the base to divide coverage set. Therefore, this paper addresses how to get the maximum coverage set number and realize node set division by distributed algorithm based on localized information.

Firstly, this paper puts forward the concept of node minimum layer overlapping subfields (MLOF). Then, it calculates network area minimum coverage layer number by MLOF. Take it as the maximum number of coverage node set. Secondly, based on maximum number of node set, it puts forward to way of dividing node set. Then, the distributed maximum coverage set number calculated algorithm MCNCA is proposed. Simulation result shows the distributed algorithm MCNCA is very effective. In the future, next step is to design the algorithm of coverage set division based on the max set number.

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REFERENCES

[1] Antoine Gallais, Jean Carle, David Simplot-Ryl, et al. “Localized Sensor Area Coverage with Low Communication Overhead”. *IEEE Transaction MOBILE COMPUTING* ,2008, 7(5):661-672.
[2] Chong Liu, Kui Wu, Yang Xiao. “Random Coverage with Guaranteed Connectivity:Joint Scheduling for Wireless Sensor Networks”. *IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS*,2006,17(6):562-575.
[3] Lan Wang , Yang Xiao1. “A survey of energy- efficient scheduling mechanisms in sensor networks”. *Mobile Networks and Applications* , 2006 , 11 (5) : 723- 740.
[4] Fan Ye, Zhong, G., Cheng, J,et al. “PEAS: a robust energy conserving protocol for long-lived sensor networks”. *Proceedings of the 23rd International Conference on Distributed Computing Systems*. Rhode Island, USA: IEEE Computer Society , 2003:28-37.
[5] E. Shih, S. Cho, N. Ickes, R. Min, A. Sinha, A. Wang,and A. Chandrakasan. “Physical layer driven protocol and algorithm design for energy-efficient wireless sensor networks ”. *In Proc. of ACM MobiCom’01*, Rome, Italy, July,2001.
[6] Lan Wang , Yang Xiao1. “A survey of energy- efficient scheduling mechanisms in sensor networks”. *Mobile Networks and Applications* , 2006 , 11 (5) : 723- 740.
[7] You-Chiun Wang, Yu-Chee Tseng. “Distributed Deployment Schemes for Mobile Wireless Sensor Networks to Ensure Multilevel Coverage”. *IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS*,2008,19(9):1280-1294.
[8] Boukerche A,Xin Fei,Araujo R.B,et al. “A Local Information Exchange Based Coverage-Preserving Protocol For Wireless Sensor Networks”.*Proceeding of the IEEE International Conference on Communications*. Istanbul, Turkey : IEEE Computer Society ,2006: 3420 - 3425.
[9] Mihaela Cardei, My T. Thai, Yingshu Li, Weili Wu. “Energy-Efficient Target Coverage in wireless Sensor Networks”. *IEEE INFORM 2005*,march 2005.
[10] Mihaela Cardei, Jie Wu, Mingming Lu, and Mohammad O. Pervaiz. “Maximum Network Lifetime in Wireless Sensor Networks with Adjustable Sensing Ranges” .*Proceeding of IEEE International Conference on Wireless And Mobile Computing, Networking And Communications 2005*.
[11] S.Slijepcevic, M. Potkpnjak, “Power efficient organization of wireless sensor networks”. *Proceeding of IEEE International Conference on Communications 2001*. IEEE Computer Society , 2001:472:476.

[12] H. Zhang, J.C Hou. “On the upper bound of a-lifetime for large sensor network”.*ACM Transactions on Sensor Networks*,2005,1(2):272-300.
[13] Z.Abrams,A. Goel, S .Plotkin. “Set K-cover algorithms for energy efficient monitoring in wireless sensor networks” .*Proceeding of the third International Symposium on Information Processing In Sensor Networks(IPSN).* 2004:424 – 432.
[14] Xin Ai,Vikram Srinivasan,Chen-Khong Tham. “DRACo: Distributed, Robust and Asynchronous Coverage in Wireless Sensor Networks”. *Proceeding of the 4th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, SECON '07*. California, USA.IEEE Computer Society , 2007 :530-539.
[15] Xin Ai,Vikram Srinivasan,Chen-Khong Tham.. “Optimality and Complexity of pure Nash Equilibria in the Coverage Game” . *IEEE Journal on Selected Area in Communications*.2008,26 (7):1170:1182.

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