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A Review on Node Deployment of Wireless Sensor Network

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Abstract

Wireless sensor network (WSN) is nowadays being applied in many different civilian applications like vehicle tracking, habitat monitoring, forest surveillance, earthquake observation, biomedical or health care applications and building surveillance. To a large extent the effectiveness of the wireless sensor networks depends on the coverage provided by the sensor deployment scheme. There are different deployment demands and optimization goals in different environment. In this paper, firstly the existing deployment method of sensor network nodes is summarized and discussed. Then three performance evaluation indexes are analyzed in detail. At last, the main deployment model of sensor network nodes is presented.

Keywords: *node deployment, coverage, connectivity, energy*

1. Introduction

Along with the rapid development of wireless communication, integrated circuit, sensors and micro electro mechanical systems (MEMS) and so on, the information acquisition technology of sensors has been developed to the integration, MEMS and networking, so wireless sensor network becomes increasingly mature. It is consisted of a large number of tiny sensor node using the radio communication, and its purpose is to collaboratively sensor, collect and deal with the real-time information from the object which is detected in the detection area of network, and send to the objects that need it. Therefore, the way of node's deployment influences the network's effectiveness in the whole WSN [1-2].

Good network node deployment can not only reduces the node redundancy and the network costs, but also can prolong the service life of the network. For example, in the building of traffic warning system, the collection of all kinds of transportation information which affects the traffic control is the foundation of getting good control effect. Therefore, in order to achieve the collection of traffic information using wireless sensor network, the coverage of sensor nodes deployment becomes one key work that is how to make use of effective node deployment to achieve maximum coverage, provide good connectivity and energy saving performance.

Management node, sink node and sensor single node make up the network structure of road wireless sensor node deployment,as shown in Fig.1. Management node in the network obtains data from the Internet, then stores the data in the database and provides records and search services. Sink node receives all kinds of traffic flow information, road information and people information, then do data fusion, and send the results to the management node,. Sensor node includes fixed node and vehicle node. Fixed nodes are respectively buried in road ground to check the road situation and buried in the two sides of road to collect the other traffic information. The client and mobile terminal will perform the function of information access.

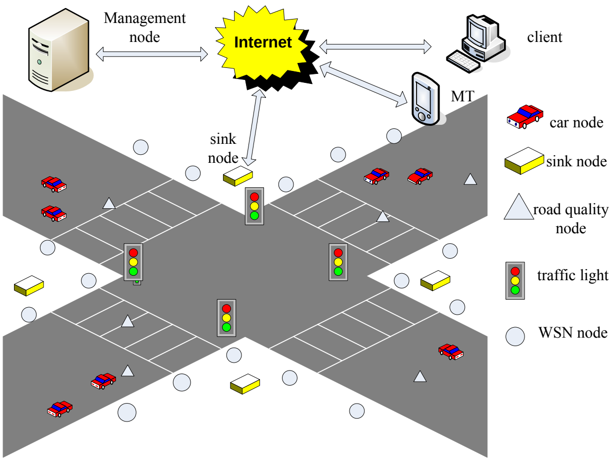

Fig. 1 Wireless sensor network for intelligent traffic.

In this paper, a integrated evaluation function is presented based on coverage, energy conservation and connectivity, according to the purpose of sensor node deployment in some systems. The analysis and discussion of the nodes deployment especially random deplyment are also given in this paper.

2. Classification of Node Deployment

At present, the researches on the deployment of wireless sensor nodes mainly concentrated in the static and the dynamic deployment.

2.1 Static Deployment

The static deployment chooses the best location according to the optimization strategy, and the location of the sensor nodes has no change in the lifetime of the WSN. At present, the static deployment includes the deterministic deployment and the randomly deployment.

The method of the deterministic deployment is firstly to do the surveyed area meshing and then carries on the network node deployment. In the study of the deterministic sensor node deployment based on the target coverage, the paper [3] proposes an deployment approach of sensor nodes by using the maximum multi-overlapping domains of target points and the genetic algorithm, which reduces the network deployment cost and realizes the optimal allocation of spaces resources in wireless sensor networks. The paper [4] proposes a method with target coverage based on grid scan. It first divide the area into grids. Then the best grid ia chosen to place the next sensor. The method can use the least nodes to achieve the target coverage, meet the required level of the whole coverage and get better positions for node deployment. Moreover, the deployment of wireless sensor network in deterministic space with obstacles is researched in paper [5]. Sensor's detection models and coverage quality evaluation are set up. Based on the probabilistic detection model with false alarm rate, a new deployment method is proposed. Watershed algorithm is employed to choose the deploying sub-area. Then Delaunay triangulation is used to generate the candidate positions for new nodes. Thus, the placement of WSN nodes is realized orderly and efficiently, and the proposed method can attain better detection probability and coverage uniformity compared with some methods. In the paper [6], the author also presents a deployment method of sensor nodes used in detecting and measuring the changes of temporal traffic patterns in large scale .

Different with the deterministic deployment, the random deployment is usually used in dangerous environment without stuff on duty, such as forest surveillance, earthquake observation and battlefield. large quantity of wireless sensor nodes are thrown in these areas, and then self-organized network formed.

The self-organized algorithms is proposed by waking up some sensor nodes or making some sensor nodes sleep. The paper [7] proposed a mixed algorithm for visual sensor network, This algorithm used the virtual potential field to make the sensor nodes shift positions and change directions automatically in detection area based on directional sensing model. With the completion of multiple prior coverage of hot targets which needed higher quality requirements, the algorithm could maximize the coverage rate throughout the detection area.The paper [8] also proposed a strategy of WSN nodes randomly deployment based on Poisson distribution. In this strategy, first established the model of WSN node distribution, and then find the relationship between the percentage of coverage area and the nodes density of target area, lastly find the best range of nodes density to get the optimal deployment.

2.2 Dynamic Deployment

The dynamic deployment may be backed to the deployment of the robot. In order to make the sensor networks get the maximum performance, sensor nodes need automatically move to proper location, then start to work. Random deployment, namely randomly throw nodes firstly, and then using a variety of optimization algorithm for deployment optimization. Such as Virtual force algorithm [9], virtual force oriented particles algorithm [10], simulated annealing algorithm [11], particle swarm optimization algorithm [12] and simulated annealing genetic algorithm [13].

3. Performance index of Node Deployment

The key points of the research on node deployment algorithm are to increase the coverage area, enhance network connectivity, prolong the network lifetime, make the load balance, improve the accuracy of the data transmission and strengthen the tolerance of nodes. Obviously, it has the certain difficulty if just using random node deployment to completely meet those design goals. At the same time, how to reduce the deployment cost is still needed to be solved, although it can meet the needs of major and minor deployment objectives. Generally, the optimization of the sensor nodes deployment mainly includes the following performance indexes.

3. 1.Coverage Area

How to get maximum coverage is always the hotspot of the optimization problem in wireless sensor network deployment. Coverage is an important issue in WSN and is related to energy saving, connectivity, and network reconfiguration. It mainly solves how to deploy the sensor nodes to achieve effective coverage of the service area so that every point in the service area is monitored at least by one sensor node. A good coverage is indispensable for the effectiveness of wireless sensor networks [14]. Assume that the sensor radiation range is the coverage area of disk shape, the radius equal to radiation range, and the ratio of the area covered by node against whole area of deployment is the index of the monitoring area coverage.

Literature [15] puts forward a kind of model similarly to grid scanning algorithm, wherein the obstacle will hinder the detection of sensor node to the target and the accuracy of the target detection probability is changing with the distance between sensor nodes and detection target . Literature [16] puts forward a method of using the minimum quantity of sensor nodes to realize the maximum coverage, and presents the triangle grid computing algorithm which makes any three adjacent nodes form a equilateral triangle. By regulating the distance between nodes to control coverage and proved that the detection area will be completely covered when $d_{th} = \sqrt{3}r$ (r , node perception radius). As shown in Fig.2. We also can get the approvement from literature [11].

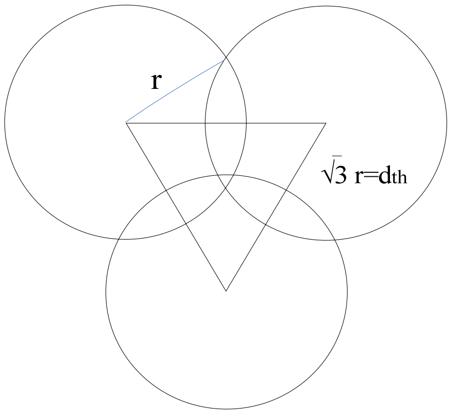

Fig. 2 Maximum coverage area.

3.2 Net Connectivity

Network connectivity is the communication between the wireless sensor nodes, the node and base station, base station and the client, the client and the server. But in the early days, the network connectivity is not difficult problem. The literature [17] considered the complete coverage and connectivity of the sensor nodes, which are located in the sensing radius of node and are connected. For this, we only need to build routing between the node and base station to send the data.

3.3 Network Lifetime

One of the most important requirements of WSN is to reduce the energy consumption. Hence, there is a need for energy efficient communication and routing techniques that will increase the network lifetime [18]. The major cause of energy waste is collision. When a node receives more than one packet at the same time, these packets are termed collided, even when they coincide only partially. All packets that cause the collision have to be discarded and retransmissions of these packets are required, which increases energy consumption. The second reason for energy waste is overhearing, which means that a node receives packets that are destined to other nodes. The third energy waste occurs as a result of control-packet overhead. They investigate differences of the behaviour of our agent based SMAC protocols in real deployment compared to the results produced using our custom based simulator, which ignores the lower layers effects, such as packet collision and overhearing.

4. Modeling Method

4.1 Perceptual Model

When deploying a Wireless Network System in a region, the distance between target position and node will affects the sensory ability to information of sensor node. According to the different characteristics of sensor nodes, each sensor nodes' sensing range to the target is different. And only when the target has a certain distance from sensor node, the target could be detected. So, for the characteristic of the sensor, when the target distances to sensor node beyond a certain range, the sensory ability of the node will appear unstable phenomenon. At present, three perceptual models has been proposed: boolen sensing model, probabilistic sensing model, directional sensing model.

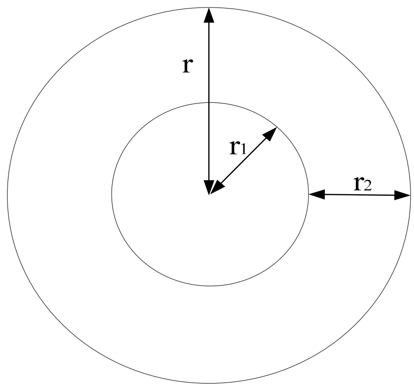

Fig. 3 Perception radius of sensor node.

The probabilistic sensing model reflects the changing regularity of sensing ability, which changing with the distance between the target and sensor node, as shown in Fig.3. So, there's a notion of fuzzy coverage in sensor network. This paper only considers the same membership function parameters of the problem, and the perception radius of every node are identical .If assuming the coordinate of the sensor node S_k is (x_k, y_k) , the coordinate of perception target p is (x, y) , $P(S_k, p)$ is the probability of perception. According to the characteristics of fuzzy covered sensors, assume that the model based on the node S_k and the object p as the following equation shown.

$$P(S_k, p)=\begin{cases} 0 & r \le d(S_k, p) \\ e^{-\lambda a^{\beta}} & r_1 \le d(S_k, p) < r \\ 1 & r_1 > d(S_k, p) \end{cases} \quad (1)$$

In equation (1), λ and β are the characteristic parameters (λ >0 , $1 \geqq \beta$ >0) , $a = d(S_k, p) - r_1$. Based on the parameter λ and β , the threshold value of sensor's sensing range is d_{th} :

$$d_{th} = \exp(-\lambda r_3^{\beta}) \quad (2)$$

And the distance between wireless sensor node S_k and p is $d(s_k, p)$:

$$d(S_k, p) = \sqrt{(x_k - x_p)^2 + (y_k - y_p)^2} \quad (3)$$

In Fig.3, there is the definition of wireless sensor node perception radius. In Fig.4, it shows the optimal distance of two nodes so as to get the maximum deployment area.

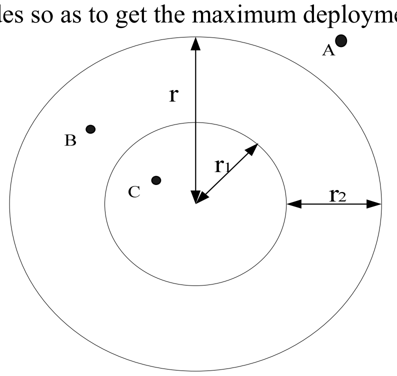

Fig. 4 Monitoring objects and node distance.

4.2 Energy consumption Model

The energy consumption of the sensor node in the working process includes the energy to produce the local data, the energy to receive data, the energy to transfer data and the energy consumption when the node in the dormant state. The energy to produce data is as small as the energy consumption of the sleeping node, and they are so small that can be neglected. When every sensor node is endowed with the same initial energy, the nodes near the sink node will be leaded to early death because of transmitting large quantities of data. So the whole network will lose its energy balance. So making the load of every node balance becomes the key problem of promoting an improvement in saving energy. Power control is one of the effective ways to prolong system lifetime, including two transmission patterns: transmission with high power and more jumping transmission with low power. But the former will lead the energy of node far from the sink to run out firstly, and the later will increase the load of the whole network. So an energy model base on adjusting the distance among the nodes to balance network load was improved to achieve the effective network nodes deployment.

Every node is endowed with the same initial energy E_0 . Assume that the energy of receiving unit data is e_r , the energy of transmitting unit data to the next node is e_i :

$$e_i = e_r + kd_i^2 \quad (4)$$

then the total energy consumption of the node S_i is E_i :

$$E_i = (i-1)le_r + ilkd_i^2 \quad (5)$$

In this equation, l is the number of data packets of per unit produced by each node and d_i is the distance between the node s_i and s_{i-1} . So, the lifetime of the node s_i is T_i :

$$T_i = \frac{E_0}{E_i} \quad (6)$$

In the wireless sensor network, the lifetime of network is T_{net} .When the energy of any sensor node is run out, the whole network will stop work, so T_{net} is the minimum of all nodes' lifetime:'

$$T_{net} = \min(T_1, T_2 \cdots T_n) \quad (7)$$

In order to extend the lifetime by making each node well utilize its energy, we let each node run out of energy at the same time and become dead at the same time. In addition, for keeping the connectivity of node, the distance between nodes should be limited. Assuming the distance of region that is deployed by sensor node is D . So the energy model of network could be describe as follows:

$$\begin{cases} E_1 = E_2 = \cdots = E_n \\ kd_1^2 = e_r + 2kd_2^2 = \cdots = (i-1)e_r + ikd_i^2 \\ \quad = (n-1)e_r + nkd_n^2 \\ 0 < di < r \\ \sum_{i=1}^{n} d_i = D \end{cases} \quad (8)$$

According to the load and the distance of transmission of each node, the last deployment distance of adjacent nodes will has the relationship like: $d_1 > d_2 > \cdots > d_n$.

4.3 Coverage ratio Model

As a assessment index to measure the degree of detecting area coverage, the coveragy rate is an important computing object in the deployment of senor nodes. In the process of the optimized deployment, the value of the coverage ratio decides whether to continue the optimized deployment. When the value of coverage ratio reaches a certain value, the course of deployment ends.

Assume that amounts of sensor nodes will be deployed in an area.The number of the nodes is n, $width$ is the width of this area and $length$ is the length of this area. The overlapping area is first computed, and the computational equation is as follows:

$$overlapi = \sum_{j=d}^{k}(2*r^2*\theta - r*d_{ij}*\sin\theta) \quad (9)$$

The $overlapi$ is the overlapping area of the sensor node i which intersects with the other sensor nodes; the $d_{ij}=\sqrt{(x_i-x_j)^2+(y_i-y_j)^2}$ is the distance between the sensor node i and j; k is the set of the sensor nodes that meet the conditions: $d_{ij}<2r$, $k>i$; the d is the minimum number of this set but greater than i; $\theta=\arccos\frac{d_{ij}}{2*r}$ is the angle between the two intersection of any two sensor nodes. So the coverage ratio could be calculated by the equation (10).

$$coverate = \frac{n*\pi*r^2-\sum_{i=1}^{n}overlapi}{width*length} \quad (10)$$

As shown in Fig.5, we could well understand the definition of each parameter in equation (9).

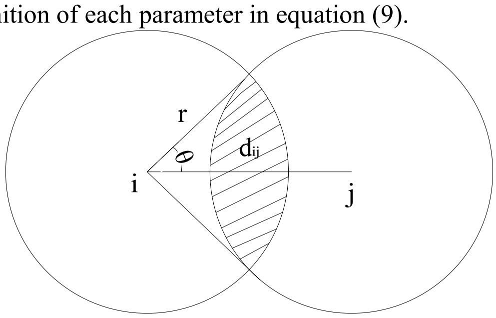

Fig.5 The overlapping area of sensor nodes

5. Conclusions

In this paper, the complete process of wireless sensor network about the deployment are summarized and analysed. In the light of information collection system, the preliminary modelling method has been summarized. In the future work, I will do further research and implementation of sensor nodes deployment.

Acknowledgments

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References

.[1] M. Chithik Raja, and V. S. Balasubramanian, "Analysis and a report of wireless sensor networks and applications", International Journal of computer science issues, Vol. 8, No. 4, 2011, pp. 589-597

[2] G. K. Ragesh, and K. Baskaran, "An Overview of Applications, Standards and Challenges in Futuristic Wireless Body Area Networks", International Journal of computer science issues, Vol. 9, No. 1, 2012, pp. 180-186

[3] X. He, X. L. Gui, and J. An, "A Deterministic Deployment Approach of Nodes in Wireless Sensor Networks for Target Coverage", Journal of XiAn Jiaotong University Vol. 44, No.6，2010，pp.6-10.

[4] X. M. Guo, C. J. Zhao, X. T. Yang et al, "A Deterministic Sensor Node Deployment Method with Target Coverage Based on Grid Scan", Chinese Journal of Sensors and Actuators, Vol.25, No.1, 2012, pp.104-109

[5] Y. Z. Zhang, C. D. Wu, L. Cheng et al, "Research of node deployment strategy for wireless sensor in deterministic space", Control and Decision, Vol. 25, No. 11, 2010, pp. 1625-1629

[6] T. Qin, X. H. Guan, and W. Li, "Dynamic Features Measurement and Analysis for Large-scale Network", in Proceedings of International Conference on Communications, 2008, pp. 212-216

[7] H. Xiang, L: Peng, G. Liu et al, "Multiple target coverage considering area coverage in visual sensor network", Application Research of Computers, Vol..29, No. 9, 2012, pp. 3428-3431

[8] M. Li, D. R. Ding, and T. L. Guo, "Random Deployment Strategy of Wireless Sensor Network Node", Computer Engineering, Vol. 38, No. 5, 2012, pp. 99-101

[9] Q. Luo, and Z. M. PAN, "An Algorithm of Deployment in Small-Scale Underwater Wireless Sensor Networks", Chinese Journal of Sensors and Actuators, Vo. 24, No. 7, 2011, pp. 1043-1047

[10] X. Wang, S. Wang, and J. J. MA, "Dynamic Sensor Deployment Strategy Based on Virtuai Force-Directed Particle Swarm Optimization in Wireless Sensor Networks", Acta Electronica Sinica, Vol. 35, No. 11, 2007, pp. 2038-2042

[11] F. Y. S. Lin, and P. L. Chiu, "A Near-optimal Sensor Placement Algorithm to Achieve Complete Coverage Discrimination in Sensor Network,", IEEE Communications Letters，Vol. 9, No. 1, 2005, pp43-45

[12] Y. Liu, "Wireless Sensor Network Deployment BasedonGenetic Algorithm and Simulated Annealing Algorithm", Computer Simulation, Vol. 28, No.5, 2011, pp. 171-174

[13] W. H. Liao, Y. C. Kao, and Y. S. Li, "A Sensor Deployment Approach Using Glowworm Swarm Optimization Algorithm in Wireless Sensor Networks", Expert Systems with Applications, Vol. 38, No. 2011, pp. 12180–12188.

[14] A. Boukerche, X..Fei, and R. B. Araujo, "A Coverage Preserving and Hole Tolerant Based Scheme for the Irregular Sensing Range in Wireless Sensor Networks", in Proceedings of the Global Telecommunications Conference, 2006, pp. 1-5

[15] S. Dhillon, and K. Chakrabarty, "Sensor Placement for Effective coverage and surveillance in distributed sensor

networks", in Proceedings of the IEEE Wireless Communications and Networking Conference, 2003, Vol. 3, pp.1609-1614 .
[16] D. Pompili, T. Melodia, and L. F.Akyildiz, "Deployment analysis in underwater acoustic wireless sensor networks", in Proceedings of the ACM International Workshop on Under-Water Networks, 2006, pp.48-55.
[17] K. Kar, and S. Banerjee, "Node placement for connected coverage in sensor networks", in Proceedings of the Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, 2003, pp. 50-52
[18] E. M. Shakshuki, H. Malik, and T. R. Sheltami, "A Comparative Study on Simulation vs. Real Time Deployment in Wireless Sensor Networks", Journal of Systems and Software Vol. 84, No. 1, 2011, pp. 45–54.

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