ISSN: 2664-9640

Research on Optimization of Mesh Routing Based on Greedy Particle Ant Colony Algorithm

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Abstract

Aiming at the wireless Mesh routing optimization problem, in order to change the traditional ant colony algorithm's high computational cost and the shortcomings of the optimization process that is easy to converge to a certain link, an improved ant colony embedded with Greedy Particle Property (GPP) is proposed. Algorithm-GPP_Ant algorithm. The algorithm is first based on ant colony optimization. After each iteration finds a path, the ant colony assigns the optimization result to particles, and uses the particle swarm to find the optimal routing link. Comparing simulation and traditional ant colony algorithm, GPP_Ant algorithm has faster optimization convergence speed and better system-wide optimization performance.

Keywords

Wireless Mesh network; Ant colony algorithm; Particle swarm optimization; Greedy particle nature; GPP_Ant algorithm; Overall Importance.

1. Introduction

The wireless Mesh consists of the backbone network and the client. A large number of wireless routers form the backbone network to connect to the external Internet network, and the client part is connected to the backbone network, thus forming a regional temporary self-organizing communication grid.

In the case of emergency communication, Mesh network has stable topology and flexible network structure, so it has great research value in the temporary arrangement of emergency communication network. This paper focuses on the wireless Mesh AD hoc network in the emergency communication environment, information exchange is large, if the traditional routing optimization method, there will be major communication link congestion and other problems, in-depth research on wireless Mesh routing technology, to propose a method that can not only ensure the transmission quality of routing optimization, The algorithm can also balance the node load of Mesh network under the condition of heavy load of emergency communication.

As the prospect of wireless Mesh network has been gradually recognized by the majority of scholars, there has been a certain amount of achievements in the research of wireless Mesh routing technology. Literature [1] proposed a multi-path route discovery method for wireless Mesh network optimized by particle swarm optimization, and defined congestion prediction and node forwarding excellence functions as fitness functions of particle swarm optimization model, so as to ensure the global fitness of the path calculated and alleviate the overload problem of some nodes. However, particle swarm optimization algorithm alone has the disadvantage that the obtained route may not be the shortest route. Although the fitness of the global path is improved, the transmission efficiency of the path is still not guaranteed. In reference [2], a routing algorithm combining AODV and ant colony algorithm was proposed to solve the load balancing problem of Mesh AD hoc network. Based on route discovery and maintenance of AODV, ant colony algorithm was introduced to reduce transmission delay by

ISSN: 2664-9640

considering pheromone concentration as well as the load of the next node. It can also balance the load of each node. However, the ant colony algorithm itself has the disadvantage of slow convergence speed. If the calculation of node load is added in the ant colony optimization process, the efficiency of the optimization will be reduced. Literature [3] describes an improved energy optimization algorithm based on ant colony algorithm, on the basis of ant colony algorithm to join the concept of distance and limit the search Angle, when a node in the process of transmission is too "hot", select "hot" insufficient residual energy and distance far away "hot point", and the node when routing optimization candidate list take out. In this way, hot points are not overloaded, which increases the lifetime of the Mesh network. Literature [4] proposed a hybrid algorithm combining ant colony algorithm and immune algorithm for QoS routing in wireless Mesh networks. The new algorithm has both the global optimality of immune algorithm and the robustness of ant colony algorithm. Literature [5] proposed a multi-path routing protocol based on ant colony algorithm. The residual cache of MAC layer is used as pheromone, and the lowest correlation strategy is used to select multipath routes, so as to construct multipath routes that meet QoS requirements. Literature [6] proposed a multipath multicast routing protocol. In this algorithm, slots are allocated in the multi-path routing tree so that the total number of routes can meet the requirements of bandwidth and quality of service. References [7,8,9,10] mainly focus on the improvement and optimization of ant colony algorithm, which provides some ideas for the fusion algorithm proposed in this paper. References [11,12,13] respectively proposed the introduction of energy efficiency balancing, opportunistic routing transmission and multi-stage enhanced auction modes for Mesh network routing optimization.

On the basis of the above research, this paper proposes a GPP_Ant algorithm embedded with Greedy Particle Property (GPP) to solve the problem that traditional ant algorithm is slow and easy to converge on local hotspot links. The algorithm is firstly based on ant colony optimization. The optimization results were assigned to the particle swarm, and then the local and global extremum iterations were carried out. The positive feedback of the ant colony algorithm and the global optimality of the particle swarm algorithm were combined to achieve the optimization effect of ensuring the transmission quality and balancing the load of each node.

2. System Model

2.1. Introduction to Wireless Mesh

A wireless Mesh network consists of a Mesh router and a Mesh client. Mesh routers constitute the backbone network and are connected to the wired Internet. Mesh routers are mainly composed of two parts, namely, wireless routers and Mesh clients. Mesh routers constitute the backbone network. Mesh Clients Connects to the Internet through the backbone network. The wireless Mesh routing optimization problem can be equivalent to a TSP problem, and the Mesh network nodes are equivalent to the TSP problem in which different cities are randomly distributed in the Mesh grid. When the source node needs to transmit messages to another destination node, the Mesh network needs to quickly find high-quality communication links.

2.2. Multi-constraint QoS routing model for WMN networks

Definition 1. For the QoS model of WMN, S= (P,L), P is the set of all network nodes in the communication scene, and L is the set of all communication links in the scene.

Definition 2. Given S= (P,L), all path sets between source node A $\in$ P and destination node B $\in$ P are denoted as G, and the path set contains corresponding node set P and link set L. QoS description of the whole process is as follows:

Delay:

$$Delay(g) = \sum_{p \in P(g)} Delay(g) + \sum_{r \in R(g)} Delay(g) \quad (1)$$

ISSN: 2664-9640

Bandwidth:

$$BandWidth(g) = min\{BandWidth(p), p \in P(g)\} \tag{2}$$

Packet Loss Probability:

$$Loss(g) = 1 - \prod_{p \in P(g)} (1 - Loss(p)) \tag{3}$$

Link Cost:

$$Cost(g) = |P(g)| \tag{4}$$

Where, the cost is the hop count of the link found by route optimization.

In WMN, the fundamental purpose of the algorithm is to solve the path G 'with the minimum cost when meeting the following QoS constraints.

Delay (g ') ≦ D;

Bandwidth (g ') ≧ B;

Loss (g ') ≦ L;

Cost(g ') is minimum ((1), (2) and (3) are satisfied).

Where D is the delay constraint, B is the bandwidth constraint, and L is the packet loss rate constraint.

3. Algorithm Description

3.1. Ant Colony Algorithm

The traditional Ant Colony Optimization algorithm (ACO) was originally used to solve the TSP problem. During the foraging process, forward-facing ants leave behind a chemical called Pheromone along their path. The ant then chooses a path based on Pheromone accumulation, eventually converging to a path with the shortest number of pheromones and the highest number of pheromones, resulting in the best output.

By the same token, the ant colony algorithm also can be used in wireless Mesh routing optimization, suppose that a wireless Mesh network area there are N nodes, these nodes is equivalent to the TSP problem in different cities, when there is need to transport the message to another node, the node can form a pair of source and destination node pairs, the node to source node will send forward ant optimization. In the process of optimization, the ant will select the next routing node according to a certain probability $P_{ij}^k(t)$, which is calculated by the following formula:

$$P_{ij}^k(t) = \begin{cases} \frac{[\tau_{ij}(t)]^\alpha \cdot [\eta_{ij}(t)]^\beta}{\sum_{s \in J_{k(i)}} [\tau_{is}(t)]^\alpha \cdot [\eta_{is}]^\beta}, j \in J_k(i) \\ 0, others \end{cases} \tag{5}$$

Where, $\tau_{ij}(t)$ is the updated value of each path pheromone, $\eta_{ij}(t)$ represents the expected value of a network node to be selected, α and β are weight factors, which are different according to the actual communication environment. Node expectation $\eta_{ij}(t)$ is defined by the following formula:

$$\eta_{ij}(t) = \frac{1}{cost(i,j)} \tag{6}$$

When all the forward ants have traversed the node city once, pheromones of each path will be updated according to the following formula:

$$\begin{cases} \tau_{ij}(t+n) = (1-\rho) \cdot \tau_{ij}(t) + \Delta\tau_{ij} \\ \Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^k \end{cases} \tag{7}$$

ρ represents pheromone volatilization coefficient, and $\Delta\tau_{ij}^k$ represents pheromone concentration released by ant k on path ij.

Pheromone concentration of each path is volatile, so pheromone concentration can be defined by the following mathematical model:

$$\Delta\tau_{ij}^{k}=\begin{cases} Q/L_k, Ant\ k's\ path\ ij \\ 0, others \end{cases} \tag{8}$$

Q is a constant, L_k representing the length of the path.

3.2. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a Swarm Optimization algorithm, which seeks the optimal solution through population cooperation. Its idea is invented by imitating the behavior of biological populations in nature when looking for food. The advantage of the algorithm is that it is simple and efficient, and generally can achieve global optimization. The convergence formula of particle swarm optimization is as follows:

$$v_{id}^{k+1}=wv_{id}^{k}+c_1r_1(pbest_i-x_{id}^{k})+c_2r_2(gbest_i-x_{id}^{k}) \tag{9}$$

$$x_{id}^{k+1}=x_{id}^{k}+v_{id}^{k+1} \tag{10}$$

$$(i=1,2,\ldots,NP;d=1,2,\ldots,D) \tag{11}$$

Where, $w>0$ is used to adjust the search scope of the solution space. v_{id}^{k} and x_{id}^{k} are used to describe the current comprehensive state of the particle, representing the velocity value and position value of the population particle belt vector respectively. c_1 and c_2 are preset constants that regulate the step size of individual particle swarm optimization. r_1 and r_2 are two random functions in $[0,1]$. The value of AAA is at. The function is to maintain the random characteristics of the algorithm and prevent the algorithm from falling into local optimization.

Particle swarm optimization algorithm has low computational cost and good optimization effect, while ant colony algorithm has natural pheromone positive feedback characteristic. If the two are combined, the computational cost can be reduced, the optimization effect of ant colony algorithm can be improved, and the optimization time of ant colony algorithm can be reduced. The third section will discuss an improved ant colony algorithm -GPP_Ant algorithm based on Greedy Particle Property (GPP).

4. GPP_Ant Algorithm

4.1. Population Initialization

The traditional ant colony algorithm, the population initialization time will put all the path pheromone to zero, so the traditional ant colony algorithm must again and again at the beginning of the optimization of all network nodes through time, then slowly put the optimal path is calculated, thus cause the ant colony algorithm computational cost is too big, also the slow convergence speed. In this paper, greedy is introduced into the ant colony algorithm. At the initial stage of the ant colony algorithm, greedy algorithm is used to generate part of the pheromone concentration distribution to reduce the computational cost of the algorithm. The realization steps of greedy algorithm are as follows:

Step 1: Add source node (i,j) to tabu TABLE $tabu_k$ as the current city of ant colony.

Step 2: Start from the source node, search for $NextList$ (all network nodes are stored in $NextList$), search for the next hop node (i',j') that is closest to the source node, and add it to tabu $tabu_k$.

Step 3: If there is a node that has not been traversed in $NextList$, go to Step (2).

Step 4: Get the initial solution of the population.

ISSN: 2664-9640

4.2. GPP Ant Algorithm Concrete Implementation

In this paper, the ant colony algorithm is optimized, the introduction of greed particles, mainly considering TanLanXing can reduce the computational cost algorithm, the particle sex can compensate for the global optimization ability of ant colony algorithm, so GPP_Ant algorithm based on greedy particle theory can make the Mesh network routing global search capability, convergence speed is faster, Computation is less expensive.

The following are the main implementation steps of GPP_Ant algorithm:

Step 1: initialize the population and set the parameters of ant colony algorithm and particle swarm optimization algorithm;

Step 2: The greedy algorithm was used to generate the initial path pheromone distribution.

Step 3: The ant selects the path according to the probability formula of Formula (5).

Step 4: Add tabu information. The node elements newly selected by ants are listed in tabu $tabu_k$ to avoid repeated selection of this node.

Step 5: After completing an iterative optimization search, record the optimal path information;

Step 6: Assign particle property to ants, calculate the fitness value of this iteration, and record the individual optimal value p_{best} and the global optimal value g_{best};

Step 7: The fitness value of the population was updated according to Formula (9) and formula (10);

Step 8: Repeat steps (3) to (7) until the iteration reaches the preset optimal threshold or the preset number of iterations, and output the result.

5. Simulation

In order to test the effect of GPP_Ant algorithm, this paper simulates and analyzes the algorithm. Firstly, the network scene model is established on the NS-2 simulator, and the GPP_Ant algorithm is imported into the optimization simulation. Finally, the simulation results are compared with the traditional ant colony algorithm (ACO) and particle swarm optimization algorithm (PSO).

5.1. Simulation Model

(1) Route optimization time: Route optimization time is defined as the time spent in the process of initiating an information transmission request from the source node to establishing a transmission route between the source node and the destination node. GPP_Ant algorithm has a faster route optimization speed in theory. This simulation is to compare the route optimization time of GPP_Ant algorithm with traditional ant colony algorithm (ACO) and particle swarm optimization algorithm (PSO) to observe whether the new routing protocol has a faster route optimization speed.

(2) Average link delay: Average link delay is defined as the average delay of all transmission links in the entire Mesh. GPP_Ant algorithm has a global optimization effect in theory, which can effectively avoid focusing on local optimal links. In this simulation, the link delay derived by GPP_Ant algorithm is compared with traditional ant colony algorithm (ACO) and particle swarm optimization algorithm (PSO). Check whether the new routing protocol can effectively shorten link delay in the Mesh network.

(3) Network lifetime: The network lifetime is defined as the time from the operation of wireless Mesh to the failure of nodes in the network. The longer the lifetime, the better the algorithm's node load balancing capability is. Theoretically, GPP_Ant algorithm can allocate node transmission links more comprehensively, and can effectively prolong the Mesh network lifetime. This simulation compares the network lifetime of GPP_Ant algorithm with traditional

ant colony algorithm (ACO) and particle swarm optimization algorithm (PSO) to observe whether the new routing protocol can effectively prolong the network lifetime.

5.2. Simulation Environment

Table 1 Simulation environment parameters

Simulation Environment	Parameters
Node distribution region	1500m*1000m
Node transmission distance	100m
Node movement model	Random Direction Model
Node movement speed	3m/s
Channels are available for each node	6
Duration of each simulation	3000s
Number of nodes	50~200

5.3. Interpretation of Result

Figure 1 shows the relationship between the number of nodes in the Mesh network and the link establishment time for the three algorithms. As can be seen in the figure, as the number of nodes increases, the link establishment time of the three protocols has become shorter. This is because the more nodes there are, the more nodes that can supply the link, and the node load is small, based on the greedy particle nature. The GPP_Ant algorithm has the fastest convergence speed, followed by the particle swarm algorithm, and the ant colony algorithm is the slowest. It can be seen that the GPP_Ant algorithm can effectively speed up the routing optimization speed of the Mesh network.

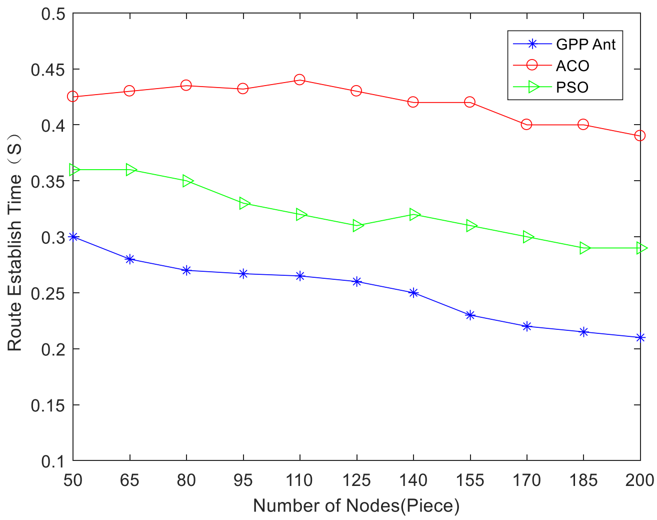

Fig. 1 Comparison diagram of link establishment time of the three algorithm

Figure 2 is a simulation diagram of the effect of the number of links on the link delay of the three algorithms in the Mesh network. In this simulation, different numbers of source and destination node pairs are randomly generated in the Mesh network with a fixed number of nodes, increasing the number of links in the Mesh network, and then comparing the link delays simulated by the three protocols, it is obvious that under the GPP_Ant algorithm The network has the lowest transmission delay and benefits from the global optimality of the GPP_Ant algorithm. Although the number of links increases, the transmission end-to-end delay has the least impact. The routing links of the GPP_Ant algorithm will not be concentrated on a few nodes. Thereby reducing the load of some nodes, reducing transmission delay, and improving efficiency. In contrast, the ant colony algorithm can easily cause routing links to be concentrated in the central transmission node of the network, resulting in node congestion, and the particle swarm algorithm path finding is also globally optimal Characteristics, so the link delay is close to the algorithm GPP_Ant proposed in this article, but GPP_Ant is the best.

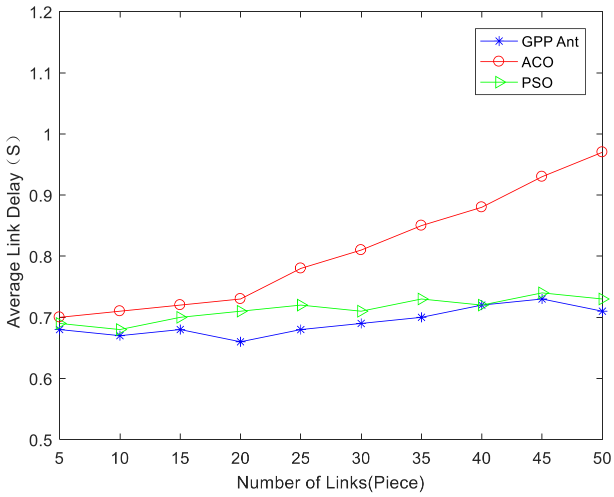

Fig. 2 Comparison diagram of average link delay of the three algorithms

Finally, for the three protocols in a Mesh network composed of 50 nodes, the number of network transmission links is continuously increased, the network life cycle time is monitored, and the simulation results in Fig. 4 are obtained. It can be seen that the survival time of the Mesh network using the GPP_Ant algorithm is longer than that of the traditional ant colony algorithm and particle swarm algorithm. At the same time, it can be seen in the figure that because the ant colony algorithm is easy to fall into the local optimum, so as the number of nodes increases , There will be too much load on some nodes, which will result in a significant reduction in network survival time, and the curve will decline the fastest. In contrast, the particle swarm optimization algorithm benefits from its multi-objective optimization to find the characteristics of the transmission link, and the network survival time under its algorithm is a little longer than that of the ant colony algorithm. Finally, the GPP_Ant algorithm used in this article shows that the network survival time is the best in the simulation results, and as the number of links increases, the curve of the survival time data becomes more stable. It can be seen that the use of GPP_Ant algorithm for routing optimization can make the data transmission of the Mesh network have The link load balance is more effective, and the transmission is more stable.

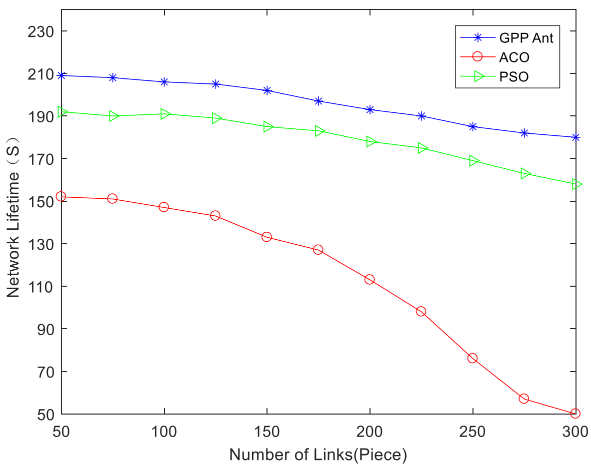

Fig. 3 Network survival time comparison diagram of the three protocols

ISSN: 2664-9640

6. Summary

This paper proposes a fusion algorithm GPP_Ant algorithm based on Greedy Particle Property (GPP). First, the greedness of the algorithm is used to generate the initial pheromone distribution, and then the particle swarm algorithm is applied to the ant colony algorithm to give the ants the particle property Nature, calculate the fitness of the optimal link, balance the load of each link of the Mesh network, and finally simulate the algorithm proposed in this paper. The simulation output results are compared with the ant colony algorithm (ACO) and the particle swarm algorithm (PSO) , The results prove that the GPP_Ant algorithm has faster routing optimization speed, shorter end-to-end delay and longer network survival time.

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