Heterogeneous Sequence Node of Associated Coverage Algorithm in Wireless Sensor Network

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Abstract

In the premise of meeting the quality of network service, how to effectively cover the monitoring area and how to prolong the network lifetime has become one of the wireless sensor network researches. Therefore, this paper proposes heterogeneous nodes based on association covering algorithm. On one hand, this algorithm is handled through the Poisson model of structure joint probability density formula and it is also based on the node density formula to establish sensor node in the monitoring area in order to efficiently cover the focused target. On the other hand, it updates through the node's own state scheduling mechanism and converts neighbor nodes dynamically about matching scheduling, which can balance the monitoring area sensor node residual energy and node energy consumption. Therefore it can achieve the purpose of prolonging network lifetime. Finally, the simulation results show that the algorithm not only can use fewer nodes to effectively cover the monitoring area completely and improve the coverage of the network but also can optimize resource allocation and prolong the network lifetime.

Keywords: wireless sensor network (WSN), scheduling strategy, lifetime, associated coverage algorithm

1. Introduction

Wireless sensor network is through a large number of sensor nodes are formed by the interaction of self organizing network architecture. It is a perception network structure that incorporates the logical information world and the objective physical world, which provided a powerful guarantee for people to change and awareness of the physical world [1]. Wireless sensor network nodes have certain computational ability, communication ability and the ability to perceive, widely used in military, industrial and agricultural production, disaster relief, security monitoring and other fields.

There are some differences exist Wireless sensor networks and other networks in architecture. First, wireless sensor network itself is through a high density nodes on the monitoring area of control, these sensor nodes are smaller in volume, limited in energy; the sensor node energy can not be effectively complement in some of more severe and dangerous environment; Second ,in high density deployment monitoring region, when in a working state a plurality of sensor nodes, for a particular target monitoring, positioning, cover and track, will lead to a plurality of sensor nodes are collecting data or the calculation of information to a neighbor node or base station transmits information to generate a large number of redundant data, this definitely will cause the phenomenon of network congestion, leading to the sensor node energy consumption so quickly, influence of the network energy consumption, reduces the network life cycle quality. Third: in the process of actual application, not all target nodes are fully covered [2]. When a node has become the concerns of the target node, request to effectively complete coverage or coverage is K degrees, namely the target node in the K sensor node sensing range. When the target node is concerned, let its be in a sensor node sensing range. So in the overlaying process, can also be considered in certain conditions, to make some sensor nodes in sleep state can effectively ensure the network energy, prolong the network life cycle.

2. Related Word

In recent years, the coverage problem in wireless sensor network has been concerned by scholars in the world. Scholars have carried out some very fruitful research points. Literature

gives the monitoring areas of all sensor nodes are divided into a number of disjoint subsets, each subset in a monitoring area conduct independent monitoring, through the clock timing function for each subset of alternate methods for monitoring area of the target node to effectively cover [3]; the authors using a self calibration method for a particular node redundant nodes into dormancy, to avoid the blind spots are round monitoring, after a specified period of time, the active node updates the local Voronoi to complete the map of monitoring regional coverage [4]; On wireless sensor networks heterogeneous nodes network topology, all nodes in monitoring area cluster processing, make high energy sensor nodes form a cluster head node, on the formation of cluster regional monitoring and coverage [5]; the paper is the use of wireless sensor network having distributed characteristics will detect and control integration, to the fused sensor node subset optimization, to save energy, prolong network cycle [6].

Literature gives an energy saving cover, the idea is to use each sensor node of the perceived distance equilibrium conditions to achieve energy-saving coverage, this method is not random mobile sensor nodes [7]. The using density control PEAS algorithm to schedule the target area sleep node and in different regions of the sensor node energy consumption itself as far as possible, to prolong the network lifetime [8]. All of the above algorithm is to a large extent can be completed the coverage and connectivity, but the solving process is too complex; in addition, with the increase of the number of sensor nodes and coverage area change, also can make the algorithm complexity is increased, thereby reducing the computational efficiency. The above six algorithms in different degree to satisfy a condition coverage requirements, but also can guarantee the connectivity of the network, but its disadvantage is node distribution unevenness caused the complexity of the algorithm is too high, speed too slow, and a plurality of sensor node position changes will occur more frequently perceived area multiple cover the possibility [9, 10].

3. Related Word
3.1. Network Model and Hypothesis
The following hypotheses are advanced on the network model:

Hypothesis 1: The monitored area is much larger than the sensor node sensing area, not considering the boundary factors on the monitoring of regional influence.

Hypothesis 2: Sensor node sensing radius and radius of communication will appear a disk shape and the communication radius greater than or equal to 2 times the radius of perception.

Hypothesis 3: Each sensor node can be through their own information to their location information.

Hypothesis 4: The initial state, and each sensor of node energy is the same, all sensor nodes have the same processing capacity, and equal status.

3.2. Basic Definition
Definition 1: the distance between any two nodes $d(i, j)$ are called nodes i and j Euclidean distance, when $d(i, j) < 2R$ referred to the neighbor node, node i and j.

Definition 2: in the monitoring of the target area, when a target node is K sensor node coverage, called K heavy cover.

Definition 3: in the monitoring of the target area, all sensor nodes coverage Union and all sensor nodes range and than, called network covering efficiency:

$$EA = \bigcup_{N=1,2...N} S_i \Big/ \sum_{N=1,2...N} S_i \tag{1}$$

Definition 4: Covering the region of coverage for:

$$p(s_i, s_j) = \begin{cases} 0 & \text{if } R_s \le d(s_i, s_j) \\ e^{-\varepsilon d} & \text{if } (R_s - R_e) < d(s_i, s_j) < R_s \\ 1 & \text{if } d(s_i, s_j) \le (R_s - R_e) \end{cases} \tag{2}$$

Among them: ε is sensor node physical parameters; R_e said sensor node monitoring dynamic parameters in the said sensor nodes; $d\left(s_i, s_j\right)$ Euclidean distance; when $d\left(s_i, s_j\right) \leq \left(R_s - R_e\right)$, this time node s_i is detected, it is not detected [11].

3.3. Deductive Reasoning and Probability Density
Theorem 1: When and only when the three equal circles intersect at one point, and form an equilateral triangle length of a side is $\sqrt{3}$,covering the efficiency of EA maximum, That is: $EA \leq 82.73\%$

Proof: As shown in Figure1:

Figure 1. (a) Any intersection Of two circles, b) Any three circles intersect at one point

Firstly, Figure 1(a) were analyzed, as are three. Two intersect, and the intersection region are equal, so $\square O_1 O_2 O_3$ is an equilateral triangle, with side length $O_1 O_2$ is r, an equilateral triangle $\square O_1 O_2 O_3$ three interior angles are respectively $\pi/3$, $\angle O_2 O_1 O_3 = \pi/3$, $S_{\square O_1 O_2 O_3} = \frac{1}{2} r^2 \sin \frac{\pi}{3}$, since three, round two intersection, and completely covered on the plane the Euclidean distance, $d_i < 2r$, let the equilateral triangle $\square O_1 O_2 O_3$ the maximum length to keep the $S_{\square O_1 O_2 O_3}$ area is the largest, the three circle intersect at a point B, as shown in Figure 1(b) as shown, connect to the $O_3 B$ and extended to two points to A, connecting the $O_2 A$, set three the radius of the circle of 1, $S_{\square ABO_2} = \sqrt{3}/4$, $S_{ABO_2} = \pi/6$, according to the formula (1) we get $EA = S_{\square ABO_2} / S_{ABO_2}$, $EA = = \frac{3\sqrt{3}}{2\pi} = 82.73\%$ namely in the completely covered cases the maximum coverage of the efficiency value is 82.73%.

Theorem 2: Sensor node monitoring area A, the monitoring of regional node density λ, a monitoring area A node number X subject to node K probability density:

$$P\left(X = k\right) = e^{-\lambda A} \cdot \left(\lambda A\right)^k / k! \tag{3}$$

Proof: the monitoring area is S, in the monitoring region of arbitrary nodes subordinated to the K node distribution probability of $p = A/S$, when the number of nodes of n probability obeys two type distribution is:

$$P\left(X = k\right) = C_n^k p^k \left(1 - p\right)^{n-k} \tag{4}$$

According to the node density formula $\lambda = n/S$ into arbitrary node distribution probability of P:

$$p = A\lambda/n \tag{5}$$

Equation (5) into the formula (4):

$$P(X=k) = C_n^k \left(A\lambda/n \right)^k \left(1 - A\lambda/n \right)^{n-k}$$
$$= \frac{n!\left(A\lambda \right)^k \left(1 - A\lambda/n \right)^n}{(n-k)!k!(n-A\lambda)^k} \tag{6}$$

When $n \to \infty$ and its limit available:

$$P(X=k) = \lim_{n\to\infty}\left(\frac{n!\left(A\lambda \right)^k \left(1 - A\lambda/n \right)^n}{(n-k)!k!(n-A\lambda)^k} \right) = e^{-\lambda A}\left(A\lambda \right)^k / k! \tag{7}$$

That is: $P(X=k) = e^{-\lambda A} \cdot \left(\lambda A \right)^k / k!$

4. Coverage Control and Scheduling of Nodes

In order to achieve the efficient coverage on monitoring region by minimal node, the purpose is to better extend network existence period. Make the network lifetime maximization is the basic method to make the network system of the node energy minimization. That is to say, in the network monitoring region to let each sensor node to consume all their energy as much as possible, but in practical application process exists the position difference, the sensor node energy consumption is not the same; for example: in close proximity to the base station node for forwarding a large amount of data and the formation of excessive energy consumption and rapid death. Therefore, the node exists between energy consumption disequilibrium phenomenon, which requires the deployment of nodes, considering the different regional deployed nodes is also different. Its purpose is to balance each sensor node energy has to balance the network deployment, while the network effectively covering algorithm finally, can be achieved on the node energy consumption effectively resist, the lower energy nodes not too quick death, thereby extending the network cycle.

4.1. Dynamic Form

When the target into a cluster head monitoring area, to the neighbor cluster head node sends a packet containing the target information, all the monitoring to the target cluster are dynamically in the target around to form a group, cluster member nodes only with the cluster node communication, the cluster head and between cluster heads can be mutually communication. Involved in tracking the cluster number depending on the size of the radius of the grid. For example, if the access grid side length equal to the radius of communication node, then a maximum of only four cluster capable of simultaneously monitoring to the target. When at the same time two or more than two cluster head and monitoring to the target, we select these clusters in a cluster head node as a leader node, cluster head first to the neighbor hair to send their and monitoring the distance between the target data information, if the cluster head received a distance closer to the target hair to information, give up campaign to become leader node. Selection criteria for: first, choose from the closest cluster head node; second, if there are two or more than two cluster head node and the target and the distance between the same, residual energy larger the lead node. All the monitoring to the target cluster head node will be sent to a leader node data first, and then by the leading node calculation and data fusion are transmitted to a data center node. As shown in Figure 2.

When the mobile target leading away from the node, because of the need to transmit data over long distances to the leader node, or a new cluster head node monitoring to the target, then a leader node is no longer applicable acts as a leader node, fast the election of a new leader node is very necessary. Here we shall, when there is a new cluster head node joins the mobile target tracking, under the leadership of node selection rules, in all involved in tracking the cluster head node selects a distance to a target the nearest cluster head node as its new leader node, data reported by the new leader node is sent to a data center.
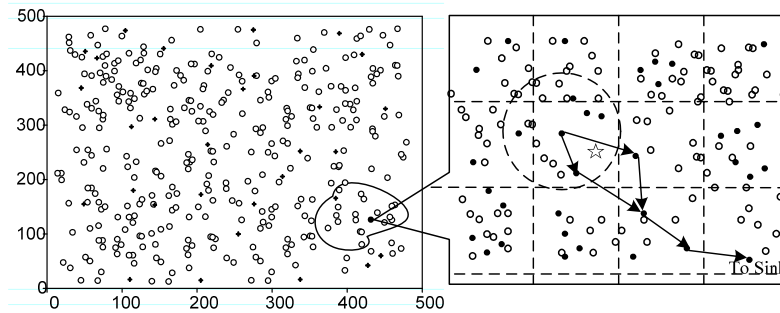
Figure 2. The Target Node Coverage Area Diagram

4.2. Node Scheduling Strategy

The sensor node is a round number as the cycle to work. During an initialization phase, the sensor node closed its induction module, update their information and the neighbor node. In the scheduling process to go through five states, respectively, the start state, judge state of competition state, hibernation, the listening state, a five state conversion constitute the sensor node scheduling strategy. First of all, to judge if the node meet the dormancy condition, such as meet into hibernation, or into the competitive status, when entering into competition, start a timer; secondly, when the node competitive success, node to the start state, competition failure node into the listening state; again, in a sense node on success to receive the neighbor node to broadcast news On-duty Message, update its neighbor nodes' information, thus entering the judgment condition; fourth, in the starting state of the node to its neighbor node sends a On-duty Message, which contains the start node only ID identification and location information, and carries on the effective coverage of the work; fifth, in order to save the energy of the node, for accurate monitoring region to effectively cover, the sensor node will turn off unnecessary device to prolong the network life cycle. In practical application process, the sensor node according to the neighbor node's information to dispatch their information, until sure sensor node itself as the start state or resting state so far, as shown in Figure 3.
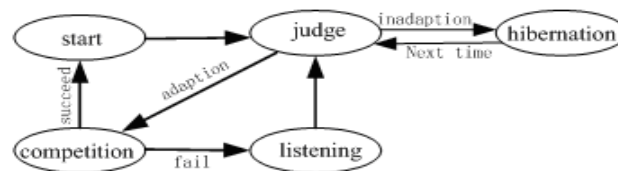

Figure 3. Node Scheduling State Diagram

5. System Assessment

Wireless sensor network node energy consumption most are from to in data processing and communication, contains the main data calculation, data processing and data transmission on three aspects, including data transmission by the consumption of energy is higher, the wireless communication consumption model was studied, its model:

$$E_{Tr}(k,d) = E_{T-elec}k + E_{amp}(k,d)$$

$$= \begin{cases} E_{T-elec}k + \varepsilon_{fs}d^2k & d < d_0 \\ E_{T-elec}k + \varepsilon_{amp}d^4k & d \geq d_0 \end{cases} \tag{8}$$

$$E_{Rx}(k) = E_{R-elec}k \tag{9}$$

On the type, $E_{T\text{-}elec}$ and $E_{R\text{-}elec}$ wireless sending and receiving module of energy consumption; ε_{fs} and ε_{amp} said free space model and the multiple attenuation model amp consumption parameters; d_0 is constant.

In order to verify the effectiveness of the algorithm and stability, the experiment from the two aspects of the comparison, the simulation platform is MATLAB7, the simulation region is set to 500m× 500m, sensor nodes is 300, sensor node sensing radius is 5m, the initial each node's energy is the same 2J, network bandwidth is 1Mbps, packet size is 100bits, the sampling period is 10s.

The first case: the algorithm and LEACH protocol comparison experiment, validation in the same round number, the network energy consumption contrast conditions, as shown in Figure 4.

From the Figure 4 can be seen, in the initial moments, two algorithms of the network energy consumption approximately equal; but as time goes on, the algorithm of the network energy consumption less than LEACH protocol of energy consumption, and this algorithm to the subsequent time tends to be stable, in the entire network cover cycle, this algorithm can effectively save the sensor node energy, prolong the network life cycle.

In second cases, using this algorithm with PEAS algorithm in coverage on the comparison experiment, the coverage rate of 99% that is completely covered, the experimental data are in 100 simulation data by extracting the average value, as shown in Figure 5.

From seeing the graph 5, as time progresses, two algorithms of coverage has declined. The initial phase, two algorithms of coverage, but in t=1500, PEAS algorithm coverage declined more obvious, the algorithm still maintain higher coverage. In the same node under the effect of this algorithm, coverage was significantly higher than that of PEAS algorithm, to verify the effectiveness of this algorithm.
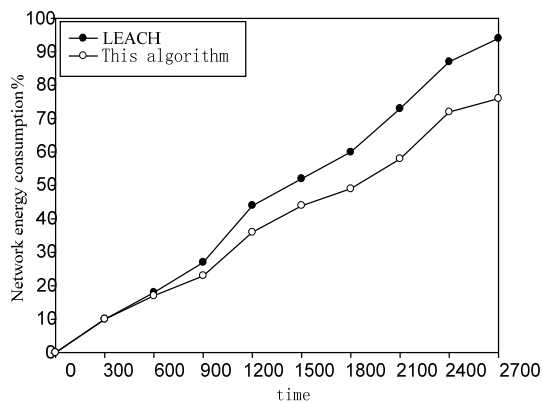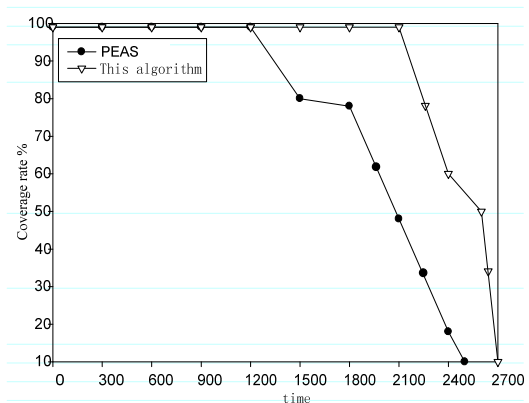
Figure 4. Network Energy Diagram

Figure 5. Different Rounds of the Network Coverage

6. Conclusion

This paper studies the coverage problem in wireless sensor network, using the node to node state transition mechanism for effective control, giving the Poisson distribution model and reasoning the joint probability density, and verifying the efficiency of coverage, quantifying the node density distribution, optimizing the network resources. Using relationship between the sensor node and the target node, it gives the coverage model of monitoring region network, identifies the sensor node and the target node affiliation, as well as the effects that K heavy coverage puts on the network monitoring region. Using the node state transition mechanism, it constructs the node wheels work system model. Finally through the simulation experiment on the LEACH protocol and PEAS algorithm comparison experiment, in the network energy consumption and network coverage rate of this algorithm, this paper is higher than above two algorithms, achieving the goal of prolonging the network lifetime and improving the quality of network service.

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