The Optimum Nodes on Clustering-based Routing in Wireless Sensor Networks

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ABSTRACT ：— This paper considers the problem in maintaining the coverage of a wireless sensor network on cluster base of algorithm. While the sensing units of sensor nodes keep up an optimal coverage range, the sensor node can save energy. Therefore, we will propose the coverage and connectivity approach to node optimum clustering called ONCR (Optimum Nodes on Clustering-based Routing), which used the optimum coverage and connectivity of a node and same serial number to transmitting next node. ONCR can also calculate the optimum node number of a cluster. In this article, the ONCR distributes the energy consumption evenly among all sensor nodes and improves the network lifetime and the average energy savings. Further, the mobility adaptability of ONCR makes it suitable for use in mobile sensor networks with frequent topology changes. We implement the ONCR algorithm with different parameters and compare the performance to Low-Energy Adaptive Clustering Hierarchy (LEACH). Experimental results show the advantage of ONCR in the context of sensor networks.

Key-Words：*sensor , cluster , coverage , connectivity*

1. Introduction

Sensor networks [1] consist of a large number of tiny sensors with limited power and computational capability. It applies to the inhuman handling work, such as detect the humidity and temperature and collect messages in the mountain area, monitor and data aggregation[2,3] in dangerous area, monitor the condition in the building and monitor the enemy direction in the battleground, etc. By way of the development in microprocessor technology, communication technology and battery technology, the sensor node has interaction wireless communication and information handle ability. Therefore, for saving the energy consumption in transmission and solving the distance problem, if the sensor is far away from the sink, the sensor nodes need to use multiple-hop relay to create the network routing. So the data and aggregated of sensor nodes can through by multiple-hop routing to sink. Then each coverage range of sensor node will effect the energy dissipation. Therefore, we will find the better at coverage range for sensor nodes. For solving the limited energy of sensor nodes, these aimed at the effective coverage of the sensor nodes. This paper is organized as follows. In Section 2 we review related work and in Section 3 we will presents the routing protocol algorithm. In Section 4 we evaluate the algorithms via simulation. We summarize the results and discuss future research directions in Section 5.

2. Related Work

2.1、LEACH

A clustering scheme called Low-Energy Adaptive Clustering Hierarchy (LEACH)[4] is proposed in that employs the technique of randomly rotating the role of a cluster head among all the nodes in the network. The operation of LEACH is organized in rounds where each round consists of a setup phase and a transmission phase. During the setup phase, the network will be separated some clusters and will select a cluster head node in each cluster randomly. During the transmission phase, the cluster heads collect data from nodes within their respective clusters and apply data fusion before forwarding them directly to the BS. LEACH provides sensor networks with many good features, such as clustering-based, two roles of sensor nodes. However, it expenses much energy in cluster heads when forward data packets to the BS directly.

2.2 、Coverage and Connectivity

1.Coverage: Each sensor has their induction plane to operate. A effective node can represent the relative information in the induction plane.
2.Connectivity: Each sensor node has the largest and direct communication plane to confirm the connection.
Therefore, the sensor nodes only monitor and collect the information in the providing coverage and connectivity [5].

3. Coverage with Connectivity : Necessary and Sufficient Conditions

To design the saving energy consumption of sensor node is an important struggle in wireless sensor network. Because the sensor nodes device of cost is down so we can randomly and effectively operate many sensor nodes in the wireless network. The sensor nodes are deployed the high-density network to solve the problem. However, the high-density of sensor nodes in the wireless network also cause information overlapping [6] and more energy consumption. So, we consider the effective coverage in the high-density wireless network to reduce the overlap.

3.1 、Grid Structure

The paper is going to use grid structure to design. Also, the range covered with 2 nodes is best with the radius of node in Fig. 3.1.1 shows the nodes in the coverage of the grid structure area.

3.2 、Coverage Region

There are four phases of the coverage region [7] in the nodes:

1. Phase1: CADB area occurring intersection simultaneously in two nodes.(Fig. 3.1.1)
2. Phase2: The measure of the arc BDFE in four nodes.(Fig. 3.1.2)
3. Phase3: The arc ACG area among three nodes.(Fig. 3.1.3)
4. Phase4: The arc DBE area outside intersection with three nodes.(Fig. 3.1.4)

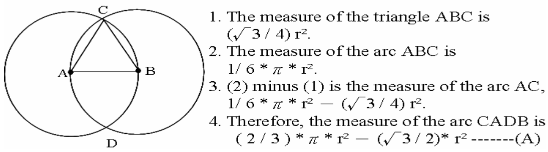

Fig. 3.1.1 Phase1

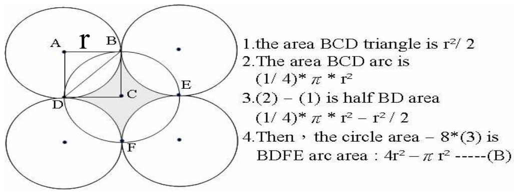

Fig. 3.1.2 Phase2

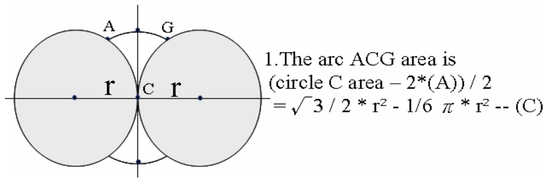

Fig. 3.1.3 Phase3

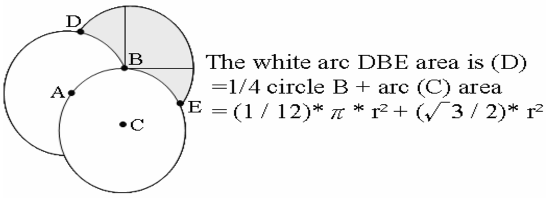

Fig. 3.1.4 Phase4

3.3 、The nodes of density in grid area

We discuss the above nodes coverage with grid area. We use the different color to represent the node group and calculate the coverage (minus the overlapping area). Then, we calculate the area covering from all nodes among grid area.

3.3.1 、The first part of coverage on grid area

1. The blue nodes in D x D area as Fig. 3.1.1：

(1).The calculation in vertical side each 2r distance has a node so each vertical side has $\frac{D}{2r}$ nodes.

(2).The calculation in horizontal side each 2r distance has a node so each horizontal side has $\frac{D}{2r}$ nodes.

2. There are $(\frac{D}{2r})^2$ nodes.

3. The measure of area is $\frac{1}{4}\pi D^2$. ---------- (E)

3.3.2、The second part of coverage on grid area

1. The red nodes in D x D area as Fig. 3.1.1：

(1).The calculation in vertical side each 2r distance has a node so each vertical side has $(\frac{D}{2r})-1$ nodes.

(2).The calculation in horizontal side each 2r distance has a node so each horizontal side has $(\frac{D}{2r})-1$ nodes.

2. There are $((\frac{D}{2r})-1)^2$ nodes.

3. A minus the intersection overlapping area of the blue node.(arc area is $4r^2 - \pi r^2$)

4. The measure of area:

$$D^2 - 4Dr - \frac{1}{4}D^2\pi + D\pi r + 4r^2 - \pi r^2 \quad \text{-------- (F)}$$

3.3.3、The third part of coverage on grid area

1. The black nodes in D x D area as Fig. 3.1.1：

(1).The calculation in vertical side each 2r distance has a node so each horizontal side has $\frac{D}{2r}$ nodes.

(2).The calculation in horizontal side each 2r distance has a node so each horizontal side has $\frac{D}{2r}$ nodes.

2. The measure area of the black nodes：

(1).The arc area intersection between the upper column, blue nodes and the lower column, black nodes is $\{2*[(\frac{D}{2r}-1)*(\frac{\sqrt{3}}{2}r^2-\frac{1}{6}\pi r^2)]\}$

(2).The most right arc area intersection excluding the upper and lower nodes is

$$\{((\frac{D}{2r})-2)*(\frac{\sqrt{3}}{2}r^2-\frac{1}{6}\pi r^2)\}$$

(3).The most right arc area intersection of the upper and lower nodes is

$$\{2*(\frac{1}{12}\pi r^2+\frac{\sqrt{3}}{2}r^2)\}$$

3. The measure of area is

$$(\frac{\sqrt{3}}{2})Dr-\sqrt{3}r^2-\frac{1}{6}D\pi r+\frac{1}{3}\pi r^2 \quad \text{---- (G)}$$

3.3.4、The forth part of coverage on grid area

1. The orange nodes in D x D area as Fig. 3.1.1

(1).The calculation in vertical side (the leftest side) each 2r distance has a node so each horizontal side has $\frac{D}{2r}$ nodes.

2. The measure of area in orange nodes is

$$\frac{\sqrt{3}}{2}Dr-\sqrt{3}r^2-\frac{1}{6}D\pi r+\frac{1}{3}\pi r^2 \quad \text{------------ (H)}$$

Therefore, the result from the total coverage of four parts is as follows:
The total coverage (I) is : (E) + (F) + (G) + (H) =

$$D^2+(\sqrt{3}-4)Dr-\frac{1}{3}D\pi r+(4-2\sqrt{3})r^2-\frac{1}{3}\pi r^2$$

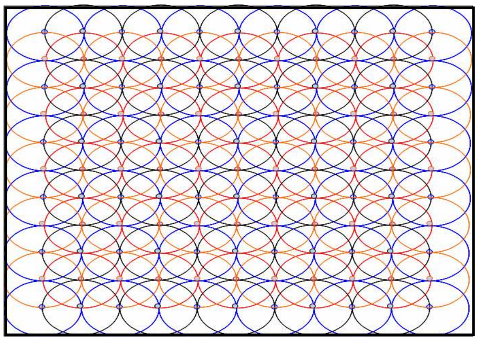

Fig. 3.1.1 Grid Structure

3.3.5、The density in grid area

Then the density of grid area d = (I) / D^2 =

$$1+\frac{(\sqrt{3}-4)r}{D}+\frac{r}{3D}\pi+\frac{4-2\sqrt{3}}{D^2}r^2-\frac{r^2}{3D^2}\pi \quad \text{----- (J)}$$

3.3.6、The optimum cluster of formula

The area of each cluster is $Z = d\pi c^2$. The cluster of area is Z. The coverage range of nodes density in the D x D of area is d. And the connected range of node is c. Therefore the sensor node number of the optimum cluster number of nodes [8] is

$$N=(\frac{D}{2r})^2/(d\pi c^2)=(\frac{D}{2r})^2/(\pi c^2)*(J)=$$

$$\frac{D^4}{(D^2-2.268Dr+0.536r^2-\frac{1}{3}D\pi r-\frac{1}{3}\pi r^2)\pi c^2 r^2} \quad \text{--(K)}$$

3.4、Calculation the optimum nodes

In this section, we study required and sufficient conditions for the grid network to node covering the unit area. Before presenting details of the proposed optimum cluster of formula (K), we will express an example for this section. When the edge of grid network is D = 100(m), each node of cover radius is r = 2(m). So we will obtain the best node quantity of the cluster for the value into this formula. At the same time, we discuss the different value of the connectivity. The following example r represents covering radius of the node, c is connecting range of the node and N is the number of the node.

(1).When c = r , then N = 213.22 (nodes)

(2).When c = 2r , then N = 53.31 (nodes)

(3).When c = 3r , then N = 23.69 (nodes)

(4)When c = 4r , then N = 13.33 (nodes)

(5).When c = 5r , then N = 8.53 (nodes) ………

Moreover related cluster topology uses the regard equilateral triangle of characteristic to show the cluster group in WSN. The regard equilateral triangle have equal than edges and the distance of max is edge length. So, when the edge length of the equilateral triangle is r, it shows that there can be the distances of length of radius 3 nodes. And when the edge length of the equilateral triangle is 2r, it shows that there can be the distances of length of radius 6 nodes. Therefore, depending on the regard equilateral triangle rule, we can receive the quantity of the following nodes.

(1)When the regard equilateral triangle of edge is r, then N = 3 (nodes)

(2).When the regard equilateral triangle of edge is 2r, then N = 6 (nodes)

(3).When the regard equilateral triangle of edge is 3r, then N = 10 (nodes)

(4).When the regard equilateral triangle of edge is 4r, then N = 15 (nodes)

(5).When the regard equilateral triangle of edge is 5r, then N = 21 (nodes) ………..

Regarding the above results, we find each cluster that the nodes number is 213.22 upon formula (K) condition that the c is equal to r. But the edge length of the equilateral triangle is r then the nodes number is 3. However, the nodes number is not correspond both. While c = r、c = 2r and c = 3r are also not correspond at the nodes number. Until the c = 4r, it needs 13.33 nodes. Then corresponds the equilateral triangle length of edge is 4r, the suitable for nodes quantity is 15. Because the both regard equilateral triangle and formula of nodes number are almost equal. Therefore, we find the c = 4r can be to accord with the nodes number. But other node is counted and differed greatly.

3.5、ONCR of Algorithm

About the ONCR of algorithm will divide into 3 parts to prove.

3.5.1、Building a Cluster Topology

We will build up the cluster topology with the sensor nodes in the WSN as Fig. 3.5.1.1. To building the cluster by regard equilateral triangle and an edge length is 4r. The first step is to set up the upper right 1st node of the initial value =1. The serial number of nodes are from right top to left down. Each cluster has the equal nodes. Each cluster is at most 15 nodes. The rest nodes are fewer than 15 nodes and still become one cluster. Reset the nodes create itself one cluster.

3.5.2、Routing Protocol

This session describe the algorithm of routing protocol as Fig. 3.5.2.1. It explains as follows to mainly divide into 5 steps.

1. Each cluster of node① set as cluster head for initial value.
2. Each cluster head is transmitted to the next cluster head that regarded as this cluster in accordance with the same node serial number.
3. The cluster head of the last cluster is transmitted the messages to sink.
4. Then the cluster of cluster head is selected by node serial number and accumulates 1.
5. Jump the step (2) until node energy is dissipated.

3.5.3、Fault Tolerance

We start the mechanism of fault tolerance as Fig. 3.5.3.1.It explains as follows to mainly divide into 3 steps.

1. Elected as cluster head by the next serial number.
2. Elected as new cluster head while transmitting to the next cluster and remain original serial

number of cluster head.

3. Following Step (1)(2), the messages transmit to base station.

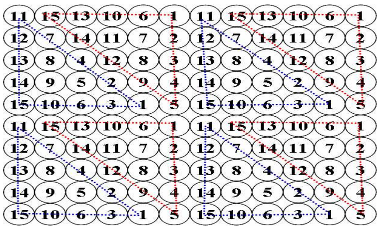

Fig. 3.5.1.1 Building a Cluster Topology

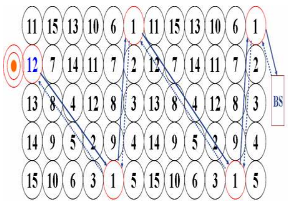

Fig. 3.5.2.1
Routing Protocol

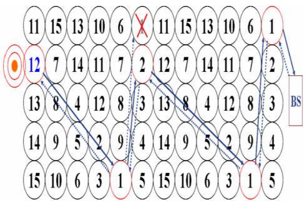

Fig. 3.5.3.1
Fault Tolerance

4、Simulation Experiments

4.1、Parameter

The same set of parameters used in all experiments throughout the article as the Table1.

Table1 Simulation parameters

Parameters	Values
the total energy dissipated in the transmitter of the source node	ETx = (50 nJ/bit)
the energy cost incurred in the receiver of the destination node	ERx = (50 nJ/bit)
eFS and eTR denote transmit amplifier parameters corresponding to the free-space and the two-ray models	eFS = (10 pJ/b/m^2) eTR=(0.0013 pJ/b/m^4)
data aggregation	EDA = 5(nJ/b/message)
sensor node number	500(nodes)
each node is assigned an initial energy	2(J)
the number of data frames transmitted for each round	50(messages/round)
the data message size	500(bytes)
the length of the packet header	25 (bytes)
network topologies	100(m) × 100(m)
each node is assigned an radius	2(m)

4.2、The Radio Model

In our simulation experiments analysis, we discussed the radio model [9]. The transmit and receive energy costs for the transfer of a k-bit data message between two nodes separated by a distance of r meters is given by equations 1 and 2, respectively.

$$E_T(\mathrm{k}, r) = E_{Tx}\mathrm{k} + E_{amp}(r)\mathrm{k} \quad (1)$$

$$E_R(\mathrm{k}) = E_{Rx}\mathrm{k} \quad (2)$$

Given a threshold transmission distance of ro, the free-space model is employed when $r \leqq ro$, and the two-ray model is applied for cases where $r > ro$. Using these two models, the energy required by the transmit amplifier $E_{amp}(r)$ is given by

$$E_{amp}(r) = \begin{cases} \varepsilon_{FS} r^2, & r \leqq ro \\ \varepsilon_{TR} r^4, & r > ro \end{cases} \quad (3)$$

Where ε_{FS} and ε_{TR} denote transmit amplifier parameters corresponding to the free-space and the two-ray models, respectively, and ro is the threshold distance given by $ro = \sqrt{\varepsilon_{FS} / \varepsilon_{TR}}$ (4)

4.3、Performance Evaluation

To evaluate the performance of ONCR, we simulated the different nodes of number from cluster topology of edge length. Compared with 4 different cluster topology nodes number, namely each cluster have cluster5 (15 nodes) and cluster9 (45 nodes) have better then cluster7 (28 nodes) and cluster11 (66 nodes). To compares simultaneously 2 parts namely have the average energy dissipation and number of nodes alive. The simulate result in Fig. 4.3.1 and Fig. 4.3.2. And in cluster5, which had exhausted of energy until 200 rounds, but in cluster9 actually when 198 rounds. Therefore, cluster5 has a best from these different of result cluster. At the same time, the result also conforms to in front of us inferential reasoning. In alive of nodes part, also have same of simulated result. The Cluster5 results have better then other cluster in surplus alive nodes. Simultaneously the cluster5 is show gradually to die in surplus alive nodes, .but other cluster node has the phenomenon after a rounds number which the play falls. Another we will compare ONCR and LEACH in these 2 parts. In average energy dissipation part, which the LEACH had been completed dissipation of energy about 157 rounds as Fig. 4.3.3. But the cluster5 of ONCR algorithm have 200 rounds to transmit information. The alive nodes of compute are also present the ONCR better then LEACH as Fig. 4.3.4. Therefore, we propose the ONCR method can save the energy and the efficiency and the fault-tolerant aspect has the good contribution.

5. Conclusion

We propose the ONCR routing have saving energy in the limited energy of nodes. For connecting the cluster concept, we discuss the effective coverage among the nodes and design the average density in the grid area. We can calculate the optimum nodes number from the coverage range. Each cluster was selected the cluster head by serial number of nodes. And the cluster head transmit and collect information efficiently in the wireless network. The cluster head transmit data to sink by through next cluster head of same serial number. At same time, the ONCR routing protocol can balance dissipation energy of sensor nodes in the wireless network. The simulate result shows these novel routing protocol have performance in saving energy. We would study the challenges and performance when different sensors and random design the nodes in wireless network.

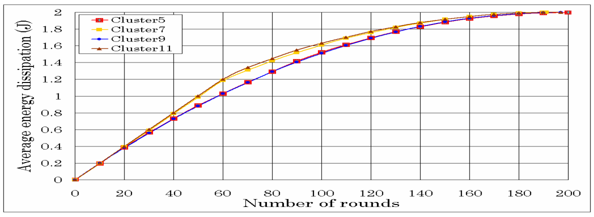

Fig. 4.3.1 The average energy dissipation of ONCR

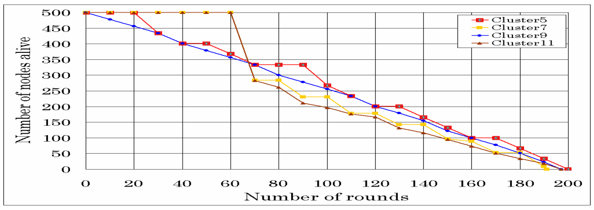

Fig. 4.3.2 The nodes alive of ONCR

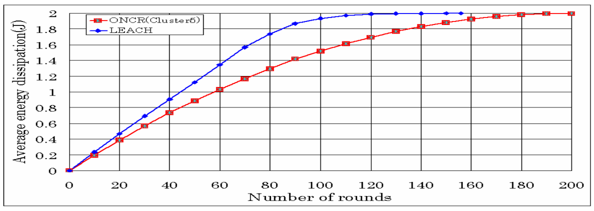

Fig. 4.3.3 A comparison ONCR and LEACH of average energy dissipation

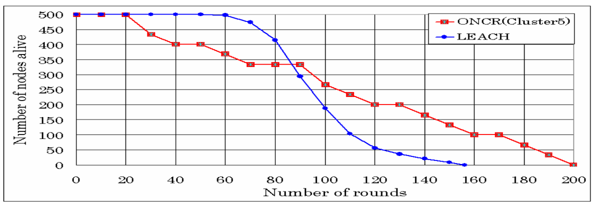

Fig. 4.3.4 A comparison ONCR and LEACH of system lifetime

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