

An Estimation Approach for Uniformity of Node-Distribution in Wireless Sensor Networks

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Abstract—Whether nodes-distribution is uniformity or not in WSNs(wireless sensor networks, WSNs) has a great influence on the using of nodes' energy and networks' coverage probability, connectivity and life time. Therefore, to estimate uniformity of node distribution in WSNs, we propose several estimation indexes, which are: U-measure index, distance-measure index, area-ration index and clustering index. At the same time, we compare the calculated data of the above indexes for 6 cases of net node distribution. Simulation results show that these indexes can estimate the uniformity of node-distribution in WSNs mostly.

Keywords—wireless sensor networks(WSNs); node distribution; uniformity estimation; estimation indexes

I. INTRODUCTION

Wireless Sensor Networks(WSNs) are intelligent networks, containing a lot of sensor nodes with particular function, which transmit information mutually and complete particular function synergistically by wireless self-organized communication^[1]. Because the number of nodes in WSNs is enormous, the deployment of nodes is only random. Therefore, to the simulation of nodes' region in WSNs, nodes simulation deployed are always random or uniform. But if nodes in nets are deployed uniformly, the performance of nodes will be improved mostly. Literature [2] has showed that node-distribution is uniform in theory, the coverage regional and average density of working nodes, so as to determine broadcasting range of every node. In the algorithm of cluster, the choice of cluster heads is much more important. If the choice of cluster heads is uniform, the networks' coverage probability and connectivity will be great affected. Literature [3] has showed a distributed clustering routing-HEED, which makes the distribution of cluster nodes uniform so as to get the reasonable topological structure, and prolong the nets' lifetime. However, the uniformity we mentioned is in relative, even the random is also considered the uniformity. Therefore, we can not judge whether nodes-distribution is uniform definitely. To discuss this problem, we propose several estimation indexes to estimate uniformity of node-distribution in WSNs.

For convenience of research, the deployment of nodes is only in square area. The edge length is R , and the coordinates of node i is (x_i, y_i) .

II. 6 Cases of Net Node Distribution

Here, we example 6 cases of net's node-distribution.

Figure1 shows the distribution of nodes is uniform. This distribution is in ideal condition, and in practical, it is difficult to realize. Figure2 shows the distribution of nodes is random, which is in general. However, the distributions, like Figure3-6, are always appeared. Node-distribution that is too aggregation or too dispersed is not we want. For these distributions, the nodes' performance will not be reflected, and the networks' coverage probability, connectivity and lifetime will be great affected.

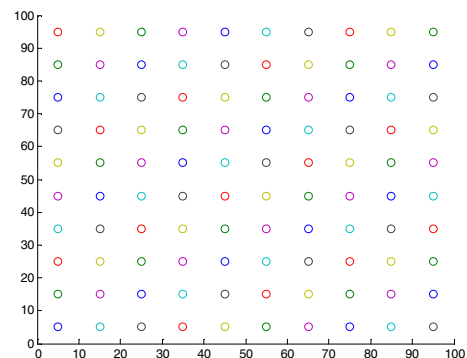


Figure1. Node-distribution is uniform

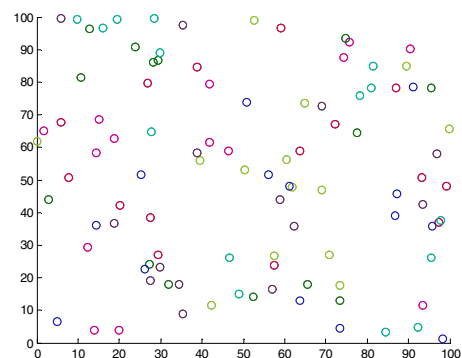


Figure2. Node-distribution is random

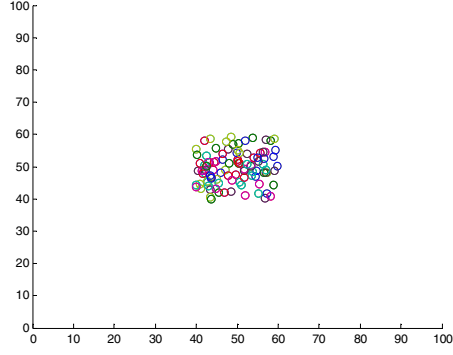


Figure3 Node-distribution is only in centre area

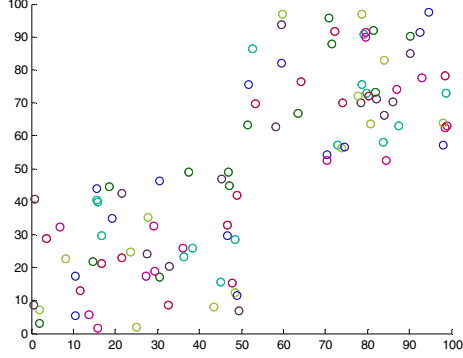


Figure4 Node-distribution is in diagonal area

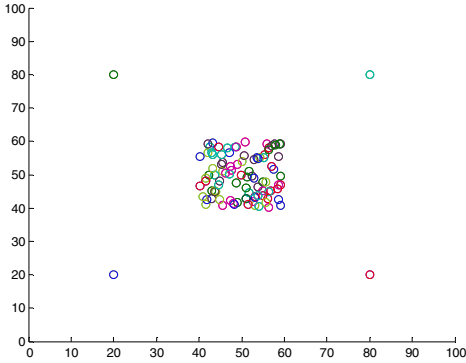


Figure5 Node-distribution is in centre area in most

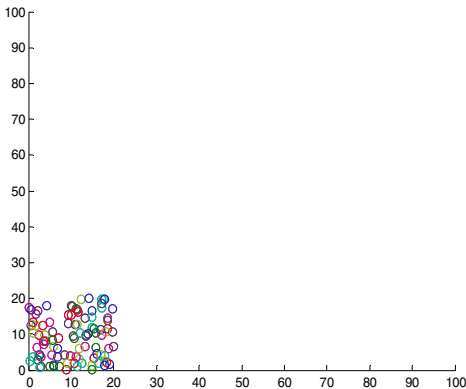


Figure6 Node-Distribution is only in corner area

III. ESTIMATION INDEXES FOR UNIFORMITY OF NODE-DISTRIBUTION

A U-measure

Literature [2] has showed a measure method for solution's uniformity, which is U-measure variance. Therefore we could apply this method to estimate uniformity of node-distribution.

First, for every node of the net, we find the nearest node to it, and then obtain the distance between them. If every distance is equal between the node and the node that is closest to it, then we could judge the distribution is uniformity.

Suppose u_i is the closest distance to node, i , and we call it is the minimum distance.

$$U = \sum_{i=1}^n (u_i - \bar{u})^2 \quad (\bar{u} = \frac{1}{n} \sum_{i=1}^n u_i) \quad (1)$$

Formulation (1) is called the U-measure variance. If U tends to 0 faster, node-distribution is much more uniform.

However, for this index, we may think that node-distribution is only in corner area, as in Figure6. This distribution tends to uniformity only in a small region, but not in whole region. Therefore, we propose the second index.

B Distance-Measure

Based on the coordinate of nodes, we obtain the average value of all abscissa and ordinate. That is

$$\begin{aligned} \bar{x} &= \sum_{i=1}^n x_i \\ \bar{y} &= \sum_{i=1}^n y_i \end{aligned} \quad (2)$$

We know the center of the net is $(\frac{R}{2}, \frac{R}{2})$, then if the distance between the two nodes is smaller, on a certain aspect, node-distribution is more uniform.

$$\sqrt{(\bar{x} - \frac{R}{2})^2 + (\bar{y} - \frac{R}{2})^2} \quad (3)$$

That is the value of the formulation (3) is smaller, it is better.

However, for this index, we may think that if all nodes are distributed in center region, the distance is low also, as in Figure2. As the former index, it can not explain node-distribution is uniform.

C Area-Ratio

This index is mainly discussed whether nodes are filled the whole region. Here we also use the u_i defined in U-measure. Using the half of u_i as the radius, and the node as the circle center, we call those circles as the minimal circle of every node. Then we add all areas of the minimal circle, that is

$$S = \sum_{i=1}^N \pi u_i^2 \quad (4)$$

If it close to the area of uniform node-distribution much more, and then node-distribution is uniform much more. But

when we choose the minimal radius, we ignore the existence of boundary point. For this selection of minimal radius, the area we get may beyond the area of the net. Therefore, as choosing the minimal radius, we add the distance of the node to all four boundaries: $up - \min$, $down - \min$, $left - \min$, $right - \min$. We choose the minimal from the five values. And then the area we get will not beyond the area of the net. That is

$$r_i = \min(u_i, up - \min, down - \min, left - \min, right - \min) \quad (5)$$

$$S_i = \sum_{i=1}^N \pi r_i^2 \quad (6)$$

For this index, we compare it with the area of minimal circle in uniform node-distribution, that is

$$\text{area-ratio} = \sum_{i=1}^N \pi r_i^2 / S_{\text{uniformity}} \quad (7)$$

If the area-ratio is closer to 1, the node-distribution is much more uniform.

But for this index, we neglect that most of nodes concentrate in certain region, but only a few nodes distribute far from those nodes, as in Figure5. The area we get may be large.

D Clustering Method

Literature [5] has showed a color clustering method. We know that every node in net has an average area, that is

$$s = \text{regional area} / \text{number of nodes} \quad (8)$$

We may think that there is only one node in the average area in uniform region, so we use the clustering method in Literature [5] as an index to judge the uniformity of node-distribution.

Concrete method is as follows. Suppose the set of all groups as $\{x_1, x_2, \dots, x_n\}$, among that, n is defined as the number of groups, n_i is defined as the number of nodes in group x_i . First we use the average area R of every node as a hold value, that is

$$R = \sqrt{s} \quad (9)$$

And then we take the first node as the first group. After that, when we get a node, according to compare the distance of the two nodes and the hold value, we judge that whether the node belongs to the groups existed. If it is existed, supposing x_i , then n_i is added 1; If not, then we establish another group.

We may think that if the number of clustering is closer to the number of nodes, and after the clustering, the number of clustering in which the number of nodes is 1 is much more, and then the node-distribution is much more uniform. At the same time, as the node-distribution is uniform, the number of clustering is the number of nodes, and the number of clustering in which the number of nodes is 1 is also the number of nodes.

IV. RESUL COMPARING

We use the former indexes to make a comparing to 6 node-distribution.

When illustrating the degree of the uniformity to 6 node-distribution, we has a standard, that is uniform node-distribution, as in Figure1. We judge whether node-distribution is uniform or not in other region, and we consider the indexes of uniform region as a standard. If the indexes of node-distribution in certain region are closer to the indexes in uniform region, then we think that this region is much more uniform. In these indexes, we think the distance-measure as the first predetermined condition. As in Figure6, we can directly observer the node-distribution is too dispersed in certain region, so we can not judge to other indexes. Next we use the U-measure, as in Figure5. The value of U-measure is too large. For some distributions, if these indexes are not too much difference, the index of area-ratio is used as an important index. In Figure3, nodes are distributed in certain region. Though the value of U-measure is small, the value of area-ratio is small too. We could consider nodes only possess a certain region, but not the whole region. For the clustering method, we believe it is similar to area-ratio. From Figure1, Figure3 and Figure4, the value of area-ratio and clustering method increased and decreased simultaneously. But if there is not the first two indexes as the predetermined condition, as in Figure5, the two indexes is out of proportion. So the two indexes also have difference.

TABLE 1. Comparing of 6 Node-distribution

Node-distribution	(1)	(2)	(3)		(4)	
			(3.1)	(3.2)	(4.1)	(4.2)
①	0	0	785.4	100%	100	100
②	2.36	6.39	243.2	31.0%	76	57
③	1.08	0.24	102.0	13.0%	12	1
④	2.53	4.64	123.0	15.7%	58	35
⑤	0.06	34.2	307.1	39.1%	13	5
⑥	57.1	0.30	101.8	13.0%	11	1

(In TABLE 1, (1)--Distance-measure, (2)--U-measure, (3)--Area-ratio, (3.1)--Sum of areas, (3.2)-- Number of clustering, (4)-- Clustering method, (4.1)--Number of clustering, (4.2)--Number of node is 1; ①--uniformity, ②--random, ③--only in centre area, ④--in diagonal area, ⑤--in centre area in most, ⑥--only in corner area)

V. CONCLUSION

Simulation results show that these indexes can estimate the uniformity of node-distribution in WSNs mostly. However, the Figures we proposed have some subjective one-sidedness, and that may not illustrate all special situations. If we could judge which regional nodes is uniform, and which regional nodes is aggregation or dispersed, and then net distribution and performance will be affected greatly, especially to nodes' second deployment. That will be our future direction.

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