Study on the Application of Ant Colony Algorithm in the Route of Internet of Things

Ying Lu and Wen Hu

School of Computer and Information Engineering,
Harbin University of Commerce, Harbin, China
l1978y@hrbcu.edu.cn

Abstract

In the routing processing of Internet of things, network traffic distribution changes constantly, network links and nodes will also fail randomly or some new nodes will be added; the autocatalytic and positive feedback mechanism of the ant colony algorithm conforms to the characteristics of the route searching. This paper uses ant colony algorithm to search route; uses the broadcast signaling, which is featured with the random multi-sending and the short life cycle, to overcome the problem of more network nodes and more variable network structure. The simulation results show that searching route by ant colony algorithm in Internet of things can reduce the broadcast storm effectively. With the increasing number of nodes in the route searching, the time of route setup was significantly shortened.

Keywords: *ant colony algorithm; Internet of things; route processing; network structure*

1. Introduction

Intelligent optimization algorithm is the optimized method based on simulating natural phenomena, which includes ant colony algorithm, particle swarm algorithm, genetic algorithm, tabu search, simulated annealing algorithm and immune algorithm, etc. Compared with the traditional mathematical programming methods, intelligent optimization algorithm is better for multi-objective optimization. As an intelligent optimization algorithm, the basic idea of the ant colony algorithm comes from the foraging behavior of real ant colony. An ant is simple, but they can perform complex tasks when they get together. Biological studies show that the ant colony can always find the shortest path from the nest to the food; ants cast pheromone for distributed memory along the way by a mechanism called stigmergy, and share information with other ants through indirect communication. Many studies show that the optimization of ant colony algorithm is very good, that is, the optimization process is speed up by the principle of positive feedback; and they cooperate well through the exchange and transmission of information between different individuals to find a better solution.

Internet of things is the third wave in the global information industry after the computer, the Internet and mobile communication network. This concept was put forward by professor Ashton of the Massachusetts institute of technology Auto - ID center in 1999. It is defined as: it is a net work of linking all items to the Internet through the information sensing equipment such as radio frequency identification and barcode, and realizing intelligent identification and management function [1]. In a report released by the international telecommunication union, the concept of Internet of things is extended by changing “content networking” into the “Internet of Things”, this paper also puts forward the idea that at there is the interconnection at any time, in any place, among any object, and to realize the omnipresent network and ubiquitous computing [2].

In the environment of Internet of things, information transmission can not do without routing protocol, and routing protocol directly affects the performance of Internet of things. The routing algorithms plays a key role in the routing protocol, because adopting a certain algorithm often determines the final search results and directly affects the quality of the routing protocol performance [3]. We have to collect a lot of data for Internet of things, but there are a lot of network node and network topology is irregular [4, 5]. Different from ordinary Internets which are mostly point to point, or a fixed point for multicast, the Internet of things is a net of irregular multipoint to multi-point communication [6, 7], and communication participants may be immediately join or leave, so we can't use the common TCP/IP network routing search algorithms. Thus, the design of routing algorithm is very important for Internet of things.

2. The Dynamic Routing Algorithm in Internet of Things

2.1. Characteristics of Internet of things

Internet of things is composed of a large number of limited equipments. Therefore, the Internet of things routing algorithms must consider the following features of Internet of things comprehensively.

2.1.1. Self-organizing network: There are two nodes deployment in Internet of things, they are predefined deployment and random deployment. In the situation of predefined deployment, the nodes are placed according to the request, and information is transmitted through designed path. In the situation of random deployment, the nodes are randomly placed, nodes' position cannot be accurate positioning, in this case, the nodes must have the ability self organizing.

2.1.2. Energy limited: A large number of sensors are deployed in Internet of things, and the sensors collect environmental information periodically according to certain frequency, so the data have the feature of real-time and constantly update data. But it is not feasible for the sensors used in the traditional Internet of things based on IP protocol because the sensor nodes' energy and bandwidth are small. Since the sensor node is self-organized, each node and its adjacent nodes will be connected automatically, collected and transmitted data dispersively with the absence of human interference.

2.1.3. Dynamic network: In practical applications, Internet of things is always changed dynamically, for the moving of nodes sometimes, the joining of the new items, the change of environmental conditions will change the topology of the network [8], therefore, Internet of things must be equipped with a dynamic adaptability.

2.1.4. Mass nodes: In order to get accurate data, a lot of sensor nodes are deployed inside Internet of things, hence, it is not realistic to distribute a physical address for each node.

2.2. Routing algorithm in Internet of things

The features of Internet of things mentioned above bring considerable difficulties to route search. The traditional routing algorithms, such as link-state algorithm, distance vector algorithm, etc, already can not adapt to the dynamic changes of the Internet of things. It is likely to result in the network signaling storm if we still follow the conventional route search algorithms. With the appearance of all kinds of intelligent algorithm one after another, some scholars apply them to the Internet of things routing study, such as application of simulated annealing algorithm and genetic algorithm to solve routing problem.

The route of Internet of things should have the characteristics, for instance, using smaller communication overhead and processing power to calculate the optimal path, and adapting to the dynamic change of the topology structure in Internet of things. These characteristics match those of ant colony algorithm, for the process of nodes' looking for routing in the net is very similar to that of ants searching for food, so there are more advantages in ant colony algorithm when compared with simulated annealing algorithm and genetic algorithm. Ant colony algorithm can be used in different network, and search the optimal link in the network in the premise of the quality of service, and improve transmission efficiency of the network. This paper tries to study the use of ant colony algorithm to find route, using the random sent broadcast signaling which has a very short life cycle to overcome the problems of more network node and variable network structure; at the same time, to reduce the network storm in the process of route searching.

3. Routing Algorithm based on Ant Colony Algorithm

3.1. The Basic Principle of Ant Colony Algorithm

Ant colony algorithm is proposed by an Italian scholar Dorigo M who gets the inspiration from ant colony foraging process. A single ant is not very intelligent, it looks like there is no centralized command, but they can coordinate and work together, and they can always find the shortest path between a food source and ant nest on the feed time [9]. The study found that ants will release a volatile chemical in its dealings path at their foraging, called as Pheromone. In Figure 1, node A stands for ant nest, node F stands for food source. When it starts, we release some ants at node A. We assume that at the first choice, the ants select to crawl to the food source through the line of ABF, ADF, AEF separately with the equal probability of choosing each line, because ABF, AEF are longer, the ants that choose ADF will first return to ant nest. So concentration of the pheromone on ADF is higher than that of the other two lines, the subsequent departure ants will choose ADF with high probability. However, unlike other ants, some of them do not repeat the same route, they make their own rules to choose the line of ACF—a new way which is even shorter than the original road, therefore, more ants are attracted to shorter roads gradually.

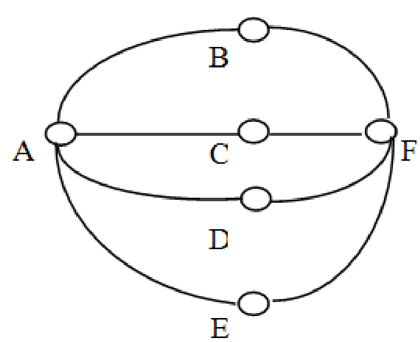

Figure 1. Principle of Ant Colony Algorithm

Ant colony algorithm is a kind of heuristic algorithm which is self-organized and to learn automatically according to the application to the different environments. It is featured by the parallelism, positive feedback, robustness and discreteness. The ant colony algorithm is firstly used in solving the traveling salesman problem, and it is also suitable for solving the problems of combinatorial optimization, such as vehicle routing problem, quadrantic assignment problem, Job - shop scheduling problem and so on.

When we apply ant colony algorithm to solve practical problems, the first step is to generate a certain amount of artificial ant colony, then we should enable each ant to build a solution or a part of the solution, make the artificial ants start from the question on the initial state, and choose the next nodes to arrive according to the pheromone concentration until eventually form a legal way, that is, to set up a solution. An ant releases the pheromone with the direct proportion with the solution quality level it has found in the path, and then each ant starts a new process of solving the problems till find the satisfactory solution.

At present, the ant colony algorithm has obtained some achievements when it is applied to routing research. CORREIA F and VAZAO T puts forward a kind of simple ant routing algorithm for limited self-organization network energy characteristic [10]. In this way, during the stage of searching route, only one broadcast routing of the neighbor nodes is allowed to find group, thus the routing consumption is reduced, but it's also result in a big delay. MISRA S, DHURANDHER S K and OBAIDAT M S also put forward another kind of ant routing algorithm [11]. Their method can avoid error-prone node to retransmit the group, however, the time for the nodes to process grouping is extend. Li Hongsheng, Liu Sumin, Hu Bing apply the ant colony algorithm to the nodes' energy management and to establish a new routing way, so they can reduce the power consumption of the nodes effectively [12].

3.2. A comparison of artificial ants and real ants

The ant colony algorithm is inspired by the foraging behavior of real ants, there are similarities and differences between the artificial ants and real ants.

3.2.1. Similarities

1) Mutual cooperation in ant colony: The artificial ants and real ants both change the environment on their paths. The real ants leave pheromone on the path while artificial ants change the digital information stored on the path; the information can record the performance state of ants' current and historical solution, and can be read or modified by the succeeding artificial ants. Single artificial ant can construct a solution to the problem, but the optimal (suboptimal) solution can be found only through the mutual cooperation of many artificial ants, and the cooperation between the individual artificial ants is fulfilled through reading or writing the state variables of the problem.

2) The same task: The artificial ants and real ants have the same tasks, that is, to find the shortest path between the origin (the nest) to the destination(the food). Artificial ants and real ants both can not jump, and can only move step-by-step between adjacent nodes until traverse all nodes. In order to find the shortest path after several times of path-searching, the current mobile sequence should be recorded.

3) Partial Movement: The artificial ants and real ants move from a node to the next by the strategy of probability selection. This strategy only uses the partial information without predicting the future state by forward-looking strategy, so, the strategy is adopted partially both in time and in space.

3. 2. 2. Differences

The artificial ants have some characteristics that real ants do not possess:

1) Artificial ants exist in a discrete space, and they move from one discrete state to another.

2) Artificial ants have the internal state, that is, the memory capacity of artificial ants can remember the places they have passed.

3) Artificial ants exist in an environment with no relation to the time.

4) Artificial ants are not totally blind obedience, and inspired by the space feature of the problem. For example, the majority of the artificial ants will update the pheromone on the path only after finding a solution.

5) The additional performance of artificial ants can improve the optimization efficiency of algorithm, such as partial optimization, future prediction and back-off, which do not exist in real ant colony. In many specific applications, artificial ants can exchange information during partial optimization, and some artificial ants in some advanced ant colony algorithm can predict the future simply.

3.3. Process of ant colony algorithm

In ant colony algorithm, artificial ants represent the random construction process of a solution, It starts from the initial empty solution, adds components of solutions to the partial solutions continuously and establishes a complete solution. Process of the ant colony algorithm shows in Figure 2:

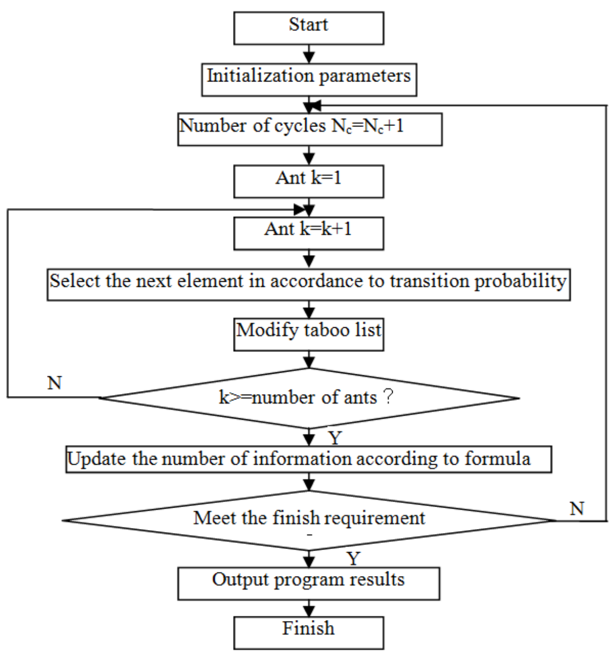

Figure 2. Process of ant colony algorithm

3.4. Routing Algorithm Model

We demonstrate the model by the example of finding a solution of a net work with n nodes. Assuming that in order to establish a network routing, m nodes transmit the searching signaling at the same time. d_{ij} $(i, j = 1, 2,...,n)$ represents for the distance between node of *i* and *j*, $\tau_{ij}(t)$ represents for the number of effective signaling (within life cycle) received during the path between the node *i* and *j* at the time of *t*.

In the initialization, we select different m nodes randomly, the number of effective signaling between the node *i* and *j* is τ_{ij} (0). The tabuk first element of each signaling k is assigned as starting node.

Here, $p_{ij}^{k}(t)$ represents for the probability that signaling *k* transfer from node *i* to node *j* at the time of *t*, then:

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum_{reallowed k} \tau_{ir}^{\alpha}(t)\eta_{ir}^{\beta}(t)}, j \in allowed_k \\ 0, \ otherwise \end{cases} \qquad (1)$$

Among them, the allowedk = {0, 1... , *n* - 1} - tabuk represents for the nodes set of signaling *k* next allowed to pass through. Different from and the actual ant colony, the artificial ant group has the ability of memory, tabuk (*k* = 1, 2,..., *m*) is used to record the nodes that signaling *k* pass through at the present time, it is adjusted dynamically with forwarding process of signaling *k*. Signaling τ_{ij} (*t*) will gradually become valid with the passage of time, 1-ρ stands for its degree of fading away; α , β separately represent for the accumulated amount of information of signaling in the process of retransmission, and the different roles heuristic factor played in the path selection during the signaling retransmission; η_{ij} (*t*) stands for expectations degree of the transfer between node *i* to the node *j*, we can make the decision according to a certain heuristic algorithm.

After the moments of *n*, Signaling *k* go through all the nodes, and complete *a* cycle. At this time, the amount of information in all paths should be updated according to the following equation:

$$\tau_{ij}(t+n) = \rho \cdot \tau_{ij}(t) + \Delta\tau_{ij} \qquad (2)$$

Then,

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \qquad (3)$$

$\Delta\tau_{ij}^{k}$ stands for the amount of information of signaling k's traces left between node I and node *j* in this cycle in. Its calculation method is decided by the calculation model, and M.D origo had once given three different models--- ant cycle system, ant quantity system, ant density system [6]. In the most commonly used model of ant cycle system:

$$\Delta\tau_{ij}^{k} = \begin{cases} Q / L_k, \text{if signaling } k \text{ passes through the node } i \text{ and } j \text{ in this cycle} \\ 0, otherwise \end{cases} \qquad (4)$$

Then, Q stands for the constant, Lk stands for the length of the path that signaling k has walked in this cycle.

3.5. The simulation process

Step 1 The initialization of the parameter. Let's make time $t = 0$, the times of search $nc = 0$; make $\tau_{ij}(0)$ on each side $\tau_{ij}(0) = c$, in this equation, c stands for a constant, and $\Delta\tau_{ij} = 0$; and then choose m nodes from n nodes randomly.

Step 2 Place the initial starting point of each signaling in the current solution set $tabu_k(s)$, move each signaling $k(k = 1,..., m)$, to the next node j according to the probability p_{ij}^{k}; and place the node j in tabuk (s).

Step 3 Signaling k can go through all the nodes and thus complete a cycle after the period of time of n. Then we can calculate the total path length L_k that each signaling has passed through, and updated that to find the shortest path.

Step 4 To update the information $\tau_{ij}(t + n)$ on each side.

Step 5 Place $\Delta\tau_{ij} = 0$ on each side; $nc = nc + 1$.

Step 6 if $nc <$ the selected number of times NC_{MAX} which are reserved, then turn Step 2; otherwise, print out the shortest path, terminate the entire program.

4. The Simulation Results

Take the network 4 by 4 as an example, we make the simulation of searching the route based on ant colony algorithm.

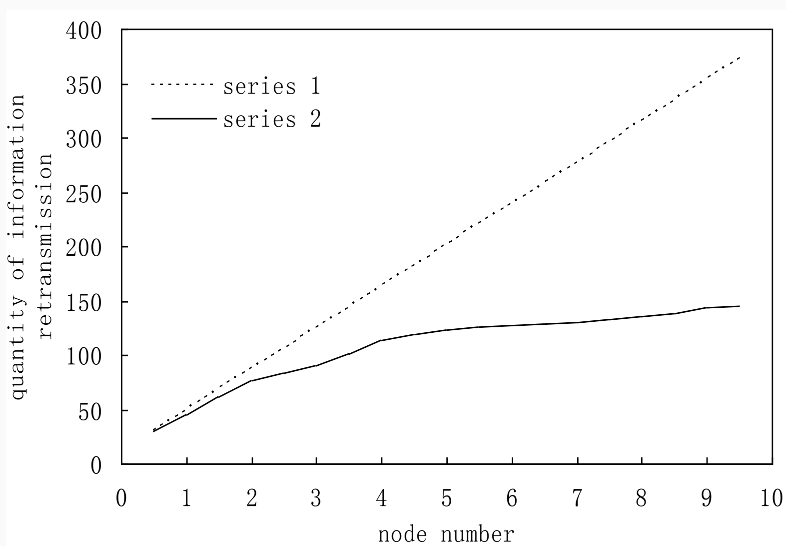

Figure 3. The contrast of signaling transfer quantity between the common broadcast route searching and searching route through ant colony algorithm contrast

In Figure 3, abscissa axis represents for the number of nodes that participate in searching route, vertical axis is the quantity of information retransmission, so it is obvious that searching route through ant colony algorithm can reduce the broadcast storm effective effectively.

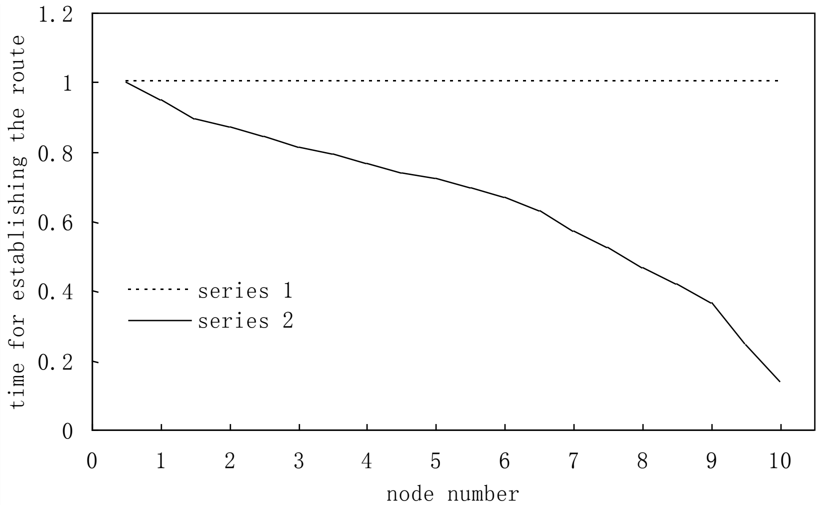

Figure 4. The contrast of establishing time between searching route through the general broadcast and that through ant colony algorithm

In Figure 4, abscissa axis represents for the number of nodes that participate in searching route, vertical axis is the time for establishing the route, if we set establishing time of the entire network broadcast routing is 1, we can conclude that with using ant colony algorithm to establish routing, the time of establishing the route was significantly shortened with the increasing number of nodes in searching route.

5. Conclusion

This paper studies that we can search the route through ant colony algorithm, and using the broadcast signaling which is featured with the random sending and the short life cycle to overcome the problem of more network nodes and more variable network structure, at the same time to reduce the broadcast storm effectively.

Acknowledgements

Project Supported by the Natural Science Foundation of Heilongjiang Province, China (Grant No: F201034).

References

[1] H. D. Gao, Y. J. Guo, J. Q. Cui, H. G. Hao and H. Shi, "A Communication Protocol of RFID Systems in Internet of Things", International Journal of Security and Its Applications, vol. 6, no. 2, **(2012)**, pp. 91-102.

[2] J. D. Prince, "Etechnology Educated Groceries:The Internet of Things on the Rise", Journal of Electronic Resources in Medical Libraries, vol. 9, no. 3, **(2012)**, pp. 232-239.

[3] A. L. Bleda, A. J. Jara, R. Maestre, G. Santa and A. F. G. Skarmeta, "Evaluation of the impact of furniture on communications performance for ubiquitous deployment of wireless sensor networks in smart homes", Sensors (Basel, Switzerland), vol. 12, no. 5, **(2012)**, pp. 6463-6469.

[4] P. Nand and S. C. Sharma, "Performance study of Broadcast based Mobile Adhoc Routing Protocols AODV, DSR and DYMO", International Journal of Security and Its Applications, vol. 5, no. 1, (2011), pp. 53-64.

[5] D. Kothandaraman, A. Amuthan, C. Chellappan and N. Sreenath, "Prevention of Vulnerabilities on Location-based Geocasting and Forwarding Routing Protocol in Mobile Ad-hoc Network", International Journal of Security and Its Applications, vol. 5, no. 1, **(2011)**, pp. 65-76.

[6] D. Liu, P. H. Cai, J. L. Wang, R. Pan and H. Zhao, "The Design and Implement of TCP/IP Protocol Cluster on AVR Singlechip", Journal of Software Engineering and Applications, vol. 3, no. 8, **(2010)**, pp. 761-766.

[7] Y. Ling, Y. Gu and G. Wei, "Detect SYN Flooding Attack in Edge Routers', International Journal of Security and Its Applications, vol. 3, no. 1, **(2009)**, pp. 31-46.
[8] G. P. Zhang and W. T. Gong, "The Research of Access Control Based on UCON in the Internet of Things", Journal of Software, vol. 6, no. 4, **(2011)**, pp. 724-731.
[9] F. Wang, "Research on Location Selecting for Logistics Distribution Center Based on Ant Colony Algorithm", Journal of Convergence Information Technology, vol. 7, no. 16, **(2012)**, pp. 255-262.
[10] F. Correia and T. Vazao, "Simple ant routing algorithm strategies for a (Multipurpose) MANET model", Ad Hoc Networks, vol. 8, no. 8, **(2010)**, pp. 810-823.
[11] S. Misra, S. K. Dhurandher and M. S. Obaidat, "A low- overhead fault- tolerant routing algorithm for mobile ad hoc networks: A scheme and its simulation analysis", Simulation Modelling Practice and Theory, vol. 18, no. 5, **(2010)**, pp. 637-649.
[12] H. S. Li, S. Liu and B. Hu, "Design of Node Power Management in WSN Based on Ant Colony Algorithm of International Conference on Networks Security, Wireless Communications and Trusted Computing", Washington D. C., USA: IEEE Computer Society., **(2009)**, pp. 73-743.

Authors

Ying Lu, Master, work in Computer and Information Engineering, Harbin University of Commerce, China; lecturer. The major research fields: artificial intelligence, information services; e-commerce and e-government.

Wen Hu, master supervisor, president of School of the Computer and Information Engineering, Harbin University of Commerce, China. backup leader of " Electronic Commerce" provincial key discipline echelon and academic leader of secondary doctoral discipline "electronic commerce and information service" in first-class doctoral discipline "business administration".