An IoT Ant Colony Foraging Routing Algorithm Based on Markov Decision Model

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Abstract—**This paper proposes a Markov decision ant colony routing selection algorithm based on the multi-parameter equilibrium. In this routing algorithm, five unit group Markov routing decision model based on IoT is build, network link quality, node residual energy and neighbor node number three aspects is considered, the node next-hop route set is gained by the value iteration process, ant colony algorithm is used to calculate the transition probability of nodes in allow decision set, and the optimal path selection of IoT routing is completed. Simulation results show that in the algorithm the overhead generated by messages is reduced effectively, the network energy consumption is balanced, and the network life cycle is prolonged.**

Keywords-IoT; Markov decision model; Ant colony algorithm; Energy balance; optimal path

I. INTRODUCTION

With the development and revolution in the field of information, the internet of things has become the key technology in the field of wireless communications. As the network intellectualization requirements increasingly intense, the new requirements of routing protocols' intellectualization are put forward. Because of the complexity of IoT[1] (the Internet of Things) and its special requirements of routing selection, it is difficult to adapt to different environment when Making routing selection only considers a small amount of elements in the network.

At present related area scientific research workers have proposed a variety of IoT routing protocols with the ability of self-organization, self-learning, self- decision and self-configuration based on the traditional flooding protocol, gossiping protocol, rumor routing protocol, LEACH (Low Energy Adaptive Clustering Hierarchy) protocol, self-organization network routing protocol and so on[2–3]. Such as: energy balance routing algorithm based on Markov game[4],

TrANTHOCNET[5] routing algorithm both with credence and robustness, discrete particle swarm routing algorithm constructed of optimization minimum energy consumption multicast tree[6] and so on.

This paper proposes a Markov decision ant colony routing selection algorithm based on the multi-parameter equilibrium. In this paper according to the practical application environment with different weights to reach equilibrium, network link quality, node residual energy and neighbor node number three aspects is considered, and the equilibrium results is made as the evaluation standard of the Markov routing decision model's evaluation function. This paper builds five unit group Markov routing decision model based on IoT, through the value iteration process to gain the nodes' allow decision set, namely the next-hop route set. In this paper, ant colony foraging process is imitated for routing selection, the transition probability of nodes in allow decision set is calculated, and the optimal path selection of IoT routing link is completed by using the transition probability. Thus the paper promotes the network overall performance, prolongs the network life cycle, and achieves global routing optimal strategy selection.

II. IoT ANT COLONY FORAGING ROUTING BASED ON MARKOV DECISION MODEL

IoT is a complex network consisting of large-scale nodes. In the routing selection phase, selecting different path will affect the network overall performance, and it is very important to measure the pros and cons of path, when choosing the path only consider a single parameter can not adapt to different environment well and conduct comprehensive evaluation. Team intends to use the link quality, node residual energy and neighbor number three parameters to evaluate the path which can well reflect the network performance, and makes the three parameters' equilibrium results as the evaluation standard of the Markov

routing decision model's evaluation function according to the requirements of different application background deploying different weights to the three qualified parameter. This topic plans to build the Markov routing decisions model based on IoT to assess the path within the scope of node communication, using the five unit group {$J(i)$, S, $A(i)$, $T(j|i,a)$, $R(i,a)$} consisted of decision stage set $J(i)$, node state set S, forward action set $A(i)$, state transition probability $T(j|i,a)$, compensation value $R(i,a)$ as the Markov routing decisions model. J is {0,1,2,…n}. n is the maximum number of nodes in node communication scope. i is the current node status values. j is the selected node status values. a is packet forwarding operations. Define value function $V_t(i)$ is the evaluation function model, the specific formula such as (1), setting stage step for t and using value iteration process.

$$V_t(i,a) = \max_{a \in A(i)} \left\{ R(i,a) + \gamma \sum_{j \in J} T(j|i,a) V_{t-1}(j) \right\} \quad (1)$$

Among them, $T(j|i,a)$ is the transition probability from node i to node j when carry out a. $\gamma \in (0,1]$ is the discount factor. The optimal value function $V_t^{\ast}(i)$ is the equilibrium results of the link quality, node residual energy and neighbor number three parameters, value iteration is took for the evaluation function, and the allow decision set of all the not less than the optimal value function is got as the solution of the Markov routing decision problem, and as the basis of ant colony measure the pros and cons of local path.

In order to select the global optimal path, this team draws ants foraging process into IoT network routing optimal strategy selection, studies show that the ants have the ability to find the shortest path between nest and food, and will also leave a kind of pheromone on the path, the greater the pheromone concentration, the more ants attracted, so that the ant colony find the shortest path. This team takes the build process of communication path between source node to destination node as ants foraging process, the source node is took as a nest and the destination node as food, the allow decision set acquired by the Markov routing decision model is made as the basis of ant colony measure the pros and cons of local path, and the concentration of the pheromone is calculated by the corresponding evaluation function value. The specific formula such as (2) namely the concentration of the pheromone is the proportion of t stage taking a action's evaluation function value of allow decision set's evaluation function value sum ratio.

$$\tau_t(j|i) = \frac{V_t(i,a)}{\sum_{a \in A(i)} V_t(i,a)} \quad (2)$$

In the premise of known pheromone, in t stage, ant colony calculates the transition probability of allow decision set reaching the communication range, the specific formula such as (3), and selects the maximum transition probability as the next-hop routing.

$$p_t(j|i) = \begin{cases} \dfrac{[\tau_t(j|i)]^{\alpha}[\eta(j|i)]^{\beta}}{\sum_{j \in J(i)}[\tau_t(j|i)]^{\alpha}[\eta(j|i)]^{\beta}}, & j \in J(i) \\ 0, & else \end{cases} \quad (3)$$

Among them, $J(i)$ is the allow decision set of Markov routing decisions model, namely the nodes set within the scope of i node communication range. $\tau_t(j|i)$ is the pheromone concentration between i node to j node for t stage. $\eta(j|i)$ is the heuristic factor between i node to j node, usually taking the reciprocal of Euclidean distance between i node to j node. α is the proportion of ant colony according to path selection by the pheromone. β is the relative strength influenced by heuristic factor.

When the source node has data sent to the destination node, the build process of communication path between source node to destination node is took as ants foraging process, the source node is took as a nest and the destination node as food, and node calculates the transition probability of allow decision set within its communication, through the transition probability to select the optimal path. Because of that transmitting data packet directly can cause the increase of network delay and energy consumption, before data transmission this team plans to use forward ants to find optimal path. Underneath is the description of routing selection process combined with figure 1.

Node a is set to the source node, and it is also named the nest of ant. Node b is set to the destination node, and it is also named the food. The forward ant is send during the routing discovery phase. The backward ant is send during the routing validation phase. The purpose of forward ant is to search available path and choose the optimal path before sending data, and the purpose of backward ant is to update the path and determine the optimal path, making the data transmitting according to the path. When the source node needs to send data to the destination node, the source node first needs to check the routing table, if there is an item to the destination node, then the data is transmitted according to existing routing. If there is no existing routing, the Markov routing decision process that proposed in this research is used. According to the application background, three parameters proportion of the link quality, node residual energy and the number of neighbor node are weighed. Then the path within the scope of communication is evaluated, the evaluation function value $V_t(a)$ of the path that meet the requirements within the scope of the current phase node communication is calculated. According to the evaluation function value, the pheromone concentration is calculated, and the current phase transition probability $p_t(\bullet|a)$ of the set of allow decisions within the scope of communication is also calculated. The path of biggest transition probability is selected as the forward direction of forward ants. If the forward ants reach the destination node, the path of least hop is selected to transmit back ants. The routing table of each node along the road is updated until nest of ants, and the backward ants are declared of death, so the routing building process is complete.
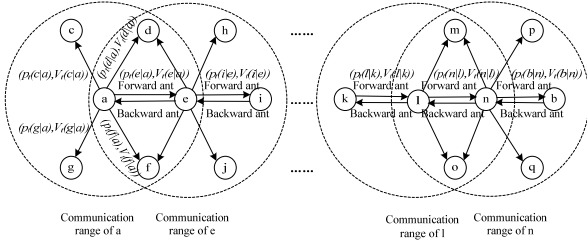
Figure 1 IoT ant colony foraging routing process based on Markov decision model of t state

III. SIMULATION AND ANALYSIS

Energy consumption model of wireless communication is :

$$E_{tx} = \begin{cases} l \bullet E_{elec} + l \bullet e_{fs} \bullet d^2 & if \quad d \le d_0 \\ l \bullet E_{elec} + l \bullet e_{mp} \bullet d^4 & if \quad d > d_0 \\ l \bullet E_{elec} & if \quad d = d_0 \end{cases}$$

Among them, E_{elec} =50nJ/bit, e_{fs} =10pJ/bit/, e_{mp} =0.0013pJ/bit/ m^4 , circle round number is 1200 rounds, and the initial energy is 0.3J.

When the number of the node ranges from 100 to 1600, the performance of the ability of subsistence has been shown in figure 2 and figure 3. From the figure we can conclude that, under the condition of same number of nodes the subsistence round number of nodes is the life cycle of the network, and the life cycle of Markov-A algorithm is longer than LEACH algorithm.
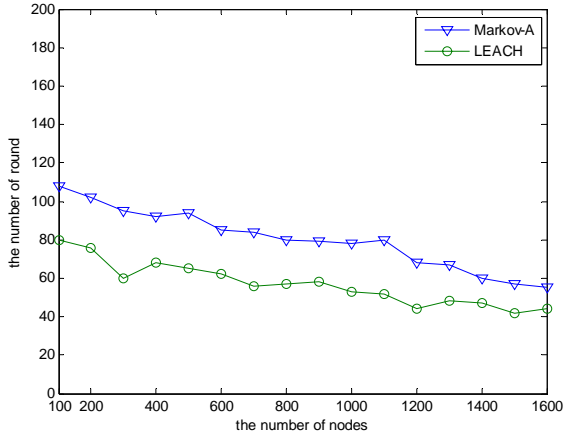

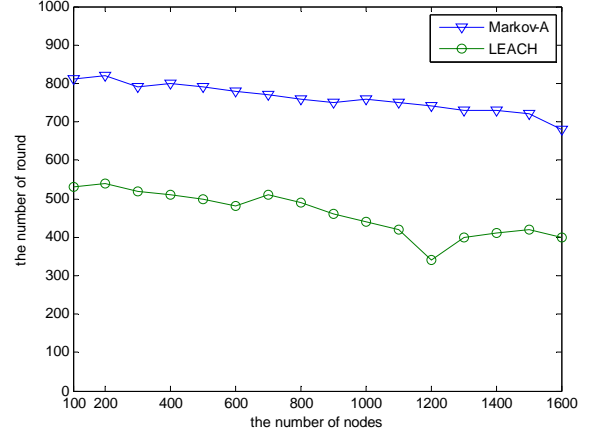Figure 2 The comparison of round number for the first dead node

Figure 3 The comparison of round number for 100% node dead

When the area is 400*400, the comparison of the number of alive nodes for two algorithms is shown in figure 4. Due to the effects of distance and the number of nodes, the first round appears the first dead node for the two algorithms. While the life cycle of Markov-A algorithm is clearly longer than LEACH algorithm. Because of the organic combination of Markov decision model and ant colony model, the data transmission energy consumption between the cluster that near the base station and away from the base station is balanced by Markov-A algorithm.
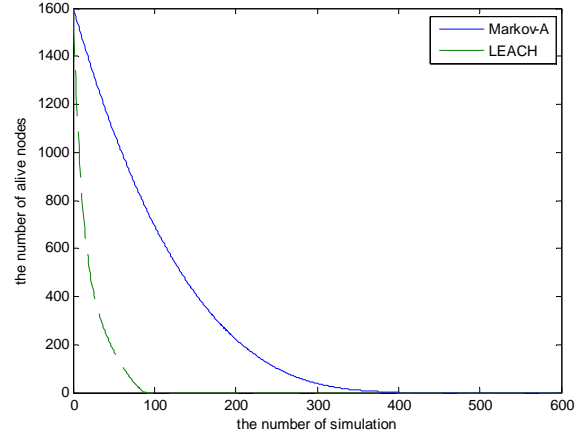

Figure 4 The comparison of the number of alive nodes

The network energy consumption comparison figure along with the change of the simulation cycle of the two algorithms is shown in figure 5. The smaller slope of the curve indicates the slower speed of energy consumption and longer network life cycle. The slope of Markov-A algorithm is clearly smaller than LEACH algorithm, and it can indicate that the energy consumption of nodes is effectively balanced by Markov-A algorithm.
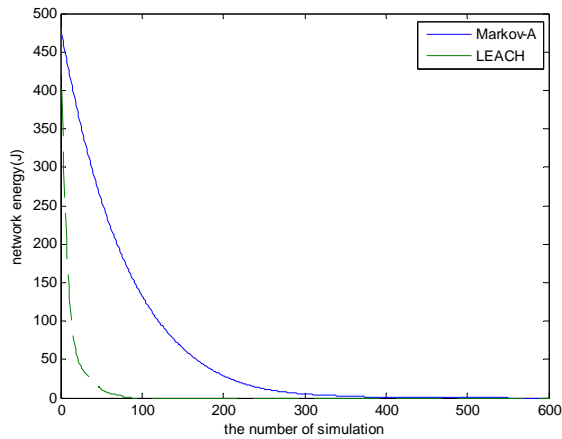
Figure 5 the comparison of network energy consumption

IV. CONCLUSIONS

According to the large-scale routing strategy, IoT ant colony foraging routing based on Markov decision model is proposed. Markov-A protocol uses Markov routing decision model to evaluate the nodes within the scope of node communication range, and gets the allow decision set which meets the requirements. The algorithm effectively reduces the overhead which is generated by control messages, and multiple hops routing between clusters make the evaluation function value of the path for allow decision set correspond to the pheromone concentration of ant colony foraging process. During the routing discovery phase, the algorithm mimics ant colony foraging in the process of routing discovery process, and calculates the transition probability of nodes, then selects the global optimal routing. Simulation results show that the problem of network "hot spots" is effectively solved by Markov-A algorithm, the energy consumption of network is balanced, and the life cycle of network is prolonged.

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