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A Nonlinear Multi-objective *k*-degree Coverage Protocol Based on Optimization Nodes Scheduling in Wireless Sensor Networks

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Abstract

In the process of coverage for multiple targets, due to the existence of a large number of redundant data make the effective monitoring area coverage decreased and force the network to consume more energy. Therefore, this paper proposes a multi-target k-coverage preservation protocol. First of all, establish the affiliation between the sensor nodes and target nodes through the network model, present a method to compute the coverage expected value of the monitoring area; secondly, in the network energy conversion, using scheduling mechanism in sensor nodes to attain the network energy balance, and achieve different network coverage quality through different nodes energy conversion. Finally, simulation results show that NMCP can effectively reduce the number of active nodes meeting certain coverage requirements and then improve the network lifetime.

Keywords*: wireless sensor networks (WSNs); network lifetime; coverage rate; multi-targets; k-degree coverage*

1. Introduction

Wireless sensor networks are composed of integrated sensor technology, micro electromechanical technology and wireless communication technology integration of wireless network system. It is due to a large number of sensor nodes through the self organizing form, in order to multi hop data transmission [1]. Sensor nodes are the main characteristics of the performance for the small volume, energy Co., with certain perception ability, computing ability and communication ability, widely used in defense, military, transportation, medical and health, environmental monitoring, earthquake relief, intelligent buildings, domain engineering [2]. At present, there are two kinds of deployment scheme in sensor node. The first scheme is artificial deployment; the other is random deployment. Artificial deployment is mainly used in a specific environment, to the environment is strictly limited; in vast numbers, the deployment scheme used is randomly deployed, random deployment no need to consider the specific environment, such as: in the natural conditions are very harsh environment, generally used in the deployment of sensor nodes is the vehicle random deployment mechanism in random deployment although can reduce the nature of human activities damage, but there are also some problems [3]. Is mainly reflected in: due to the presence of randomly deployed, will make monitoring area within a certain range in the nodes with high concentration of state, so the network scalability, comprehensive service performance, data communication, signal interference, energy waste with a series of problems [4].

Based on the above problems, the most basic question is how to achieve effective coverage of regional monitoring domain, reduce the consumption of the energy of the

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sensor nodes, with a minimum of sensor nodes complete region is the largest or is to pay attention to the effective coverage of the target node. In order to meet the requirements of certain coverage, it is not required to complete the entire monitoring area of the sensor node coverage, but to maintain a certain percentage of the monitoring area. Therefore, the coverage rate in a certain sense is one of the standards to measure the quality of network services.

In order to study the coverage problem of wireless sensor networks, an enhanced coverage control algorithm is proposed in this paper. This algorithm is studied from the following four aspects:

(1) The relevant literature at home and abroad was studied, and the advantages and disadvantages of various coverage algorithms were pointed out. The central idea of the ECCA algorithm in this paper was expounded, and the network coverage system model was constructed.

(2) Using the network coverage system model with random deployment of nodes of the normal distribution, to move the target node by the sensor nodes form the sector given the sensor node coverage and of the monitoring area in n sensor nodes coverage quality expectations of the solution process.

(3) for the whole network system model to calculate, given a random variable x in the monitoring area (in square area as the object of study) for the first time in sensor nodes covering the period hope proved the value and variance of the process and completion of N times after covering the expectation value of the solving process, while the completion of the implementation of the whole monitoring area covering the minimum number of sensor nodes solving process.

(4) through the simulation experiment, the ECCA algorithm in this paper is verified under different monitoring area, and the comparison between the number of sensor nodes and the coverage rate under different parameters.

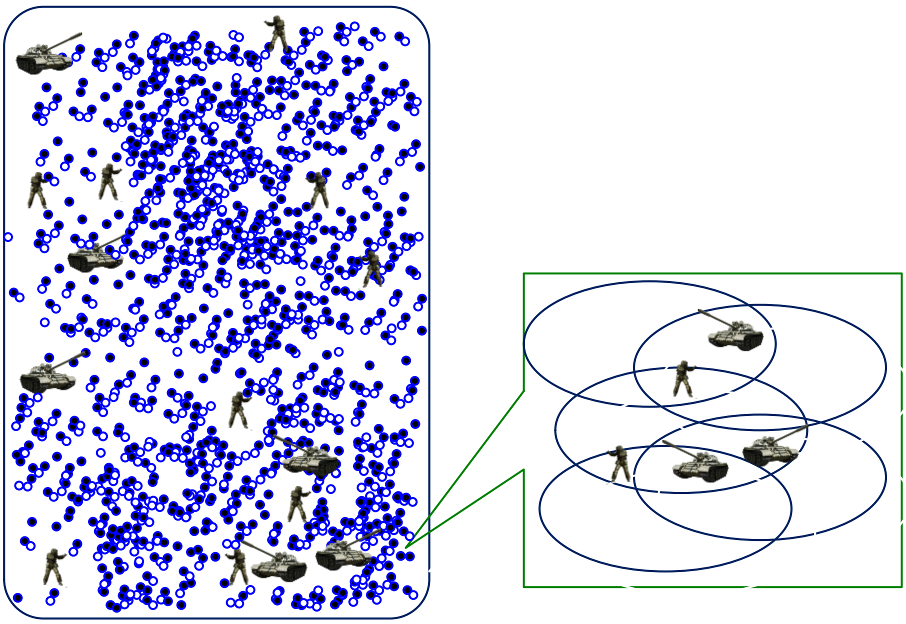

Figure 1. Schematic Diagram of *k*-degree Coverage

2. Related Works

In recent years, many scholars at home and abroad have carried out fruitful research on the coverage of wireless sensor networks, and have made some progress. A Control Algorithm (SCA) is proposed, which is based on the [5] (Scheduling). The algorithm by solving the network connectivity and coverage of the relation function between the qualities, monitoring region is given in arbitrary target node by sensor node coverage probability, and through the adjustment of the SCA algorithm dynamically active node location distribution to achieve the energy balance of the whole network. A distributed deployment node coverage algorithm is proposed in the literature [6]. The algorithm is will monitor the area is divided into several different regions, the formation of the Voronoi diagram and for each sub region for geometric computation, sub region is given in the polygon edge of maximum and minimum and maximum and minimum angle dependency relations between, on each of the calculated results of iterative optimization, the final completion of each sub region coverage purposes. [7] is using the artificial bee colony algorithm and PSO algorithm to solve the network coverage, the idea is through two intelligent algorithms of local solution set of iterative refinement, and to limit the local optimal solution of "spillover"; in the global optimization, the fitness function of local optimal solution set is optimized, and ultimately to achieve the global optimal solution and complete coverage of the whole network system. Reference [8] gives a kind of coverage holes repair optimization strategy, the thought is in the premise of satisfying certain coverage and the cavitation of a reasonable increase in the sensor nodes and to optimize the increase of nodes, are the main methods of the geometric graphics theories and knowledge of empty hole area and sensor nodes are calculated and find best hole repair position, reduce the number of sensor nodes and the completion of the network connectivity. The [9] proposed covering algorithm the maximum life cycle of obstacles based on k degree. The algorithm provides coverage has theoretical significance on the upper and lower solution method; in sensor node energy conversion, the communication path between the sensor nodes are optimized by using a greedy algorithm, and ultimately achieve balance the network energy. The [10] puts forward a covering algorithm optimization model based on the probability of the event (Event-Probability -Driven, Mechanism, EPDM). The algorithm first established the network probability model, and in the monitoring area any sensor node coverage rate is used to solve the problem, and given in the active nodes of attention to the target node k covering proof; in the path selection is through the ant colony algorithm on the of optimization to find the optimal path to achieve purpose of saving the network energy. An Energy-Efficient [11] Algorithm is proposed based on linear programming and multiple target coverage algorithm (Target Coverage, ETCA). The algorithm by linear programming method of the target node classification, the clustering of multi class targets set effectively cover, by calculating the complete residual energy of sensor nodes to achieve a balanced, realize the effective coverage of the monitoring area.

With the help of the literature [10-11] algorithm, this paper firstly establishes a model of the relationship between the sensor node and the multi target node. Based on this, a multi objective coverage preserving protocol (MTCPP) is proposed. The protocol using the subordinate relationship between the sensor node and the target node of coverage desired values were calculated, in order to ensure a reasonable coverage quality; then, by the sensor nodes scheduling mechanism completed the conversion of the energy of the whole network system, so as to achieve the equilibrium of the network energy.

3. Network Model and Coverage Quality

In order to better study the coverage of wireless sensor networks, and also to facilitate the study of NMCP algorithm, this paper makes the following assumptions:

(1) All the sensor nodes have a certain perception, and the sensing range and communication range are disking shaped [12].

(2) The sensing radius of sensor nodes is far less than the length of the monitoring area.

(3) The initial time, all the sensor node energy is equal, and with the clock synchronization.

(4) The location information of sensor nodes can be obtained by GPS.
(5) The sensing radius of the sensor nodes obeys Normal distribution.

3.1 basic definitions

Definition 1: (target coverage) in the two-dimensional plane, any target node is covered by a sensor node at least, referred to as the target coverage.

Definition 2: (*k*-degree coverage) in the monitoring area, any target node is covered by *k* sensor nodes, known as *k* degree coverage.

Definition 3: (network lifetime) from the network initial operation time, until the monitoring area of any target node can not be covered by the sensor nodes, known as the network survival period.

Definition 4: (coverage quality) in the two-dimensional plane, the ratio of the sensor node sensing area and the area of the monitoring area, called coverage quality.

3.2. Coverage Quality

Theorem 1: set arbitrary sensor node coverage rate of *p*, *k* degree coverage, set $k=2$, *m* and *n* is the number of sensor nodes move, the probability of its occurrence is p^2q^{n-2}, conditional probability is pq^{n-m-1}, here $q=1-p$.

Proof: set the number of *X* for the first round of mobile nodes, *Y* for the second round of the number of mobile nodes. According to the meaning of problems show that, in the first round of the m times the target node is covered by sensor nodes, for the second gear, in the *N* times target node has exactly twice by sensor nodes covered, *n*-2 not covered, so sensor nodes occurrence probability:

$$P\left(X=m,Y=n\right)=p^2q^{n-2} \tag{1}$$

The first round and the second round of joint probability:

$$\begin{aligned} P\left(X=m\right) &= \sum_{n=m+1}^{\infty} P\left(X=m,Y=n\right) \\ &= \sum_{n=m+1}^{\infty} p^2q^{n-2} = pq^{m-1} \end{aligned} \tag{2}$$

$$\begin{aligned} P\left(X=n\right) &= \sum_{m=1}^{n-1} P\left(X=m,Y=n\right) = \sum_{m=1}^{n-1} p^2q^{n-2} \\ &= \left(n-1\right)p^2q^{n-2} \end{aligned} \tag{3}$$

According to the multiplicative formula of probability:

$$\begin{aligned} P\left(Y=n\middle|X=m\right) &= \frac{P\left(X=m,Y=n\right)}{P\left(X=m\right)} \\ &= \frac{p^2q^{n-2}}{pq^{m-1}} = pq^{n-m-1} \end{aligned} \tag{4}$$

Theorem 2: the coverage rate of any sensor node is *p*, and the coverage rate of any point in the two-dimensional plane is: $P(nA)=1-(1-p)^n$

Proof: using mathematical induction to prove. In the two-dimensional plane, between any sensor nodes are not independent of each other, according to the probability theory, when $k=2$:

$$\mathrm{P}(A+A)=p(A)+p(A)-p(A)p(A)=1-(1-p)^2 \tag{5}$$

When $k=3$, the joint coverage is:

$$P(A+A+A)=p(A+A)+p(A)-p(A+A)p(A) \tag{6}$$

The formula (6) into the formula (5) can be obtained:

$$\mathrm{P}(A+A+A)=1-(1-p)^3 \tag{7}$$

When $k=i$ is made by the formula (7):

$$P(nA)=1-(1-p)^{\mathrm{n}} \tag{8}$$

Inference 1: in the two-dimensional plane, the sensor node coverage rate is *p*, *N* is the maximum number of continuous coverage of the sensor nodes, until the moving target node is covered, the expected value of the sensor node coverage: $E(X)=[1-(1-p)^N]p^{-1}$

Proof: in the two-dimensional plane, the number of target nodes x, because n is the maximum number of continuous coverage of the sensor node, X range is $X\in[1,2,3\ldots N]$, when $X=m$ and meet $1\le m\le N-1$, namely: the first n-1 times moving target node and not be covered by the sensor nodes, according to the distribution density function probability theory X:

$$P(X=k)=\begin{cases} p(1-p)^{k-1} & k=1,2,3\cdots N\text{-}1 \\ (1-p)^{N-1} & k=N \end{cases} \tag{9}$$

Namely:

$$E(X)=\sum_{k=1}^{N-1} kp(1-p)^{k-1}+N(1-p)^{N-1} \tag{10}$$

Set $q=1-p$, $S=\sum_{k=1}^{N-1} k(1-p)^{k-1}$, $S=\sum_{k=1}^{N-1} kq^{k-1}$ Multiplied by the Q, available on both sides of the equation: $qS=\sum_{k=1}^{N-1} kq^{k}$, namely: $(1-p)S=\sum_{k=1}^{N-2} q^{k}-(N-1)q^{N-1}=\frac{1-q^{N-1}}{1-q}-(N-1)q^{N-1}$

$$S=\frac{1-q^{N-1}}{(1-q)^2}-\frac{(N-1)q^{N-1}}{1-q}=\frac{1-(1-p)^{N-1}}{p^2}-\frac{(N-1)(1-p)^{N-1}}{p}$$

We will s into the formula (10) to:

$$\begin{aligned} E(X)&=p\left(\frac{1-(1-p)^{N-1}}{p^2}-\frac{(N-1)(1-p)^{N-1}}{p}\right)+N(1-p)^{N-1} \\ &=\frac{1-(1-p)^{N-1}}{p}-(N-1)(1-p)^{N-1}+N(1-p)^{N-1} \\ &=\frac{1-(1-p)^{N-1}+p(1-p)^{N-1}}{p}=\left[1-(1-p)^{N}\right]p^{-1} \end{aligned} \tag{11}$$

4 NMCP Protocol

4.1. Energy Conversion

For the sensor node, the energy consumption is mainly embodied in the two parts of the sensing module and communication module. When the collected data is L bits, the energy consumption of the sensing module E_R and the communication module E_T are respectively:

$$E_T(l,d)=\begin{cases} lE_{T-elec}+l\varepsilon_{fs}d^2\ , & d<d_0 \\ lE_{T-elec}+l\varepsilon_{amp}d^4\ , & d\ge d_0 \end{cases} \tag{12}$$

The model of energy consumption of the receiving module is:

$$E_R(l)=E_{R-elec}(l)=lE_{elec} \tag{13}$$

Among them, l bit is the length of the fixed transmission data, d on behalf of sensor nodes communication between Euler distance, d_0 is said sensor nodes between communication distance threshold or proportion outline amount, when the communication distance between sensor nodes is less than the d_0, energy attenuation index 2. On the contrary, the exponential decay is 4.

Definition 5: (optimal subset) design wireless sensor nodes in the sensor network into a set of G, in units of time, there is a sensor node ideas set $G_1\subset G$, the G_1 all sensor nodes completely covered in the target set T, is called G_1 is G an optimal subset.

Definition 6: (energy properties) $W=\{w_1,w_2,w_3\ldots w_n\}$ is the initial energy of sensor nodes W obey $W\sim N(\mu,\sigma^2)$ normal distribution, w_i represents the initial energy of the sensor node s_i.

Definition 7: (maximum distortion) under the premise of satisfying certain coverage, the maximum distortion is:

$$E\left[\left(s_1(x,y)-s(x,y)^2\right)\right]\le D \quad \forall s_i(x,y)\in A \tag{14}$$

$S_1(x,y)$ is the estimated value of the Euclidean distance between the sensor node and the target node, and $S(x,y)$ is the mean value of the Euclidean distance between the sensor node and the target node.

Theorem 3: the distance between the communication nodes is less than or equal to the difference between the variance and the distortion.

Prove: It is proved that the measured value of $T(x,y)$ is $s(x,y)$, which is used in the data information, which contains the measurement data. When the multi objective node is measured, the measured value is subject to Normal distribution. The energy of a given energy sensor node is $W=\{w_1,w_2,w_3\ldots w_n\}$, the Euclidean distance between the communication nodes is:

$$\begin{aligned} &R\left(\left(x_1,y_1\right),\left(x_2,y_2\right)\right)=\sqrt{\left(x_1-x_2\right)^2+\left(y_1-y_2\right)^2} \\ &=E\left[\left(S\left(x_1,y_1\right)-u\right)\left(S\left(x_2,y_2\right)-u\right)\right]=R(d) \end{aligned} \tag{15}$$

Set h as a set of data acquisition information sensor nodes, H1 as its complement, using H closest to the destination node of a sensor node calculation and measurement value to estimate in H1 a signal data. Therefore, signal at the target node (x,y) estimation values S_1 (x_0,y_0), namely:

$$s_1(x_0,y_0)=s(x_1,y_2) \tag{16}$$

According to the formula (14) and (15) available:

$$\begin{aligned} &E\left[\left(s\left(x_0,y_0\right)-\mu\right)\left(s\left(u,v\right)-\mu\right)\right]=E\left[\left(s_1\left(x_0,y_0\right)-s\left(u,v\right)\right)^2\right] \\ &=2\sigma^2-2R\left(d\left(\left(x_0,y_0\right),\left(u,v\right)\right)\right) \end{aligned} \tag{17}$$

The formula (14) into the formula (17) can be obtained:

$$R\left(d\left(\left(x_0,y_0\right),\left(u,v\right)\right)\right)\le\sigma^2-D/2 \tag{18}$$

4.2. NMCP Algorithm Idea

According to the basic idea of [13], by means of the theory of cluster technology, the monitoring area is divided into several regions; each cluster head node is responsible for the management and control of the cluster member nodes. In the initial stage of network operation, the cluster members first send the message "*k*-Coverage" to the cluster head node [14-15]. For the cluster head node, first of all, to establish a list of KL and received over the message is stored in the list, of which the received message contains sensor node ID and node's sensing range, energy attenuation and so on a variety of attributes. After one or several cycles, the cluster head nodes to collect the cluster members information, list according to the size of the residual energy of the nodes are sorted, and in front of the linked list node gives a weight; then, on all data in the list of search, and comply with the marking on the coverage target node of the sensor nodes; finally, from the cluster head nodes to meet the conditions of the members to send " *k* -Notice" message, by conforming to the conditions of the sensor nodes to cover the corresponding target node.

4.3. NMCP Algorithm Steps

Step1: The perceived strength of the cluster members.
Step2: cluster member nodes to send "*k*-Coverage" to the cluster head node. After one or a few units, the first node of the group received a message from the member within the cluster.
Step3: cluster head node to establish a linked list, and the collection of information stored in the list, while the list in accordance with the sensor node energy size ranking, while the higher energy to the node to give a certain amount of weight.

Step4: to find the conditions of the sensor nodes, and to mark the conditions of the node.
Step5: if the target node is in the k degree coverage, the cluster head will be through the search list to find the way to the sensor nodes with weak perception of the weak.
Step6: list traversal is completed; the cluster head node will be the optimal subset of the completion of the target node coverage process. Otherwise, the algorithm returns the second step.

4.3. NMCP Algorithm Description

```
Input N, R_s, E, E_thr
KL=Null
s_i=0, s_j=0, T_t=0, k=0
While (i<=N)
E(X)=∑{(s_i,D)|s_i, N(d,σ^2)/d^2}
While (T_t=t||T_t=nt)
{
    if (S_m← k-Coverage)
  KL[k].date= k -Coverage
      k++
          }
Sort_order (KL[k].data)
While (k<i)
  {
     if (Er<E_thr)
        S_i←S_m(k-Notice)
         k-Coverage(t_i) ←S_i
                }
j=k
While (j<k)
 {
    if (KL[j].data⊃KL[k].data)
        {
     Close (KL[j].data)
           k++
              }
      else
         return ()
               }
```

4.4. Complexity Analysis of NMCP Algorithm

In the analysis of NMCP algorithm, n represents the number of sensor node, m equals to the number of edges connected between any two sensor nodes. P_{min} and P_{max} are the minimum and maximum coverage value of the monitoring area. Δp means the increment of coverage after each covered process. Set $P_{min}=c$， $P_{max}=b_n$, c and b are constant coefficient. Assume: At the initial moment, the coverage percentage of sensor node is $p(0)=b/n$, at time t, the transition probability of a sensor node is greater than $c/2bn$ which also means the minimum probability of sensor node's coverage $P_{min}=c/2bn$. Set $R=(1-e)p(t-1)$ at time $t+1$, the coverage of a sensor node is:

$$\begin{aligned} p(t+1) &= \frac{p_{t+1}(t+1)}{p_{t+1}(t+1)+p_t(t+1)} \\ &\le \frac{p_{t+1}(t+1)}{c+p_t(t+1)} \le \frac{b}{(1-\Delta p)(c+ce+R)} \end{aligned} \tag{19}$$

When $L=\frac{b}{(1-e)(c+ce+R)}$, the time complexity of CASMOC algorithm is $E(T)$ which is the following

$$E(T)=\sum_{m=1}^{n-1}\left(\frac{2bn}{c(n-m)}\cdot\left[1-\frac{L}{n}\right]^{1-n}\right)$$
$$=\frac{2bn}{c}\left[1-\frac{L}{n}\right]^{1-n}\sum_{m=1}^{n-1}\frac{1}{m}\leq\frac{2bn}{c}e^{-L}H_{n-1} \quad (20)$$

Since $\sum_{m=1}^{n-1}\frac{1}{m}$ is the sum of harmonic series of first n-1 terms, let $H_{n-1}=\sum_{m=1}^{n-1}\frac{1}{m}$, then $\sum_{x=1}^{n-1}\frac{1}{x}-1<\int_1^{n-1}\frac{1}{x}dx<\sum_{x=1}^{n-1}\frac{1}{x}$ that is:

$$H_{n-1}=\sum_{m=1}^{n-1}\frac{1}{x}=\int_1^{n-1}\frac{1}{x}dx=O(\ln n) \quad (21)$$

5. System Evaluation

In order to further verify the effectiveness and feasibility of the NMCP algorithm, this paper uses MATLAB7 as the simulation platform, the simulation experiment of the NMCP literature [10] and [11], the comparison of various properties are given under different evaluation systems. The simulation parameter list as shown in Figure 1.

Table 1. List of Performance Parameters

parameter	value	parameter	value
Monitoring area III	400*400	R_c	20m
R_s	10m	$E_{\text{R-elec}}$	50J/b
Initial energy	10J	$E_{\text{T-elec}}$	50J/b
time	600s	ε_{fs}	10(J/b)/m^2
e_{min}	0.005J	ε_{amp}	100(J/b)/m^2

In this paper, the under the same network scale, NMCP algorithm and ETCA algorithm [6] and ECAPM algorithm [8] and EPDM algorithm [5] in the network life cycle, different target node size, changes in the number of sensor nodes to network operation time change and coverage of the simulation experiments, such as shown in Figure 2 to Figure 5.

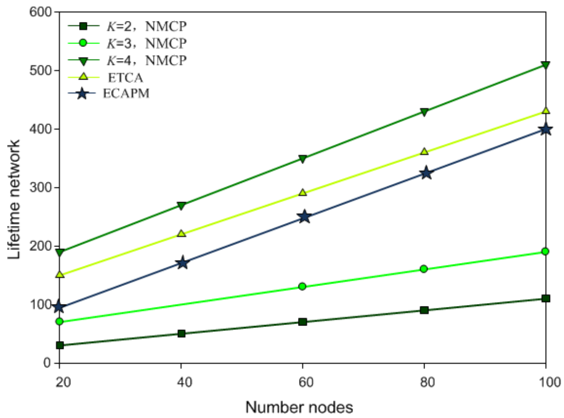

Figure 2. Comparison of Network Lifetime

Figure 2 shows the NMCP algorithm and ETCA algorithm and ECAPM algorithm in the network survival cycle simulation diagram. From Figure 2 we can see that in the initial stage of network operation, three network algorithm that runs in time quite, but random network time running, ETCA algorithm and ECAPM algorithm rise slowly, the reason is ETCA algorithm and ECAPM algorithm mainly reflected in in order to focus on the entire network into monitoring and complete the conversion between sensor nodes scheduling mechanism by linear programming method, energy consumption of the nodes is large. The NMCP the algorithm of this paper mainly through in the list to find the best node set to complete the coverage of the monitoring area, under the same number of sensor nodes, NMCP algorithm required network operation for a long time, compared to iterative 200 times and ETCA algorithm and the network lifetime longer on average of 16.33% and 19.75%.

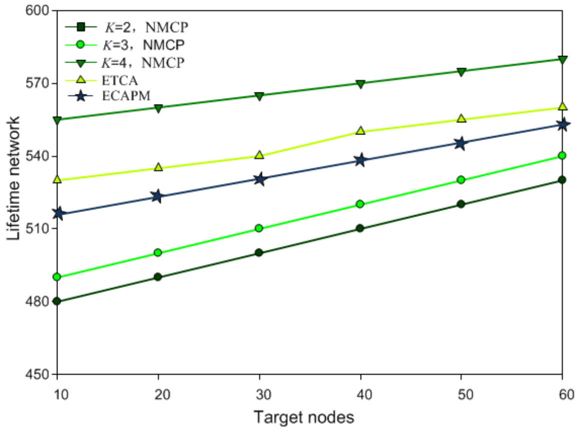

Figure 3. Network Lifetime under different Target Nodes

Figure 3 reflects the different target node number and network lifetime curve. In the initial stage of network operation, the number of sensor nodes is 348, the target number of nodes and the initial time of 10, with the increase of network operation time and the number of target node, three algorithms of network lifetime have are in a state of equilibrium, relative *k*=4, the NMCP algorithm, ETCA algorithm and ECAPM algorithm in the steady state is show small fluctuations. In the same number of reference target nodes, the average running time of network NMCP algorithm than ETCA algorithm 7.12%, 9.06%.

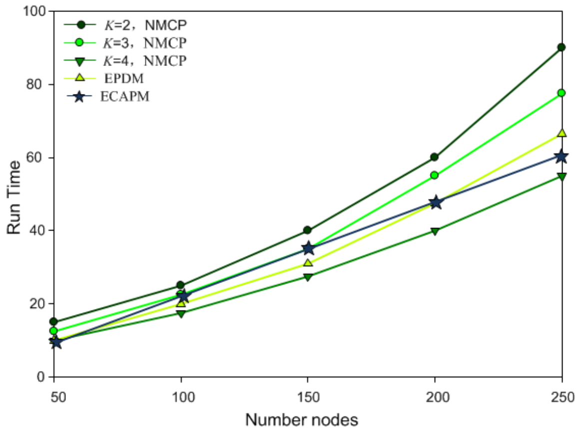

Figure 4. Comparison of the Running Time of the 4 Algorithms

Figure two shows the running time comparison of the 4 algorithms. From Figure 4 can be seen at NMCP running time of the algorithm is less than EPDM algorithm and ECAPM algorithm. The main reason is NMCP algorithm uses sub cluster structure and list with cover conditions sensor nodes search speed is higher than that of EPDM algorithm and ECAPM algorithm, reduces the coverage problem solving difficult, and EPDM algorithm although the use of clustering techniques, but during the process of covering the is centralized coverage, in energy conversion between nodes to traverse the sensor nodes in the collective after all of the nodes to determine the optimal cover set.

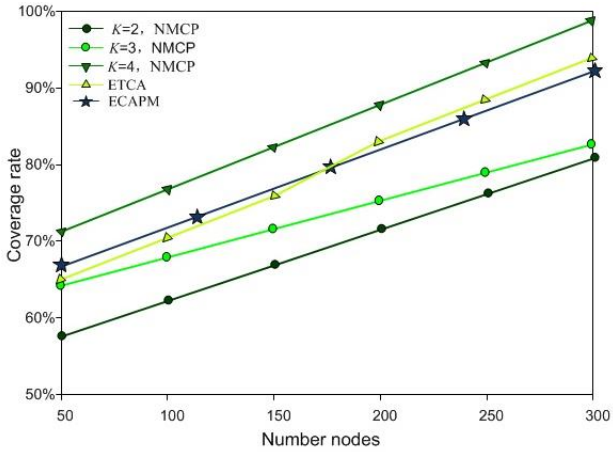

Figure 5. Comparison of Coverage

When the coverage rate is simulated, the 200*200m2 is used as the monitoring area, and the EPDM algorithm and ECAPM algorithm are compared with the experimental results. It can be seen from Figure 5, with the increase in the number of sensor nodes, three algorithms of the coverage rate also increased, when the coverage rate reached 99.9%, can be considered complete full coverage of the target node. When the number of active nodes is 50, k=4, NMCP algorithm coverage is 71%, while the number of active nodes of the EPDM algorithm and the ECAPM algorithm are 64%, 65%, when the coverage rate is 99.9%, the number of active nodes of the NMCP algorithm is 296; When the number of active nodes in the ECAPM algorithm is 296, the coverage rate of the two algorithms are 91% and 88%, respectively. In this paper, the average ratio of NMCP algorithm ECAPM algorithm EPDM algorithm coverage rate increased by 10.31%, 12.47%.

6. Conclusion

First of all, the paper analyzes the solving process of the wireless sensor network coverage in the presence of problems and shortcomings, on this basis, this paper presents a nonlinear multi-objective k coverage maintenance protocol; secondly, a network model was established based on the above analysis, and gives the between sensor nodes and target nodes from the property relations; then, the sensor nodes in the monitoring area coverage rate and the expected values were calculated and proved. Meanwhile, we also give the in the two-dimensional plane, any node is covered with multiple sensor nodes after coverage. In the aspect of node energy, the relationship between the communication distance and the maximum distortion is proved, and the realization process of the NMCP protocol is also given. Finally, the validity and feasibility of the NMCP protocol are verified by simulation experiments. The focus of the future work is mainly focused on how to achieve the effective coverage of the boundary of the monitoring area and the nonlinear coverage of the irregular monitoring area.

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References

[1] S. Z. Yu, L. Heng, C. Heng, “Optimization coverage of wireless sensor networks based on energy saving”, International Journal of Future Generation Communication and Networking, vol. 7, no. 4, **(2014)**, pp. 35-48.
[2] S. H. Lee, S. J. Lee and K. I. Moon, “A combined system of secure hashing and neural networks in sensor networks of living environment”, International Journal of Control & Automation, vol. 7, no. 9, **(2014)**, pp. 55-66.
[3] B. Kadri, M. Feham and A. Mhammed, “Efficient and secured ant routing algorithm for wireless sensor networks”, International Journal of Network Security, vol. 16, no. 2, **(2014)**, pp. 149-156.
[4] D. J. Zhao, W. Kai, L. Hui, “Maximizing the lifetime of K-discrete barrier coverage using mobile sensor”, IEEE Sensors Journal, vol. 13, no. 12, **(2013)**, pp. 4690-4701.
[5] M. F. Zhi, W. H. Zhao and He-Hui, “Connected coverage protocol using cooperative sensing model for wireless sensor networks”, Aata Electronica Sinca, vol. 39, no. 4, **(2011)**, pp. 772-779.
[6] M. Hamid, M. Kaveh and M. Amir, “Distributed deployment algorithms for improved coverage in a network of wireless mobile sensors”, IEEE Transactions on Industrial Informatics, vol. 10, no. 1, **(2014)**, pp. 163-174.
[7] S. Mini, K. Siba and L. Samrat, “Sensor deployment and scheduling for target coverage problem in wireless sensor network”, IEEE Sensors Journal, vol. 14, no. 3, **(2014)**, pp. 636-644.
[8] Z. C. Jiang, W. H. Rui, L. Qiang and Z. Li, “Optimization strategy on coverage control in wireless sensor networks based on Voronoi”, Journal on Communications, vol. 34, no. 9, **(2013)**, pp. 115-122.
[9] D. J. Zhao, W. Kai and L. Hui, “Maximizing the lifetime of K-discrete barrier coverage using mobile sensor”, IEEE Sensors Journal, vol. 13, no. 14, **(2013)**, pp. 4690-4701.
[10] S. Z. Yu, W. W. Guo and W. H. Zhao, “A novel coverage algorithm based on event-probability-driven mechanism in wireless sensor network”, EURASIP Journal on Wireless Communications and Networking, vol. 2014, no. 1, **(2014)**, pp. 1-17.
[11] X. X. Fei, W. G. Jun and L. Jie, “Polytype target coverage scheme for heterogeneous wireless sensor networks using linear programming”, Wireless Communications and Mobile Computing, vol. 14, no. 8, **(2014)**, pp. 1397-1408.
[12] Z. Wang and W. Chen. “An ID-based online/offline signature scheme without random oracles for wireless sensor networks”, Personal & Ubiquitous Computing, vol. 17, no. 5, **(2013)**, pp. 837-841.
[13] J. K. Liu, J. Baek and J. Zhou, “Efficient onling/offline identity-based signature for wireless sensor networks”, International Journal of Information Security, vol. 9, no. 4, **(2010)**, pp. 284-296.
[14] W. Z. Bo, L. J. Long and Q. H. Rong, “Achieving k-barrier coverage in hybrid directional sensor networks”, IEEE Transactions on Mobile Computing, vol. 13, no. 7, **(2014)**, pp. 1443 -1455.
[15] S. Zeyu, W. Huanzhao and W. Weiguo, “ECAPM: An enhanced coverage algorithm in wireless sensor network based on probability model”, International Journal of Distributed Sensor Networks. vol. 2015, no. 1, **(2015)**, pp. 1-12.

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