Research on Localization Algorithm of Mobile Nodes in Wireless Sensor Networks

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Abstract—**The localization and tracking of mobile nodes is a study focus in the application of wireless sensor networks. This paper makes a research on localization of mobile nodes in wireless sensor network and proposes a kind of mobile nodes localization algorithm based on ant colony algorithm. The novel algorithm uses distribution probability and transition probability of ant colony algorithm from one node to the other to calculate the weight coefficients of samples, and then determine the possible locations of mobile nodes. The simulation results show that using probability selection strategy to estimate the locations of nodes has lower computational complexity, higher positioning accuracy and stronger robustness.**

Keywords-wireless sensor networks; mobile nodes; nodes localization; ant colony algorithm.

I. INTRODUCTION

Node localization is a basic and critical problem in configuration and operation of wireless sensor networks. For most applications, get the aware data but unknowing the location of nodes is meaningless. In wireless sensor networks, in accordance with the process of positioning, whether it is measuring the distance between nodes, the location is divided into range-based location and range-free location. Whether or not in accordance with the use of positioning beacon nodes, the location is divided into positioning beacon nodes based on location and the non-beacon node algorithm. Whether or not in accordance with the mobility, node localization can be divided into static location and mobile location.

Mobile nodes localization research of wireless sensor network involves fuzzy recognition, intelligent computing and digital processing, such as a wide range of knowledge that can be widely used in wildlife tracking, forest fire detection and tracking, disaster rescuing, as well as battlefield vehicles, personnel identification and tracking and so on. Location of mobile nodes is of great theoretical and practical application value.

Though many node localization algorithms (e.g. centroid location algorithm [1], DV-HOP algorithm [2] and APIT algorithm [3]) can locate mobile nodes by keeping update their position estimating, these algorithms do not take sufficient account of nodes mobility. In order to obtain a sufficiently high positioning accuracy for mobile nodes, complex calculations are usually needed, which spend a lot of communications and compute resources, increase the difficulty of localization, even cause some algorithms out of work. Therefore, how to achieve localization for mobile nodes with low-cost, low power consumption and high-precision is one of the technology challenges.

II. RELATED WORKS

In WSN, nodes movement includes the movement of the beacon nodes and unknown nodes. Therefore, the mobile nodes localization can be divided into the mobile nodes localization based on beacon node mobile and the localization based on unknown nodes mobile.

A number of research outcomes of nodes localization in sensor networks have been existed at present. Localization of based on beacon nodes mobile has been described in [4-7], in the case that one or more beacon nodes move and the other unknown node are static in wireless sensor networks, which unknown nodes locate according to the information received from beacon nodes. And localization based on unknown nodes mobile has been described in [8]. According this method, beacon nodes are in a fixed location and can broadcast their location information throughout the network, and the rest unknown nodes which is in mobile status locate their own position based on signal intensity which they received.

On the other hand, the localization of WSN in mobile robot technology has made in-depth research. Literature [9] cited the Monte Carlo method of thinking from the robot, and applied it to wireless sensor networks in the localization of the mobile nodes. It studied firstly the problem of localization of mobile nodes when the unknown nodes and beacon nodes are moving.

Monte Carlo localization algorithm provides a new way of thinking for mobile wireless sensor network nodes localization. Being this way, a lot of localization algorithms have been derived from it. Literature [10] limited the scope of the sampling and proposed an improved algorithm from literature [9], which proposed MCB algorithm; Literature [11] predicted and improved the filtering process of the original MCL algorithm, and proposed a Dual-MCL and Mixer-CL algorithm. Literature [12] introduced the distance information into the Monte Carlo algorithm, and proposed a distance-based Monte Carlo localization algorithm. In order to improve the success rate of sampling, by the definition of the beacon node sample box and the box to limit the sampling region in a

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sample box, Literature [13] proposed a Monte Carlo Monte-Carlo boxed localization algorithm. Literature [14] proposed a sample size of self-adaptive Monte Carlo localization algorithm for the current use a fixed sample size of the problem of Monte Carlo localization algorithm.

Inspired by the Monte Carlo algorithm and ant colony algorithm, focusing on the localization of mobile nodes, using the probability choice strategy, this paper proposed mobile node localization algorithm based on the ant colony algorithm which has such characteristics as simple realization, local work, the merging jump number into pheromone as well as support for many the paths.

III. ANT COLONY ALGORITHM BASED ON PHEROMONE

Ant colony optimization algorithm has come into being by behavior of reality ant colony in nature. A great deal of researches show that ant will keep back some pheromone on way they pass through in course of finding food, moreover, the ant of the same colony can feel this kind substances and its intensity, the latter ant is apt to move to place which have more pheromone, at same time stay the pheromone to strengthen the formerly pheromone, and then, the more the ants pass through, the stronger the pheromone is, The specific process just as follows: possibilities that the latter ants choose the path with these substances are greater than the path without these substances. In the same period of time, the shorter the path is, the more the latter ants will visit it, the greater possibility of the shortest path will be selected by the other ants is. Finally, all the ants walk along the shortest path[15-16].

Now, using TSP problem (the shortest loop of n cities) explain the process of ant colony algorithm:

Step1. Creating an ant colony firstly, and put m ants in n random selective cities. According as the mainly two aspects, the ant K selects next city: the concentration of pheromone τ_{ij} at t and energy degree η_{ij} . So, the path S of the ant k is defined as:

$$P_{ij}(t)=\begin{cases}\dfrac{(\tau_{ij})^{\alpha}\cdot(\eta_{ij})^{\beta}}{\sum\limits_{u\in Jk}(\tau_{iu})^{\alpha}\cdot(\eta_{ij})^{\beta}}, j\in Jk \\ 0, \qquad\qquad \text{otherwise}\end{cases} \tag{1}$$

τ_{ij} is the concentration of path pheromone connecting i city and j city, η_{ij} is the energy degree which means cost of the path forming, such as length, energy consumption, which can enhance the ants ability of finding a new path and adapt to changes of the path. α and β are the adjustable weights of τ_{ij} and η_{ij} respectively. Ants routing tendency can be adjusted by choosing the value of α and β .

Step2. Updating remnant the concentration of pheromone. The updating equation of the concentration of track pheromone is defined as:

$$\tau_{ij}=(1-\rho)\bullet\tau_{ij}+\rho\bullet\tau(0) \tag{2}$$

Here, $\rho(0\le\rho\le 1)$ is the durability of the pheromone. The concentration of track pheromone will evaporate gradually with the time passing, $1-\rho$ is track attenuation rate. $\tau(0)$ is original value of the pheromone.

Step3. When all ants have finished once route, updating entire pheromone on the path where the optimal ant passes through, Equation is defined as:

$$\tau_{ij}=(1-\rho)\bullet\tau_{ij}+\sum_{k=1}^{K}\Delta\tau_{ij}{}^{k} \tag{3}$$

$\Delta\tau_{ij}{}^{k}$ is the quantity of the pheromone per unit length left by ant k on the path.

If the ant k passes through the path between at t and $t+1$, $\Delta\tau_{ij}^{k}$ in the local information model can be expressed as:

$$\Delta\tau_{ij}^{k}=\begin{cases}Q/d_{ij}, & \text{if ant } k \text{ has passed through } d_{ij} \text{ between at } t \text{ and } t+1\\ 0, & \text{otherwise}\end{cases} \tag{4}$$

Q is a constant of the number of ants' tracks.

When each ant has finished these operation, we call the algorithm has one iteration. Cycling these steps until the time of iteration has reached the appointing time or has no new more optimal path in definite times.

IV. LOCALIZATION OF MOBILE NODE BASED ON ANT COLONY ALGORITHM(ACAM)

In the localization of mobile nodes based on ant colony algorithm, mobile nodes will be regarded as the ants with different attributes, the process of mobile node localization as process an ant from one node to another node. Process of mobile node localization can be expressed as follows:

Step1. In the initialization phase in the localization, select N samples randomly from the node layout region at time t and form a sample collection $X=\{X_n^i, i=0,..., M\}$, the corresponding to weight value is $W=\{w_n^i, i=0,..., M\}$. Assuming the mobile node can receive a beacon packet G_i from the i beacon node , the distance between two nodes can be estimated by RSSI. Mobile node location in time t is $m_i=(x_i, y_i)$, d_{ij} represents estimate distance between m_i and m_j, $p(\theta)$ represents the distribution of probability that mobile node reaches any position in the communication range at t+1, i.e. distribution probability that ant may reach is the next location. Literature [3] deduced the expression of $p(\theta)$ as follows:

$$p(\theta)=\left(\frac{1}{2\pi\Omega^2}e^{-z^2/2\Omega^2}\right)\bullet\pi R^2 \tag{5}$$

Where, $\Omega = 6.328R^2 / \sigma^2 + \sigma$, σ is the variance of Gaussian distribution , R is the node communication radius.

Step2. Calculating the amount of pheromone on each path. Suppose that $\tau_{ij}(t)$ is the residual amount of information on the path from m_i to m_j at time t, the amount of pheromone on the path (i, j) is defined as:

$$\tau_{ij}(t) = \begin{cases} 1, d_{ij} \le r \\ 0, d_{ij} > r \end{cases} \tag{6}$$

Where, $r = A + d_{\min} + B \bullet (d_{\max} - d_{\min})$, A,B are the constant parameters, $d_{\min} = \min(d_{ij})$, $d_{\max} = \max(d_{ij})$.

Step3. Calculating the probability from m_i to m_j : at t moment t, ants from the node m_i to select to reach position m_j , the transition probability as follows:

$$p_{ij}(t) = \frac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}}{\sum_{s \in S} \tau_{is}^{\varepsilon} \eta_{is}^{\beta}} \tag{7}$$

Where, $S = \{s \mid d_{sj} \le r, s = 1,2,\ldots, M\}$, s represents the possible position number that ants may reach at t+1 , S represents the sets in which the distance from one mobile node to the next location is less than r ,i.e. the number of cities that ants can reach the at t+1. M is total location number of ant transfer, $\eta_{is}(t)$ stands for the weight parameters.

Step4.To judge whether $p_{ij}(t) \ge p_0$, if yes, the ants move from node m_i to the neighbor m_j . p_0 is the given probability.

Step5. According to the distribution of a probability and transition probability that ant reaches the location at the next moment, we can get the location of the ants at time t+1. Their joint probability is:

$$p = p(\theta) \bullet p_{ij}(t) \tag{8}$$

Step6. According to the observation value r_i (mainly refers to the location of the beacon nodes and hops from beacon nodes), received from the mobile node from time t to time t+1 to beacons nodes, and use formula (9) for the distribution of weights for each ant. Then the weights of the ants must carry out the normalization:

$$\overline{w_n^i} = \frac{w_n^i}{\sum_{i=1}^{n} w_n^i} 。 \tag{9}$$

Step7. Output the location coordinates at t+1,that is:

$$. \ (x_j, y_j) = (\sum_{j}^{n} x_n^j \overline{w_n^j}, \sum_{j}^{n} y_n^j \overline{w_n^j}) \tag{10}$$

V. SIMULATION RESULTS ANALYSIS

In order to verify the effect of algorithm, we made a simulation for the algorithm in this paper. Set the number of ants N as the number of samples, according to the maximum distance and the minimum distance among the samples, we let $r = 0.25 + d_{\min} + 0.32 * (d_{\max} - d_{\min})$, $\alpha = 1$, $\beta = 1$ 。 $\tau_{ij}(0) = 0$, and transition probability $p(0) = 0.6$. In the process of simulation, all nodes are initially randomly distributing in a barrier-free rectangular area 100x100, the transmission radius of all nodes $\upsilon = R$, node moving speed $\upsilon = R$,and 100 nodes are randomly deployed in the region, Of these ,there are 20 beacon nodes. Nodes have the capacity of ranging and the capacity to determine whether a node within the scope of its communications or not. Beacon nodes are fixed, and unknown node is moving.

A. The mobile nodes routing path simulation

Figure1 is the path of sensing region after optimizing the mobile node by ACO. As seen from the figure, using a mobile node to traversal of these path points and sending beacon signals at this location can help the nodes spread of sensor region to localize. The optimal path of mobile node is shortest path in traversal of these locations.

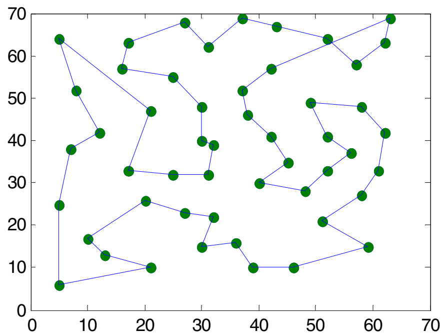

Fig. 1 Mobile node routing path

B. The impact of positioning accuracy cause by beacon nodes number

The impact of positioning error which caused by beacon is described in Figure 2. We can see that the more beacon nodes, the smaller the position error. The more beacon nodes, the cost of layout will increase. However, when positioning, it can receive more beacons node information to filter the can not samples, thereby reducing the positioning error. Comparing the MCL algorithm in the literature [9] to the MCB algorithm in the literature [10], ACAM can limit the scope of sampling to improve the sample quality, thereby positioning error getting smaller. When the number of the beacon nodes is greater than 18, the positioning error of MCL, MCB and ACAM is close to gradually.

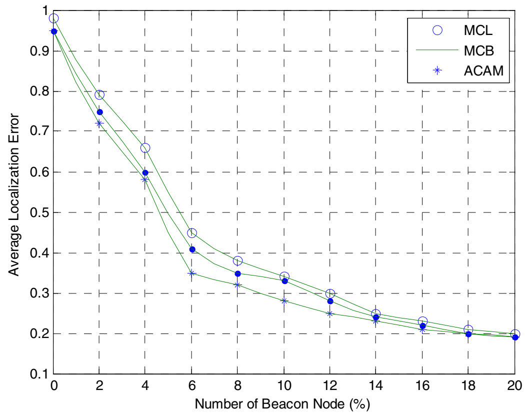

Fig. 2 Beacon Nodes and The Average Positioning Error

C. The impact of positioning accuracy caused by velocity of node moving speed

The impact on positioning error which caused by moving velocity of nodes has been described in Figure 3. In the process of the node is moving, the average positioning error of the nodes is decreasing, but as the speed increasing, the degradation of the samples is serious, the positioning error increases. Here, the node positioning accuracy of MCL algorithm is lowest for the sampling region of the samples is the largest. MCB algorithm reduces the sampling area using the overlap of the beacons node communication region, and it can collect more samples in a unit time, so the node positioning accuracy is improved. ACAM algorithm uses the distribution probability and the moving probability to strengthen the conditions to anticipate for the sample filtering, so the node positioning accuracy is improved.

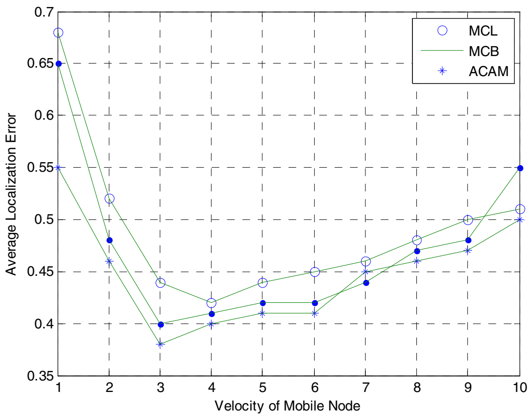

Fig. 3. Velocity of Mobile Node and Average Location Error

VI. CONCLUSION

In this paper, based on study of ant colony algorithm, we put forward and designed a mobile node location algorithm based on the ant colony algorithm. It calculates the weight coefficients of the samples to determine the possible location of the mobile node by this algorithm according to the distribution probability as well as the transition probability of nodes. The simulation shows that the algorithm has a certain application value with a lower computational complexity, and higher positioning accuracy and stronger Robustness.

REFERENCES

[1] Bulusu N,Heidemann J,Estrin D,GPS-less low cost outdoor localization for very small devices[J].IEEE Personal Communication,2000,7(5):28-34.

[2] D.Niculescu and B.Nath. Ad hoc positioning system(APS)[C].the IEEE GlobeCom,San Sntonio,AZ,Nov,2001.

[3] He T,Huang C,Blum BM, Stankovic JA,Abdelzaher T. Range-free localization schemes for large scale sensor networks[C]. the 9th Annual Int'l Conference on Mobile Computing and Networking(Mobicom),San Diego,CA.2003:81-95.

[4] Kim K,Lee W.A mobile beacon-assisted localization scheme for wireless sensor networks[C].the 16th International Conference on Computer Communications and Networks. Hawaii:IEEE Society Communications,2007,57-62.

[5] Xiao B,Chen H,Zhou S.A walking beacon-assisted localization in wireless sensor networks[C].the IEEE International Conference on Communications. Hong Kong,2007,3070-3075.

[6] Shi W R,Xu L,Xu Y S.Localization algorithm with mobile anchor in static wireless sensor network[J]. Chinese Journal of Scientific Instrument,2007,28(3):385-393.

[7] Pathirana P N,Bulusu N,Savkin A V,et al.Node localization using mobile robots in delay-tolerant sensor networks[J].IEEE Transactions on Mobile Computing, 2005,4(3): 285-296.

[8] Bergamo P,Mazzini G. Localization in sensor networks with fading and mobility. [C].the 13th IEEE International Symposium on Personal,Indoor and Mobile Radio Communications. Lisbon:IEEE Communications Society,2002,750-754.

[9] HU L, EVANS D. Localization for mobile sensor networks[C].the 10th Annual International Conference on Mobile Computing and Networking. Philadelphia : ACM Press. 2004 : 45-57.

[10] BAGGIO A, LANGENDOEN K. Monte-carlo localization for mobile wireless sensor networks[C].2nd International Conference on Mobile Ad-hoc and Sensor Networks(MSN 2006). Hang Kong : Springer Verlag Press. 2006 : 317-328.

[11] ENRIQUE S N, VICEKANANDAN V, WONG W S V. Dual and mixture monte carlo localization algorithms for mobile wireless sensor networks[C].IEEE Wireless Communications and Networking Conference. Hong Kong : IEEE Press. 2007 : 317-328.

[12] Dil B,Dulman S,Havinga P.Range-Based localization in mobile sensor networks[J]. Lecture Notes in Computer Science,2006,3868(2):164-179.

[13] Baggio A,Langendoen K. Monte-Carlo localization for mobile wireless sensor networks[J]. Lecture Notes in Computer Science,2006,4325(11):317-328.

[14] Wang W D,Zhu Q X.Varying the sample number for Monte Carlo localization in mobile sensor networks[C].the 2nd International Multisymposium on Computer and Computational Sciences. Washington DC:IEEE Computer Society,2007,490-495.

[15] Ho S L, et al. A modified ant colony optimization algorithm modeled on tabu-search methods[M]. Magnetics,IEEE Transactions on, 2006, 42(4):1195-1198.

[16] Fang L,Du V, Ning P.A beacon-less location discovery scheme for wireless sensor networks[C].IEEE Conference on Computer Communications(INFOCOM).2005:1632-1638.