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An Improved Centroid Algorithm in Wireless Sensor Network

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Abstract: Due to the anisotropic network, the distribution of nodes is completely random, network topology is not uniform, through the centroid algorithm there are some errors between estimated position and actual position of nodes, "cluster effect" error is prone to made in the positioning process. In order to overcome the positioning error resulting, a modified centroid algorithm is proposed that adds the stage of a correction of node estimated position on the basis of the traditional centroid algorithm positioning completion.

Key words: Wireless sensor network, node localization, centroid algorithm

INTRODUCTION

The traditional centroid algorithm is based entirely on the network connectivity, without coordination between the beacon nodes and the unknown node. Therefore it is relatively simple and easy to implement. However, it is an estimate that the center of mass is used as the actual location. The accuracy of such estimate is influenced by the density and distribution of beacon node, the greater the density, the more uniform distribution, and higher positioning accuracy. However, due to the random deployment of wireless sensor network nodes to monitor regionalusually by aircraft. Therefore it is difficult to meet the requirements of uniform node distribution. Many researchers have proposed improved centroid algorithm. Such as density adaptive HEAP algorithm of beacon nodes to improves positioning accuracy by increasing beacon nodes in regions with low density (Harter and Hopper, 1994). Weighted centroid localization algorithm analyze radio propagation path loss model and improve the node positioning accuracy using he influence of unknown nodes estimated position calculated with different beacon nodes as a weighting factor (Want *et al*., 1992). The improved centroid algorithm based on genetic algorithm use improved genetic algorithm to calculate positioning weights (Niculescu and Nath, 2003). Weighted centroid localization algorithm based on the number of hops uses the hop count information as a weighting factor and reflects the influence beacon node on unknown node coordinates (Bulusu *et al*., 2000). The field center strength weighted multi-hop centroid localization algorithm improved the positioning ratio by extending the single-hop to multi-hop (Akyildiz *et al*., 2002). These algorithms are measurements obtained by the energy of new information or from the node density requirements. Due to the anisotropic network, the distribution of nodes is completely random, network topology is not uniform (Chong and Kumar, 2003), through the centroid algorithm there are some errors between estimated position and actual position of nodes, "cluster effect" error is prone to made in the positioning process. In order to overcome the positioning error resulting, a modified centroid algorithm is proposed that adds the stage of a correction of node estimated position on the basis of the traditional centroid algorithm positioning completion.

THEORY OF THE IMPROVED CENTROID ALGOTITHM

This article assumes that all the nodes in same environment where the space is two-dimensional plane. The position in the coordinate system can be completely determined with the coordinates (x, y) and require adjacent beacon nodes need to synchronize. They emit a signal that there is no overlap in time in order to avoid conflict.

Theory of the improved centroid algorithm is as the following. Firstly, determine the beacon node vertices convex polygon area, calculating the centroid of the area and using the location of the centroid position as the estimated position of unknown node. When unknown nodes obtain their own estimation position, beacon node gets the estimated location through the centroid algorithm. Correction coefficient is gotten according to the deviation information of the estimated position and

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the actual position of the beacon nodes and correction factor and related formulas are used to correct position results of the unknown node around beacon nodes.

The improved Centroid algorithm process is as follows:

- First step is node initialization. When node is randomly shed or deployed in some way, each node is firstly initialized including the identification number of the node, the time information, the communication mode is set, the transmitter and receiving mechanisms. The beacon nodes obtain their own exact location of the initial position information through receivers deployed artificially or equipped with GPS
- Second step is obtaining beacons node information. Beacons node periodically broadcasts its own information to the neighbor nodes all around including ID number and location information. After the surrounding nodes receive the broadcast information, the beacon node's ID number and location information are saved and minus one from hop count of the recieved information packet, then continue to broadcast to their neighbor nodes. When unknown node records the information from different beacon nodes, the beacon nodes also need to communicate. After beacon node receives broadcast messages from other beacon nodes, a topological network is built by self-organization
- Third step is obtaining the estimated position of unknown nodes. When beacon packet quantity exceeds a certain threshold k or reception after a certain time, the polygonal area is determined by a plurality of beacon nodes based on the received parameter information. By positioning ideas of centroid algorithm, get the the average value of polygon vertex coordinates and calculate the estimated position of the unknown node by Eq.1:

$$(x, y) = \left(\frac{x_1 + \cdots + x_k}{k}, \frac{y_1 + \cdots + y_k}{k}\right) \qquad (1)$$

- Fourth step is to fully realize the communication between neighbor beacon nodes. In order to make positioning accuracy more precisely, the beacon node should receive broadcast information from all the neighbor beacon nodes. In all nodes of the network deployment, if neighbor beacon nodes receive the broadcast information from each other, the go to step five, otherwise go to the second step to receive broadcast message of the other beacon nodes
- Fifth step is to obtain estimated position of beacon node. a certain number of neighbor beacon nodes is selected as the reference node, according to the idea of the centroid algorithm, the centroid coordinates of polygons constituted by the these beacon nodes is selected as its estimated position information
- Sixth step is to caculate beacon nodes and broadcast correction coefficient. After the beacon node get the estimated position through the fifth step, the actual location will be compared with the estimated location, the difference between the two divided by the actual position is the beacon node correction factor which can be obtained by the Eq.2:

$$\begin{cases} \mu_{xi} = \dfrac{(x_{ai} - x_{ei})}{x_{ai}} \\ \mu_{yi} = \dfrac{(y_{ai} - y_{ei})}{y_{ai}} \end{cases} \qquad (2)$$

Correction factor is then broadcast to a neighbor unknown node. In Eq. 2, (μ_{xi}, μ_{yi}) is Correction factor, (x_{ai},y_{ai}) is the actual position of beacon nodes i, (x_{ei},y_{ei}) is the estimated position of beacon nodes i.

- Seventh step is to get the average correction factor. Assuming unknown nodes received a total of n ($n \geq k$) neighbor beacon node packet information within a certain time, According to a correction coefficient of each beacon node received, get the average correction factor by Eq.3:

$$\begin{cases} \mu_{xave} = \frac{\mu_{x1} + \mu_{x2} + \cdots + \mu_{xn}}{n} \\ \mu_{yave} = \frac{\mu_{y1} + \mu_{y2} + \cdots + \mu_{yn}}{n} \end{cases} \qquad (3)$$

In Eq. 3, (μ_{xave}, μ_{yave}) is the average correction factor, (μ_{x1}, μ_{y1}) ... (μ_{xn}, μ_{yn}) are sequentially correction coefficients of beacon nodes.

- Eighth step is the unknown node amendment positioning results. After unknown node received average correction factor of beacon nodes, the difference between the estimated location of unknown node and the average correction coefficient is used as the corrected position coordinates which is used as the position coordinates of the centroid. Positioning results are corrected by Eq. 4:

$$\begin{cases} x_c = x - \mu_{xave} \\ y_c = y - \mu_{yave} \end{cases} \qquad (4)$$

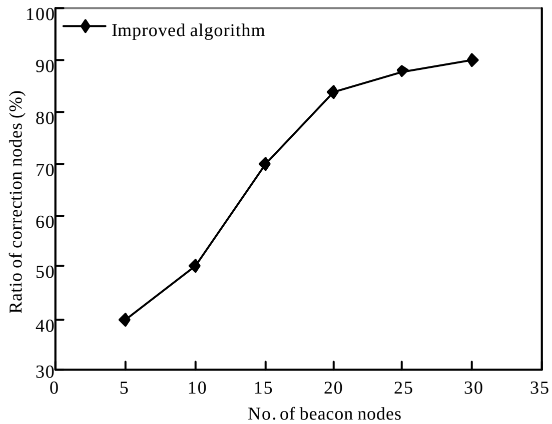

Fig. 1: Rate of corrected nodes when the total number of nodes is 100

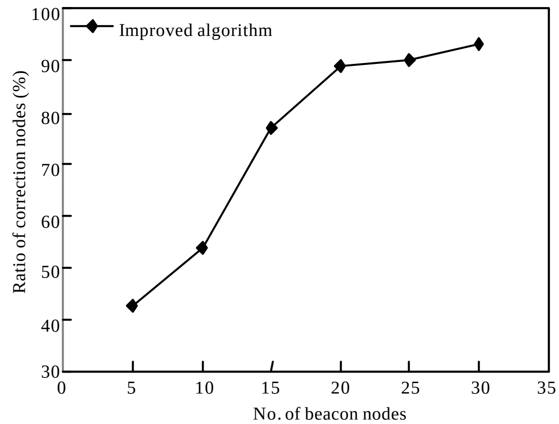

Fig. 2: Rate of corrected nodes when the total number of nodes is 300

In Eq. 4, (x_c, y_c) is the position amended of unknown node, (x, y) is the estimated position of the unknown node, (μ_{xave}, μ_{yave}) is the average correction factor

- Ninth step is that the unknown node becomes a beacon node after positioning correction which broadcasts its position information to the network and assist the other unknown nodes in the completion of positioning

The improved algorithm adds the correction phase in the traditional centroid algorithm. The beacon nodes need to communicate and also need to estimate the position then sends position correction information to neighbor's node.

SIMULATION OF IMPROVED CENTROID ALGORITHM

The following experiment is the simulation of improved centroid algorithm, Performance indicators are considered from the modified node rate.

Experimental analysis of the rate of correction nodes. In the experiment, randomly select some node as beacon node, the simulation will verify the changes that the ratio of corrections nodes increase with the total number of beacon nodes in the improved algorithm, see Fig. 1 and 2.

Simulation results show that network connectivity increase correspondly with the increase in the number of beacon nodes node in the improved algorithm. When the total number of nodes is 100 and beacon node number is 20, the proportion of correction node reaches 85%. When the total number of nodes is 300 and beacon node number is 20, the proportion of correction node reaches 90%. The

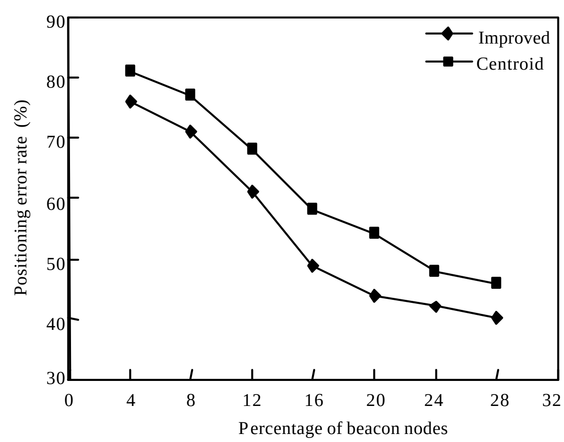

Fig. 3: Position errors when the total number of nodes is 100

experimental results demonstrate that improved algorithm can achieve most of the node's position correction when beacons node reaches a certain number.

Experimental analysis of positioning error. In this experiment, the total number of nodes 100 and 300, randomly select some node as beacon node, compare the positioning error between the centroid algorithm and the improved centroid algorithm. The result is showed in Fig. 3 and 4.

It can be seen from the simulation results that beacon node density and connectivity are two important factors which affect node positioning errors. When the percentage of beacon nodes increases gradually, its network connectivity also increases. A beacon nodecan communicate with many surrounding beacon nodes. Then the value of calculated correction coefficient is more

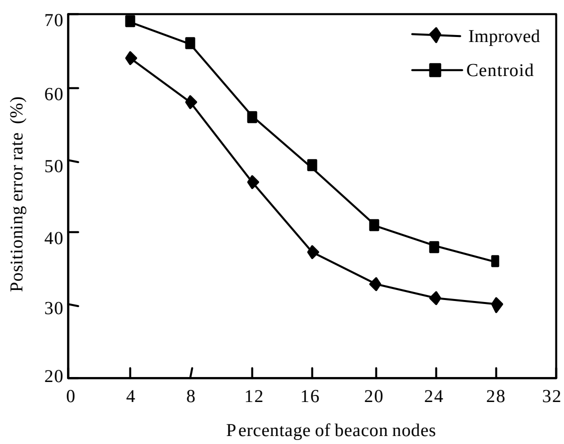

Fig. 4: Position errors when the total number of nodes is 300

accurate. Thus, when an unknown node receives the correction coefficient, it can fix its position more accurate and positioning error decreases.

When the total number of nodes is one hundred, the average location error of improved algorithm reduces 7.0% than that of the centroid algorithm. When the total number of nodes is three hundred, the average location error of improved algorithm reduces 7.9% than that of the centroid algorithm. Simulation results verify the correctness of the improved algorithm in theory.The positioning accuracy of the improved algorithm is better than centroid algorithm in both situation of different total number of nodes and different ratio of beacon nodes.

CONCLUSION

The improved algorithm adds correction stage in traditional centroid algorithm. Beacon node need to communicate to each other and estimate position. Then beacon node need to send position correction information to the surrounding neighbors. All these will cause the energy consumption of beacon node. The improved algorithm of this paper improves the positioning accuracy of the nodes at the expense of communication and calculation.

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