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Improved Correction Localization Algorithm Based on Dynamic Weighted Centroid for Wireless Sensor Networks

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Abstract: For wireless sensor network applications that require location information for sensor nodes, locations of nodes can be estimated by a number of localization algorithms. However, precise location information may be unavailable due to the constraint in energy, computation, or terrain. An improved correction localization algorithm based on dynamic weighted centroid for wireless sensor networks was proposed in this paper. The idea is that each anchor node computes its position error through its neighbor anchor nodes in its range, the position error will be transform to distance error, according the distance between unknown node and anchor node and the anchor node's distance error, the dynamic weighted value will be computed. For each unknown node, it can use the coordinate of anchor node in its range and the dynamic weighted value to compute it's coordinate. Simulation results show that the localization accuracy of the proposed algorithm is better than the traditional centroid localization algorithm and weighted centroid localization algorithm, the position error of three algorithms is decreased along radius increasing, where the decreased trend of our algorithm is significant.

Keywords: Wireless sensor networks (WSN), Centroid localization, Weight, Correction localization.

1. Introduction

With the development of electronics and wireless communications technologies, sensor nodes have a trend of miniaturization, cheap and smart. Each node has a low-power processor, un-replaced battery power, limited computation capacity and a radio transceiver for communication. Nodes are responsible for gaining data and sending to sink node, thousands of nodes to form a large wireless sensor network to monitor the huge terrains [1].

In wireless sensor networks (WSN), the location in formation is crucial, when an abnormal event occurs. The sensor node detecting the event needs the location information to locate the abnormal event and report to the sink node. Therefore, the location information is usually embedded in the report message generated by the sensor node. Without location information, wireless sensor networks can't work properly. Therefore, location awareness has become an important feature for many wireless sensor networks applications. It provides location information to each individual node in the network over which services like event reporting, routing, data aggregation and many other higher level services can be built [2]. Examples of such applications include target tracking, location-aided routing, and safety protection, *et al*. Because of cost and energy constraints, not all nodes may have been equipped with GPS [3] (Global Positioning System). Therefore, localization systems for WSN usually employ a small set of nodes which know their own position (called anchor nodes), and the anchor nodes usually randomly distribute in the network, the unknown nodes will use these anchor nodes localization to discover their coordinate. Without the location information, the raw data would not be useful for many applications [4]. Also the localization system's architecture influences the outcome of a localization system. It plays a more important role especially when we have mobile nodes or/and mobile anchors in the network. The architecture of a localization system has a significant impact on its scalability, its ability to preserve user location privacy, its ease of deployment, and its accuracy.

2. Related Work

In the past several years, a number of localization protocols have been proposed. We classify the existing localization algorithms into two categories: the stationary anchor localization algorithms and the mobile anchor localization algorithms. The deployment and number of anchor nodes could greatly influence localization accuracy [5]. However, the more anchor nodes are, the larger the cost of deployment network is. Once all the nodes are located, anchor nodes will be not so important. So some researcher used a mobile anchor node (AN) dynamic moving in the network to assist location, which can reduce cost of computation and communication. Furthermore, since the AN can move to blind areas where static anchor nodes do not cover, it may communicate with all the nodes directly, which could enhance localization accuracy [6].

Stationary anchor location algorithm use stationary anchor information for localization, which can be classified as range-based and range-free. The range-based algorithm uses absolute point-to-point distance or angle estimates for calculating the location, which are relatively precise but require additional hardware and their cost is relatively high [5], Common approaches for distance or angle estimation include received signal strength indicator (RSSI) [7]; time of arrival (TOA) [8]; time difference of arrival (TDOA) [9] and angle of arrival (AOA) [10], TOA is based on the range estimations by the signal arrival time, while TDOA relies on the difference in time between two arrived signals. Angle of arrival (AOA) to estimate node position is proposed in [10], the principle of AOA is to detect the originators of signals according to the angle of arrival, and then to calculate the positions of nodes by means of triangulation. Maximum likelihood estimation (MLE) is an alternative used in AHLoS system (Ad-Hoc Localization System) [11], whose aim is to minimize the differences between the measured distances and estimated distances to determine the position of nodes. However, equipping all sensor nodes with a GPS receiver is not a realistic solution because it increases the cost, size and energy consumption of the sensor nodes [12]. While producing fine grained locations, range-based protocols remain cost-ineffective due to the cost of hardware for radio, sound, or video signals, as well as the strict requirements on time synchronization and energy consumption. Range-based approaches can obtain more accurate measurements, but they require complex and expensive hardware [13].

The range-free scheme enables sensors to learn their location information without the aid of range estimates, it is suitable for sensor positioning due to its cost-effectiveness. An amorphous positioning algorithm, DV-Hop, addressed in [14], employs offline hop-distance estimations to improve location estimates via neighboring information exchanges. In [15], DV-Hop localization algorithm based on improved average hop distance and estimate of distance considered the feature of coincidence or part of the overlap which existed in the path from unknown nodes to beacon nodes and the path between anchor nodes, it improved average hop distance and used the error to correct. In [16], an improved localization algorithm for DV-Hop based on trusty degree used estimating the value of trusty degree to filter appropriate average distance per hop. In [17], an improved DV Hop localization algorithm for wireless sensor networks used the angle to compute the distance of unknown nodes and anchor nodes, the angle ∠ABC formed by three neighbor nodes A, B and C in the path of unknown nodes and beacon nodes, and given distance data among the nodes. This angle ∠ABC was estimated with an overlapping degree of B's neighbor node sets collecting with A and C, respectively. In [18], an improved DV-Hop positioning algorithm based on angle threshold was proposed, which can set the angle threshold to filter out the anchor nodes and improve DV-Hop's positioning capability. New node localization scheme virtual beacons-energy ratios localization (VB-ERL) and its refinements for the WSN are presented in [19]. In the scheme, the mobile node moves in the surveillance field based on the Gauss-Markov mobility model and periodically broadcasts the information packets. Each static unknown node receives the virtual beacons and energy in its sensing grange, and estimates its location by finding the intersection of a set of hyper-spheres. A two-objective evolutionary approach based on topological constraints for node localization in wireless sensor networks was proposed in [20], it takes concurrently into account during the evolutionary process both the localization accuracy and certain topological constraints induced by connectivity considerations. A direction-based localization scheme (DLS) was proposed in [21], whose main goal is for each sensor to determine its direction rather than its absolute position, DLS considers multiple messages received for a sensor to determine its direction and anchor deployment strategy to improve the estimated correctness in direction of the sensor within the communication range of the sink. Linear-regression-based weighted centroid localization algorithm in wireless sensor network was proposed in [22], it improved weighted centroid localization algorithm by the use of hops between nodes, centralization and then calibrated the nodes' position by the use of linear regression. Finally, the algorithm corrected the position through certain parameters.

The more anchor nodes are, the larger cost of deployment network is. Once all the nodes are located, anchor nodes will be not so important. So some researcher used a mobile anchor node (AN) dynamic moving in the network to assist location, which can reduce cost of computation and communication. Furthermore, since the AN can move to blind areas where static anchor nodes do not cover, it may communicate with all the nodes directly, which could enhance localization accuracy [6]. In [23], they proposed a localization scheme using a mobile anchor. Each anchor, equipped with the GPS, moves in the sensing field and broadcasts its current position periodically. The sensor nodes that obtain the information are able to compute for heir locations.

To provide localization in networks where land mark density is low, hop-based techniques propagate location announcements through out the network. Mobile anchor localization algorithms also compute node-to-node distances by RSSI, TOA, TDOA, and AOA. Zhang *et al.* [24] proposed very low energy consumption wireless sensor localization for dangerous environments with single mobile anchor node. But this algorithm cannot ensure each node receives three non-collinear anchor coordinates. Koutsonikolas *et al.* [25] studied the problem of path planning for mobile anchor to reduce localization error. Zhang *et al.* [26] proposed a range-free localization scheme using mobile anchor nodes. When running once, this algorithm only located a part of nodes. In order to increase localization efficiency, the movement mode of the MN needs to be improved. Kuang *et al.* Virtual beacons-energy ratios localization (VB-ERL) scheme using the Gauss-Markov mobility model was proposed in [26], which was fully distributed and did not need inter-sensor communication. The Gauss-Markov mobility model provided movement patterns which might be expected in the real-world for the mobile anchor node, which took full advantage of the correlation between the current velocity and location of the AN and its future velocity and location.

3. Network Model

There are a set of anchor nodes and a set of sensor nodes in a WSN. A fixed number of anchor nodes are placed with the regions of coverage overlapped and serve as reference points, broadcasting periodic anchor signals. The sensor nodes are distributed randomly in the sensing field and receive messages from anchor nodes. The main responsibility of the anchor nodes is to send out beacon signals to help the sensor nodes to locate themselves. Each sensor node listens for a fixed time period and collects the RISS information of all beacon signals from adjacent anchor nodes. In this environment, it is assumed that [22].

1) The network is a static randomly deployed network. It means a large number of sensor nodes are randomly deployed in a two-dimensional geographic space, forming a network and these nodes do not move any more after deployment.

2) There exists only one Sink node, which is deployed at a relative static place outside the WSNs.

3) There are N static anchor nodes, which their positions are known through GPS or by other means such as pre configuration, and M unknown nodes, and there is a mobile anchor node (AN).

4) The radio propagation is perfectly spherical and the transmission ranges for all radios are identical.

5) The location of each anchor node is known, namely, the location of node i is $p(i)=(x_i, y_i)$.

6) The Euclidean distance of arbitrary two nodes (i, j) is

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (1)$$

The sensing area has been divided many circles which have the same radius r, each node has the same maximum transmission distance R, and $0 \le r \le R$.

4. Improved Correction Localization Algorithm Based on Dynamic Weighted Centroid for Wireless Sensor Network

4.1. Weighted Centroid Algorithm

The main idea of the weighted centroid algorithm is determine the weighting factor according to the different reflection on unknown nodes from anchor nodes, it reflects the degree of influence of each anchor node for centroid position, which is usually according to the received signal strength (RSSI) between anchor nodes and unknown nodes. The specific approach is transform the RSSI to distance when the unknown node received the information of anchor node and form a function by distance, then it computes the weighted of each anchor node, last, using these information to locate the unknown node coordinate based on centroid algorithm.

For traditional centroid algorithm, the coordinate of unknown node j could be computed the following equation:

$$x = \frac{\sum_{i=1}^{n} x_i}{n}; y = \frac{\sum_{i=1}^{n} y_i}{n}, \qquad (2)$$

where n is the number of anchor nodes.

Assume that the distance between anchor node i and unknown node u is d_{iu}, weight value is w_{iu}, the coordinate of unknown node u through weighted centroid method is shown as:

$$x_u = \frac{\sum_{i=1}^{n} w_{iu} x_i}{\sum_{i=1}^{n} w_{ij}}; y_u = \frac{\sum_{i=1}^{n} w_{iu} y_i}{\sum_{i=1}^{n} w_{ij}}, \quad (3)$$

where n is the number of anchor nodes, $w_{iu} = 1/d_{iu}$, if the unknown node u is not directly communicate with anchor node i, w_{iu} is zero.

In wireless sensor networks, RSSI ranging is greatly affected by environmental factors, such as noise, obstacles, multi-path reflections and artificial malicious attacking. The distance between anchor node and unknown node is always not the real distance and will lead to a large position error, so it is necessary to introduce other correction methods.

4.2. Improved Correction Localization Based on Dynamic Weighted Centroid Localization Algorithm

The basic idea of our algorithm is as follow: each anchor node in one hop range of unknown node j is to run self-correct, and transforms the error of self-correct to the error of distance, each anchor node computes its trust degree according to function of distance, then it uses weighted centroid localization algorithm to gain the coordinate of unknown node u.

Assume that unknown node u has n anchor nodes in its range, d_{iu} is the distance between unknown node u and anchor node i.

For anchor node i, it can gain its estimate coordinate by Formula (2), assume that the estimate coordinate is (x'_i, y'_i) ,so the error of localization of anchor node i can be computed as:

$$e_{x\_i} = x_i - x'_i \quad e_{y\_i} = y_i - y'_i, \quad (4)$$

where (x_i, y_i) is the coordinate of anchor node i, (x'_i, y'_i) is the estimate coordinate of anchor node according to other anchor nodes in its range.

It can compute the error distance by Formula (5)

$$d_{\_error\_i} = \sqrt{e_{x\_i}^2 + e_{y\_i}^2} \quad (5)$$

We define the trust degree is T_i, it can be computed through Formula (6)

$$T_i = \frac{1}{d_{\_error\_i}} \quad (6)$$

Then the weight is defined as the following:

$$w_{ui} = \frac{1}{T_i} \times \frac{1}{d_{ui}} = \frac{1}{d_{\_error\_i}} \times \frac{1}{d_{ui}} \quad (7)$$

So the coordinate of unknown node u based on correction weighted centroid algorithm is shown in the following equation:

$$x_u = \frac{\sum_{i=1}^{n} \frac{1}{d_{\_error\_i} \times d_{iu}} x_i}{\sum_{i=1}^{n} w_{ui}}; y_u = \frac{\sum_{i=1}^{n} \frac{1}{d_{\_error\_i} \times d_{iu}} \times y_i}{\sum_{i=1}^{n} w_{ui}}, \quad (8)$$

where n is the number of anchor nodes in the range of unknown node u.

5. Simulation Results

This section provides a detailed quantitative analysis comparing the performance of our scheme with traditional centroid algorithm and weighted centroid algorithm. The average of localization value in 10 times is tests the stability.

In our experiments, the deployment area is a square plane of 500 m by 500 m. There are 70 anchor nodes and 100 unknown nodes, the radius of nodes are respectively 40 m 50 m and 60 m. The average of localization error in 10 times is tests the stability.

We can see from Fig. 1 to Fig. 2, the position error of our algorithm is decreased significantly compared with traditional centroid algorithm and weighted centroid algorithm. With the increase of anchor nodes, the position error of three algorithms is gradually decreased. Under the same conditions, the average position accuracy of our algorithm is improves 43.21 % than the traditional centroid algorithm, and improves 13.25 % than weighted centroid algorithm.

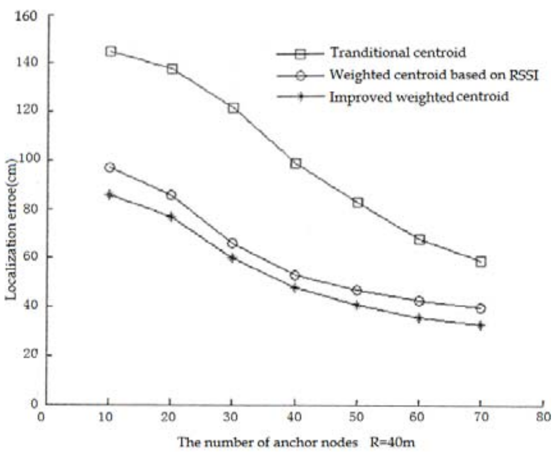

Fig. 1. The relationship between anchor number and localization error.

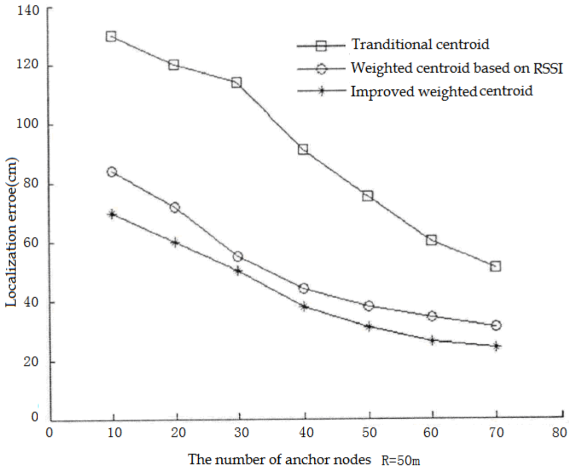

Fig. 2. The relationship between anchor number and localization error.

We can see from Fig. 3 to Fig. 5, the position error of three algorithms is decreased along radius increasing. On the whole, the improved weighted centroid algorithm is decreased 38.85 than traditional centroid algorithm and 13.18 than weighted centroid algorithm.

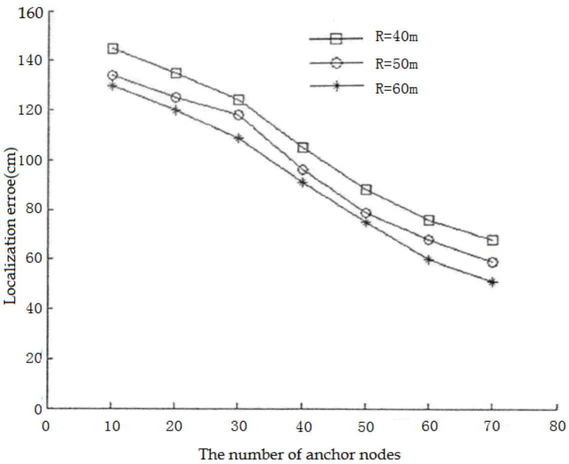

Fig. 3. The relationship of localization error for traditional centroid localization algorithm.

6. Conclusions

A number of algorithms have been proposed for the localization problem in wireless sensor networks. Yet precise location information may be unavailable due to the constraint in energy, computation, or terrain. An improved correction localization algorithm based on dynamic weighted centroid for wireless sensor networks was proposed in this paper. The idea is that each anchor node computes its position error through its neighbor anchor nodes in its range, the position error will be transform to distance error, according the distance between unknown node and anchor node and the anchor node's distance error, the dynamic weighted value will be computed. For each unknown node, it can use the coordinate of anchor node in its range and the dynamic weighted value to compute it's coordinate. Simulation results show that the localization accuracy of the proposed algorithm is better than the traditional centroid localization algorithm and weighted centroid localization algorithm, the position error of three algorithms is decreased along radius increasing, where the decreased trend of our algorithm is significant.

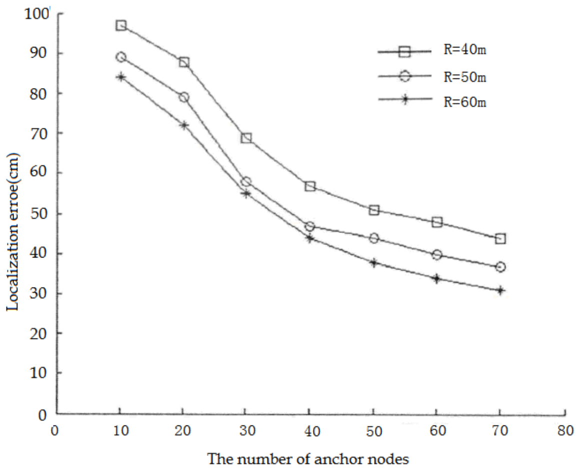

Fig. 4. The relationship of localization error for weighted centroid localization algorithm.

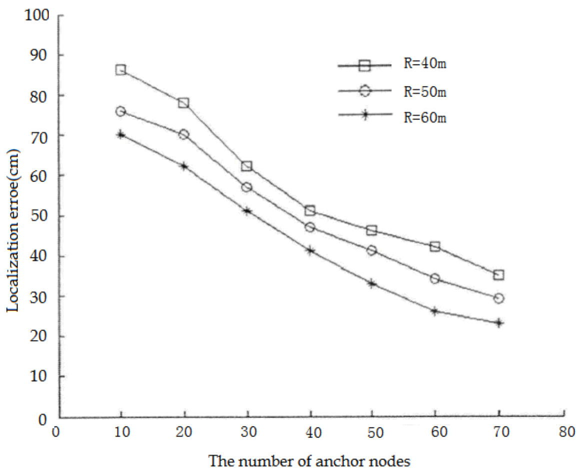

Fig. 5. The relationship of localization error for improved weighted centroid localization algorithm.

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