

Mobile Agent Routing Algorithm Based on Improved Ant Colony Algorithm

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Received: 15 April 2013 /Accepted: 20 June 2013 /Published: 28 June 2013

Abstract: At the present stage wireless sensor network exists some deficiencies such as finite energy, limited communication capability, multi-hop routing and dynamic topology. In addition too many nodes which are distributed intensively influence also performance of wireless sensor network. Besides distributed optimization problem always impact to efficiency of the network. For data processing and routing selection of wireless sensor network, a new routing algorithm based on mobile agent and ant colony optimization is proposed in the paper. The ant colony algorithm is improved and optimized in the paper. The algorithm can balance between routing efficiency and node loading. So on the one part the computing capability of sensor node and efficiency of data processing are improved. On the other part redundant data and communication consumption are reduced so that life expectancy of sensor is extended. Simulation experiments show that the new routing algorithm could solve the problems of wireless sensor network, and it has good practice application effect. Copyright © 2013 IFSA.

Keywords: Wireless sensor network, Routing algorithm, Mobile agent, Ant colony optimization.

1. Introduction

As a new mode for collecting information and processing information, wireless sensor network has become the research focus. It has broad application prospects as integrated intelligent information system which can integrate several functions such as information acquisition, information processing and information transmission. In practice, the sensor network is required to process data as much as possible by lowest energy consumption rate on condition of limited energy capacity. Even requirement of network dynamic performance that is caused by node moving should also be detected. Therefore developing communication protocol and routing algorithm for wireless sensor network is viewed as urgent task.

MinChen (reference [1]) proposed MADD (Mobile Agent based-directed diffusion) algorithm. The idea of the algorithm is that mobile agent is introduced for cooperating with DD algorithm for performing data collection of sensor network node and routing algorithm. But the limitation of the algorithm is not suitable for big-scale network structure. When the network scale becomes large, the efficiency is reduced much. LongGan proposed (reference [2]) an routing policy algorithm based on CE. The algorithm can make mobile agent data fuse. Mobile agent data of the same type is merged. So the amount of the type data is reduced. Redundant data in the transmission is effectively reduced. Simulation shows that by comparing with without using mobile agent data fusion algorithm, redundant data in sensor network is obviously reduced and survival time of

network is greatly improved. But the flaw of the algorithm is that traditional routing algorithm may lower routing efficiency. Mobile agent routing algorithm based on genetic algorithm was proposed in reference [3]. According to global information of network and genetic algorithm, initial migration route is firstly obtained. Based on the initial route, mobile agent starts migrating in WSN and performing tasks in corresponding processing node. When the network topology is changed because of failure of the sensor node or other reasons, the processing node can re-calculate a new route and collect data information, then the data is delivered to the mobile agent again while the mobile agent can continue to access remaining nodes in the WSN. After completing task in the subsequent processing nodes, mobile agent returns original processing node. In the method, position of the sensor node is assumed to be fixed or is set intentionally. So it is much different with the deployment of sensor nodes in the real world. Furthermore frequent change of network topology because failure of sensor node or other reason is often occurred will lead to extremely frequent calculating route. The result will reduce the whole network performance.

In recent years mobile agent technology is applied into data processing and routing of wireless sensor network. According to calculated route, mobile agent can collect data on sensor node in turn. Afterwards data fusion and processing can be completed. Hence the problem caused by tradition C/S model such as network congestion, overloaded node is solved well. From the above a new routing algorithm which combines mobile agent technology with ant colony optimization is proposed in the paper.

2. Idea of Mobile Agent Routing

In Mobile agent is special code which can be executed automatically. What is more, the tasks which are assigned by processing node are saved in the code. Firstly the mobile agent is constructed in processing node. Then it is distributed into sensor network. The code can move from one sensor node to another sensor node automatically. Data in the node is handled automatically. The combination of mobile agent technology and wireless sensor network has following advantages:

- (1) Network bandwidth is extended so that data traffic on the network is balanced.
- (2) Mobile agent can run asynchronously as independent unit.
- (3) Network energy consumption can be reduced and balanced.
- (4) Better stability.

In traditional distributed wireless sensor network, data transmission adopts C/S mode: The terminal node sends collected data to father processing node where data is handled. So the process causes the worst situation: the large amounts of data are moving on the network and energy is consumed seriously.

The aim of mobile agent is to reside data on the sensor node. Then the special code (agent, 1. Computing Engine) that represents user requirements is broadcasted for collecting node data on assigned area. Eventually all information are returned into user. When the agent is moving among nodes, reduplicate inductive data adjacent nodes can be fused according to certain percentage. In such a way the amount of data transmission are reduced at a certain extent. More the amount of accessed node is in the assigned area, higher accuracy of result which is obtained from data fusion is. So a suitable access path is very key for mobile agent. The path can not only balance signal strength into required level but also reduce total of energy consumption and cost of path loss.

The main aim of mobile agent routing algorithm is to choose a suitable access path. The path can achieve not only accuracy of data acquisition and fusion but also minimize energy consumption and path loss at process of data acquisition and fusion.

3. Improved Ant Colony Algorithm

Although ant colony algorithm has many advantages such as strong search capability, good adaptability and robustness, some flaws of the algorithm such as slow convergence, weak global search capability can result in some problem like stagnation, small-scale optimization.

(1) For selecting suitable next hop node j , the sensor node i need not only consider the distance with node j but also consider residual energy of node j and energy consumption from node i to node j . State transition rule:

$$p_{ij}^k = \begin{cases} \left[\tau(i,j) \right]^\alpha * \theta_{ij}^\beta / \sum_{s \in J_k(t)} \left[\tau(i,s) \right]^\alpha * \theta_{is}^\beta, & j \in J_k(t) \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

in:

$$\theta_{ij} = (E_{i-\text{remain}} + E_{j-\text{remain}} - E_{ij-\text{consume}}) / \sigma(i,j), \quad j \in J_k(t) \quad (2)$$

In (2) equation, θ indicates expectation for K-ant searching next hop node; $E_{i-\text{remain}}$ and $E_{j-\text{remain}}$ represent residual energy of current node and residual energy of next hop node; $E_{ij-\text{consume}}$ means energy consumption from node i to node j

After θ_k is introduce into probability transfer equation, distance between two sensor nodes is no longer viewed as main heuristic factor in new improved routing algorithm. Residual energy which indicates that ant searches shortest path under limited energy consumption as extra factor is added into

algorithm. So the algorithm selects a balance point between converged optimal solution and node energy consumption so that congestion which is caused by converging to the optimal solution fully can be avoided. In addition energy consumption of the whole network can also reach to the average level. Life cycle of the network is maximized.

(2) In the ant algorithm the higher pheromone is, the faster the pheromone volatilizes. In contrast the less pheromone is, the slower the pheromone volatilizes. Local update rules which are added to improved algorithm can avoid extreme conditions such as unlimited growth of pheromone on some paths, pheromone on some paths reducing to 0 abruptly. So those rules avoid the algorithm to fall to local optimum effectively.

After migration is completed from sensor node i to node j , pheromones on the corresponding paths are required to be updated according to local update rules. Update rule is given in equation (3)

$$\tau(i, j) \leftarrow (1 - \rho) * \tau(i, j) + \rho * \tau(i, j), \quad (3)$$

where ρ represents information pheromone. The value is ranged from 0 to 1.

(3) In ant algorithm pheromone on the best path is updated globally when looping is finished. In other words pheromones on the global optimal path are strengthened. If pheromone on the worst path can be updated globally or pheromones on the worst path is weakened at the same time, evolutionary process is speeded up as well as algorithm searching algorithm is improved.

It will be seen that some deficiencies of ant colony algorithm such as converging to local optimal solution easily, weak capacity of global search are overcome by combination of ant pheromones and energy on network node in the improved ant colony algorithm. The combination is that pheromones on optimal path are reduced dynamically when convergence of ant colony algorithm is ongoing. Compared with ant algorithm, global update strategy of new algorithm for pheromones on the best and the worst path can accelerate the searching speed and the speed of convergence to global optimal solution so that network congestion and excessive energy consumption of individual nodes are avoided as well the life cycle of the whole network are extended.

4. WSN Mobile Agent Routing Algorithm Based on Improved Ant Colony Algorithm

In recent years Heuristic algorithms such as LCF, GCF can obtain satisfactory results in small-scale deployment of sensor network. However, these algorithms only consider the distance between the sensor nodes while some factors like residual energy of sensor node, data processing capacity and energy consumption of data transfer are ignored. So the

performance of those algorithms becomes deterioration when distribution of nodes in sensor network is complicated.

For those flaws, the nodes which have more residual energy, powerful data processing capacity and short transmission distance is best choice for mobile agent. So finding a moving path where all nodes have above capabilities is considered as optimization problem. Ant colony algorithm is a new simulated evolutionary algorithm. It focuses on solving combinatorial optimization problem. In recent years ant algorithm is applied into the wireless sensor routing popularly.

4.1. The Idea of Algorithm

Mobile agent routing algorithm based on improved ant colony algorithm is proposed in the paper. The algorithm is also called WSNMAR.

Mobile agent with task is distributed by specified processing node in the given range of sensor network. As ant, mobile agent can search next hop node in the range of sensor network according to improved ant algorithm and complete routing migration. At the same time data on the nodes are collected and tasks which come from processing node are assigned. On the other side failure node and node beyond the scope of mobile agent communication are not be selected as next hop node. At final mobile agent will return processing node after assigned tasks is finished. The length of mobile agent routing migration is recorded.

4.2. The Algorithm Process

Step 1 Initialization.

Initialize record routing table of each node, neighbor node table: set initial energy of node, calculate distances between node and neighbor node, calculate the energy consumption of transmission between node and neighbor node;

$NC = 0$; (NC is the loop counter)

Set $e(i, j)$ as edge of sensor node i, j , set equation $\tau(i, j) = \tau_0$ (τ_0 is a constant) as initialization value of pheromone

$\Delta\tau(i, j) = 0$ is the total amount of the pheromone which is left on edge $e(i, j)$ after each iteration.

The m ants are randomly placed at n sensor nodes. The taboo table ($tabuk$) of each ant is set as empty; In processing node, m mobile agents are distributed and binds with m ants;

Step 2 solving process

```
for (i = 1; i <= n; i++)
    for (k = 1; k <= m; k++)
    {
```

Initialize starting position of the ant k . and the corresponding initial sensor node is added to the taboo table ($tabuk$);

```

if (ant k does not complete the assigned task and
taboo table is not full)
{
    if (next node j is not a failed node and j is not
processing node)
    {
        Ant k will move to the sense node j and j is added
to the tabuk ;
        The mobile agent k is also migrated to the sensor
node j;
        Local update rule (Equation (1)) is applied to
modify pheromone amount of the latest branch;
    }
}
Step 3 global updating rule is applied to update
pheromone of the optimal and worst path
for (k = 1; k <= m; k++)
{
    Search the optimal path and the worst path at one
iteration. Then global update rule (Equation (2), (3))
is applied to modify pheromone amount of each
branch in the optimal best and worst path
}
Step 4 output optimal path
if (termination condition is not met)
{
    Empty the taboo list of all the ants;
    set  $\Delta\tau(i, j) = 0$  for each  $e(i, j)$ ;
    NC = NC + 1;
    Return step 2;
}
else
Return the optimal solution;
}

```

5. Simulations and Analysis

Table 1. The simulation results of the algorithm are compared.

Algorithm Parameters			Simulation results of ant colony routing algorithm		simulation results of WSNMAR	
α	β	ρ	the shortest path length	evolving algebra	the shortest path length	evolving algebra
1	4	0.5	394.2768	326	394.2768	326
1	4	0.9	396.7138	339	396.7138	339
2	2	0.5	392.6865	340	392.6865	340
2	2	0.9	394.2371	310	394.2371	310
4	1	0.5	315.6899	346	315.6899	346
4	1	0.9	318.0540	328	318.0540	328

Simulation results from Table 1 show that the worst results that are obtained from routing algorithm based on improved ant algorithm are less than the optimal results that are obtained from routing algorithm based on ant algorithm. Furthermore required evolving algebra in routing algorithm based on improved ant algorithm is reduced from greater than 300 to less than 200. Consequently improved ant

algorithm can overcome the flaws of ant algorithm such as slow convergence, search spending much time and has stronger global search capability.

The evolutionary curve of best and worst solution of mobile agent routing algorithm based on improved ant colony routing algorithm are given in Fig. 1. Compared with mobile agent routing algorithm based on ant colony, two capabilities which are the speed of

global searching and speed of convergence are improved by adding local update rules and global pheromone update strategy for pheromone of the best and worst path.

Fig. 2 shows best routing according to improved ant algorithm: migration path of mobile agent.

Comparison from lab illustrates that distribution of energy consumption of the sensor nodes which utilize WSN mobile agent routing algorithm based on ant algorithm is unbalanced. Some nodes in the

optimal path consume too much energy while rest nodes remain lots of energy. Distribution of energy consumption of the sensor nodes which utilize WSN mobile agent routing algorithm based on improved ant algorithm is balance. In new improved algorithm, the single path is no longer considered as optimal solution for routing. Network load can be balanced on multi-path routing. So not only network congestion can be solved well but also network performance and network life-time can be improved.

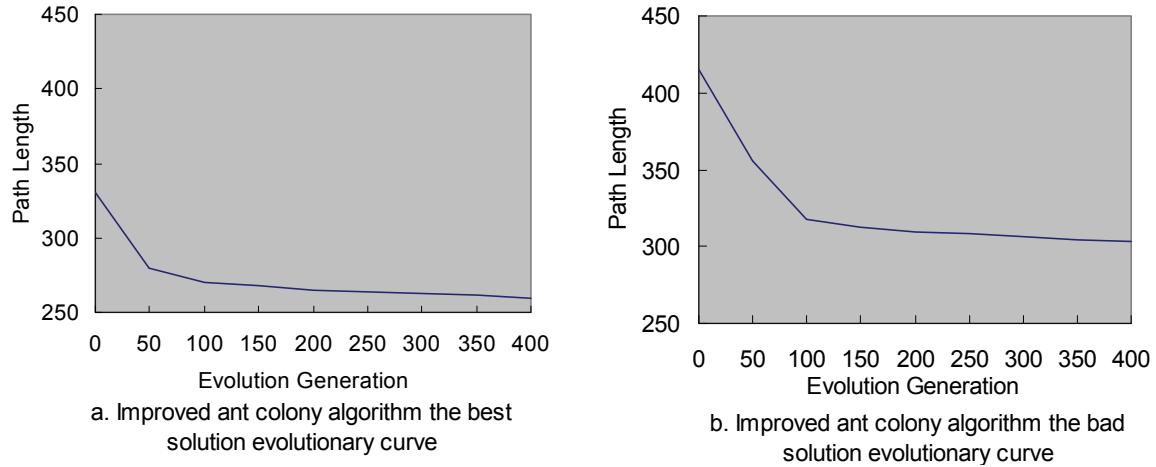


Fig. 1. The evolutionary curve of the WSNMAR algorithm.

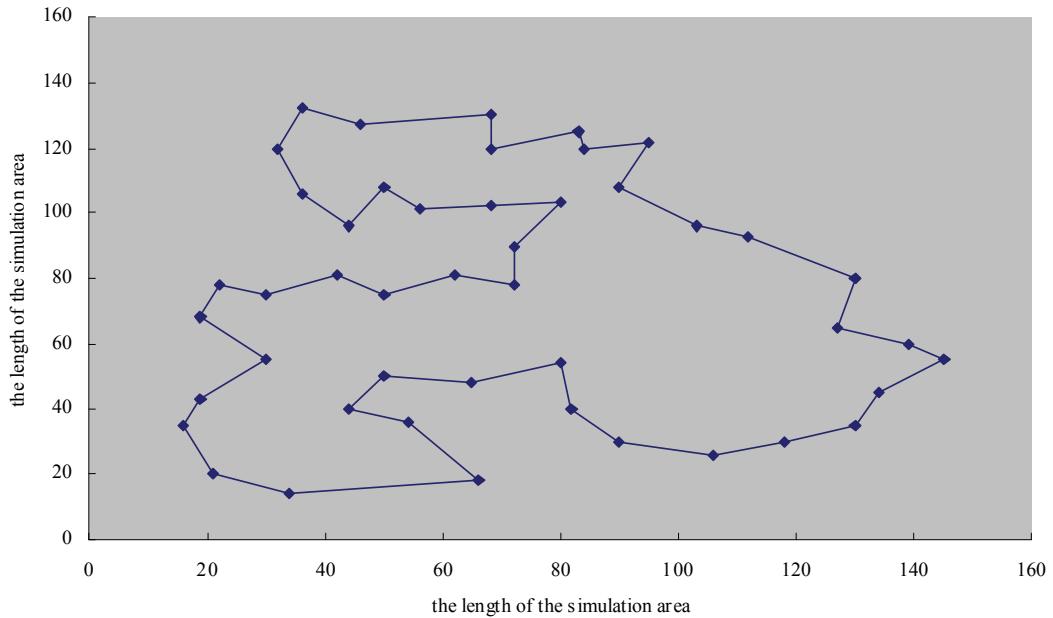


Fig. 2. The best path of the improved ant colony algorithm.

5.2. Analyses for Parameters of the Algorithm

The simulation experiment and predication in the paper show good agreement with the experimental results. The optimal combination between the various

parameters can further optimize performance of the algorithm.

(1) Test optimal value of m ants

Set $Q = 100, \alpha = 1, \beta = 7, \rho = 0.7$, different values of 6 groups is assigned to m, in the simulation environment, the experiment was carried out for 10 times. Each time the maximum number of

iteration is set to 500. Table 2 indicates experiment result is optimal when number of ants is equal with the number of node.

Table 2. The ant number m selection on the influence of the algorithm.

The ant number, m	The shortest path length	Evolution algebra
40	327.3452	155
45	328.2521	148
50	328.2521	148
60	324.1685	145
65	328.8916	143
70	328.8916	143

(2) Test influence of three parameters α , β , ρ on algorithm performance

Table 3 .The test results of Parameters α , β , ρ .

β	0	0.5	1	2	5	10
Average path length	346.1761	283.1372	281.0788	277.9547	240.6723	244.7621
α	0	0.5	1	5		
Average path length	304.7345	259.0097	234.5968	275.1922		
ρ	0.3	0.5	0.7	0.9		
Average path length	289.2839	236.4699	233.0318	243.3663		

Conclusion based on Table 3:

(1). The optimal value of α is located at nearby value 1 because average length of path is shortest. When $\alpha=0$, influence of pheromone can be eliminated completely. Possibility of mobile agent selecting nearest sensor nodes as the next migration object increases. if α is too small, the algorithm is easy to fall into local optimal solution. It is called precocious phenomenon. The phenomenon can result in excessive energy consumption on a path in the network. Network life-time drops. If α is too big, it is equivalent of laying too much stress on effect of pheromone at ant search process. The situation will cause a strong positive feedback on the local optimal path and possibility of mobile agent selecting previous paths in the future iteration becomes great. So the algorithm also fall into local optimal solution and precocity phenomenon occurs.

(2). The heuristic factor β indicates intensity of apriority and determinacy of ant at optimal searching process. The larger the value β is, the greater the possibility of ant selecting local shortest path in local point becomes. Although the convergence speed of the algorithm can be accelerated at the situation, randomness of the ant searching the optimal path becomes weaken. So search is easy to fall into local optimal solution.

Simulation shows that: optimal value of b is located at nearby 5.when $\beta=0$, pheromone is only working element in the algorithm. A process of positive feedback is formed. So the algorithm falls into precocious phenomenon. Local optimal path rather global optimal solution is produced. So the

Setting some groups for three parameters α , β , ρ at the same group, one parameter is changed while the two other parameters remain unchanged. In order to avoid accidental situation, each parameter is carried out by 10 times. Then results are averaged. Set the default value of the other parameters as: Q = 100, m = n = 60, algorithm will stop when maximum number of iteration reaches into 500.set

$$\beta \in \{0,1,2,5,10,20\},$$

$$\alpha \in \{0,0.5,1.5\},$$

$$\rho \in \{0.3,0.5,0.7,0.9\},$$

experimental data are shown in Table 3.

quality of the solution obtained is the worst in the experiment; if β value is too small, the algorithm is transformed into a random search algorithm. In this situation, it is difficult to find the optimal solution; if β is too large, shortest average path obtained tends to be deteriorated.

(3). The pheromone evaporation factor ρ will directly affect the convergence speed and global. Ant colony algorithm parameter ρ indicates the degree of evaporation of pheromone within 0-1. From the experiment test results, the optimal value of ρ is located at nearby 0.7. if p is too small (in the table above, $\rho = 0.3$), the possibility of selecting the previous search path increases. Random performance and global search capability of the algorithm will be affected .Although the larger value of ρ (such as in the above table, $\rho > 0.7$) can improve random performance and global search capability of the algorithm, quality of solution becomes worsen. The reason is that excessive evaporation of hormones maybe ignores mutual influence among individuals. So it is difficult for the algorithm to obtain the optimal solution. $\rho=0.7$ not only can make use of greedy heuristic to guide the search at early stage of calculation, but also the track can be used. Global information is stored in the value. The algorithm can forget some previous gained experiences in order to avoid early convergence to a local optimal solution. So the ant can better search the newly introduced global information.

6. Conclusions

Firstly this paper introduces mobile agent technology and deficiencies of mobile agent routing algorithm. Then a mobile agent routing algorithm based on improved ant colony algorithm is proposed. Compared with mobile agent routing algorithm based on ant colony, two capabilities of mobile agent routing algorithm based on improved ant colony that are the speed of global searching and speed of convergence are improved. The cost of Communication is reduced while life-time of node and network are extended. So the problem of transmission of large amounts of data is solved well in wireless network. Finally best combination of various parameters is obtained by experiment so that the performance of the new algorithm is optimized once more. The best combination can obviously shorten length of optimal solution (mobile agent migration path) and reduce evolution algebra of optimal solution.

Acknowledgments

This work was supported by the grants from Jiangxi Science and Technology Agency provides financial aid for “Based on industrial PDA visualization comprehensive logistics platform”. And this work was supported by Natural Science Foundation of Jiangxi (No. 20122BAB20102).

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