Balance and Optimization of Network Load Based on Two-way Feedback Ant Colony Algorithm

Dong Li

***Abstract*—Two-way feedback ant-colony algorithm is presented which aims at load balance and optimization of network resources management. The interaction and dynamic control among the pheromone of ants enable network traffic to share a number of paths; the algorithm uses ant number to represent the network traffic. The algorithm can expand as two-way feedback ant colony algorithm. When the ant judges pheromone strength of every path，it also considers optional link load conditions，then determines which path to choose, which makes the ants relatively balanced and distributed in optional links. The results of simulation experiment demonstrate that two-way feedback ant colony algorithm has superiority in reducing adaptive time comparing with the original colony algorithm, lowering packet loss rate, and improving the efficiency of load balance..**

***Index Terms*—Two-way feedback ant colony algorithm, ant colony optimization (ACO), network resource optimization, load balancing.**

I. Introduction

At present, with the constant expansion of Internet, volume of online business with high sudden and high real-time characteristics grows continuously, the network congestion is increasing seriously, distribution imbalance phenomena between resources and flow is universal. In a real-time network, the service request type initiated by customers is various. At a specific time piece, the flow through a gateway control node is irregular; network congestion often occurs in the position with relative shortage resources. The imbalance of position where congestion occurs reflects the imbalance of Internet. First distribution of resources is unbalanced, and the second is unbalanced distribution of flow. Unbalanced distribution of resources can increase or exchange network resource, unbalanced flow distribution often takes the flow scheduling algorithm or scheduling strategy to do scheduling. If congested probability increases in network link, the network performance will be lower.

Traditional routing control strategy takes the shortest path prior algorithm (such as Dijkstra algorithm) as the foundation, once the shortest path forms, the router is always tending to forward groups along the fixed shortest route, groups are often discarded because of increased congestion caused by sudden business flow, therefore, in the network searching for optimal path satisfying all constraint conditions and lower spend, and realizing the balance of resource load, become the effective method to solve the contradiction between network resources and high service quality [1]. In recent years, ant colony optimization algorithm generated from solving TSP problems and a series of discrete optimization problem, in the network routing field shows the very good application prospects [1], [2]. Basic ant colony algorithm is easy to fall into the local optimum, appearing premature stagnation phenomenon, although many scholars improve the pheromones update rules, and bring into the local search strategy, which effectively suppresses the premature stagnation phenomenon in convergence process, but after operation becoming stable network still tends to the shortest path, and there still appears congestion phenomenon facing sudden volume of business, it is difficult to realize network resources optimization disposition [3].

In order to solve congestion resulted by this problem with unreasonable distribution of resources, method of increasing network resources can not only be used, this paper introduces the anti-ant colony algorithm to solve the problem of load balance. To make the link flow achieve a balance on many exports of network, certain scheduling and load equilibrium strategy can be used to distribute the load to many links. Under the premise of low expenses, pheromone concentration on current route can become the index to choose route, avoiding the route with high pheromone concentration, which makes the network throughput as much as possible and makes the time delay as short as possible; this can transfer the flow on high load links to other low load links to reduce the packets discard on the links.

In this paper, the improved two-way feedback ant colony algorithm is used to do the research on flow optimization, algorithm firstly expands the ant colony algorithm as two-way feedback ant colony algorithm, while the ant judges pheromone strength on every path, at the same time it also considers the load situation on optional link, thus decides to choose which path to go, makes the ant relatively balanced distribute on optional links to avoid the free of link, also to avoid excessive congestion of some links and improve the efficiency.

II. Two-way Feedback Ant Colony Optimization Models

Biological inspiration mechanism is more and more applied into the research of network. And the ant colony algorithm is a biological heuristic optimization method selected through simulating ants to search for food to select intelligent route. In the study of the network traffic optimization, scholars tried different methods, Chunyong

Manuscript received March 11, 2012; revised April 13, 2012

D. Li is from College of Computer and Information Engineering, Xinxiang University, Xinxiang, China.

Yang [3] put forward the improved ant colony algorithm, in order to prevent network in a period of running time from too stubbornly choosing a fixed shortest route, who designed a selection size factor, when iteration random variable is greater than the factor, the routing selecting rules follow the ant colony algorithm; If it is less than the factor, routing selection is completely random. Jun Lu [4] in view of the load balance and optimization problem in network resources management, combing the ant colony algorithm with the network traffic engineering, presented an kind of network load dynamic equilibrium method of multi-ant colony, to realize the optimization of network resources. Jianli Ding [5] proposed a hybrid ant algorithm to realize the web resources equilibrium, through the combination of genetic algorithm and ant colony algorithm to get the optimal solution.

In some degree the above research solves the load balance problems of flow, but to the utilization of second best path in the links there are not the necessary consideration and analysis. Based on introduction of the second volume discrimination, this paper judges the best way according to the current bandwidth state of links, if the optimal path is always in high utilization rate state, non-optimal path or high-cost path are chosen to achieve the purpose of load balance, and from the reversal angle of ant colony algorithm to analysis problem, that is the idea of two-way ant colony algorithm.

A. Rules of Routing Selection

According to pheromone concentration and flow through secondary judge the link choice can be decided, to realize the load balance of flow and avoid network congestion, the experimental results show that this method implements the link load balancing and improves the network resources utilization.

Suppose each ant represents certain sizes of packets in the link to transfer, and each time the choice of certain path will take up certain size of bandwidth. Ants from source router s set out to the end of router d, in each step of the constructed journey, the ant k chooses rule according to the probability behavior known as a random proportion rule, and to determine the next step will move to which one of router nodes. If the ant k is currently locating at router i, the probability of choosing j as the next visit city is:

$$p_{ij}^{k}=\frac{\left[\tau_{ij}\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}{\sum_{l\in N^{k}}\left[\tau_{il}\right]^{\alpha}\left[\eta_{il}\right]^{\beta}},\quad j\in N^{k} \tag{1}$$

In the expression, $\eta_{ij}=d_{ij}^{-1}$ represents an in advance given heuristic information, α and β are two parameters, they decides relative influence of pheromone heuristic information, N_i^k represents the set of the adjacent cities that ant k situated in city i can directly arrive, i.e., the collection of all cities that have not been visited by ant k (the possibility is 0 to choose one from N_i^k cities). Under this probability rule, the probability of choosing some edge (i, j) is decided by the corresponding pheromone τ_{ij} and heuristic information value η_{ij} of this edge [6].

Each ant k defends a memory storage tabu[n], according to visit order it records all the router nodes serial number which has been visited. This memory storage is used to define the feasible region N^k in the given path structure rule, allows the ant k to calculate the total length of structured path, and can be used to traverse the path and release the pheromone. Now using an array Allowednode[n] to record the router nodes without passing, the array index is corresponding to node numbers. After calculating the current probability of the nodes without passing, the roulette method is used for choosing the next node. If the selected path currently has free bandwidth, so it is chosen; if there is no excess available bandwidth, it is can be chosen from other free links to avoid the happening of lost packages and keep the network resources relatively equilibrium.

B. Updates of Pheromone Information

When all the ants complete the building of path, that is after reaching the destination router node, the pheromone on each edge will be updated, namely ANT-CYCLE model, and there are also other methods, such as it will update once after the ant passes a node, experiments show that update is better after reaching the destination. First of all, all the pheromone on all edges will reduce the size of a constant factor, and the pheromone will be increased on the edges that ants pass through. The evaporation of pheromone executes according to the following:

$$\tau_{ij}\leftarrow(1-\rho)\tau_{ij},\forall(i,j)\in L \tag{2}$$

Among them ρ is the evaporation rate of pheromone, $0<\rho\leq 1$. The role of ρ parameter is to avoid the pheromone's infinite accumulation, and still can make the algorithm "forget" the selection of poorer path ago, to reduce the occurrence of local optimum. After the evaporation step of pheromone, all the ants release pheromone on the passing edges:

$$\tau_{ij}\leftarrow\tau_{ij}+\sum_{k=1}^{m}\Delta\tau_{ij}^{k},\forall(i,j)\in L \tag{3}$$

Among them, $\Delta\tau_{ij}^k$ is the pheromone amount that the ant k releases to the passed edges. $\Delta\tau_{ij}^k$ is defined as:

$$\Delta\tau_{ij}^{k}=\begin{cases}1/C^{k}\ , & \text{if edge (i,j) is in path } T^{k}\\ 0\ , & \text{otherwise}\end{cases} \tag{4}$$

Inside the expression, C^k represents the length of path T^k that ant k established, that is the sum of all the length of edges in T^k . According expression (4), better is the path constructed by ants, more pheromone will be obtained on each edge of the path. Generally speaking, if an edge is selected by more ants, and the total length of the path including this edge is shorter, thus this edge will get more pheromone, and in the later iteration it is more likely chosen by ants [6].

III. Experiment and Performance Analysis

In order to analysis the performance of two-way feedback ant colony algorithm, in VC environment the algorithm simulation experiment is preceded. The simple digraph coordinates with nine nodes are taken as data set, in the condition of considering time delays and cost, the optimization and load effect of two-way feedback ant colony algorithm are respectively executed the research.

A. Description of Simulation Experiments

Suppose the ant colony represents the bandwidth amount occupied by the data packet, each ant represents a basic network flow unit Bwide = 0.2 Mb, the biggest bandwidth capacity of link DG is 7Mb/s, in maximum 35 ants representing data are allowed to pass through at the same time; if the ants on the link take up more bandwidth, it can't accommodate new ants who choose this link, then there will produce the discard, so the network lost package rate can be obtained.

The algorithm's parameter value is m = 150, $\alpha = 1$, $\beta = 5$, $\rho = 0.5$, Q = 100. Because the number of ants is 150, which means 30 Mb data packets will reach the destination router node G from source point router node D, from the optimal angle, if only path cost is taken into account, all ants will choose the shortest path, exceeding the maximum capacity of a link will cause the generation of congestion and increase the packets loss rate. On the base of using basic ant colony algorithm to find the path with less cost, this algorithm sets a bandwidth limit value, after the optimal route reaches to a certain bandwidth utilization rate, ants are not allowed to choose this path and distributed to other better routing, to achieve relatively homogeneous distribution and the effective use of network resources.

B. Analysis of Network Load Balance Performance

Network load balance performance test chooses the following two network performance statistics as a standard, to measure the network performance and reflect the balance and optimization conditions of network resources.

The utilization rate of average bandwidth $\overline{B} = \frac{1}{t}\sum_{i=1}^{\infty} bwidth(i,T)$.

Average rate of lost package $\overline{L} = \frac{1}{t}\sum_{i=1}^{\infty} loss(i,T)$.

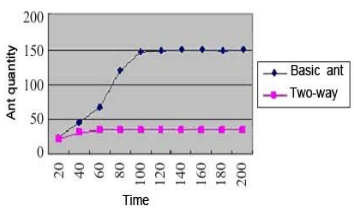
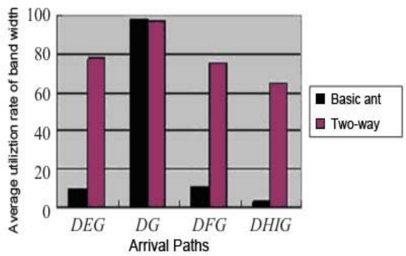


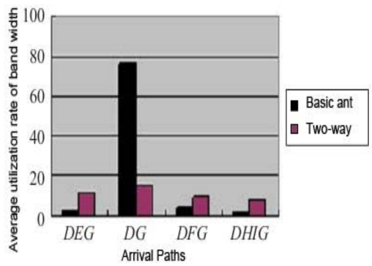
Fig. 1. The quantity change on the shortest route DG.

The experimental results of network path are shown in Fig. 1, thereinto, the x axis presents time, the y axis presents the ant number N of path DG. Basic ant colony algorithm can in a short period of time find the shortest path to reach the end of routing and release pheromone which influence the late ants, although the path on consumption has been optimized, this will cause great congestion with loss of data packets in the shortest path; which will leads the lost of data packets. And different with basic ant colony algorithm, the algorithm will control the shortest route DG load in a lower level, number of ants keeps within 35, that is the link bandwidth capacity is controlled within 7Mb/s to reduce the lost of package and network congestion.

The experimental results show because of the accumulation of pheromone, the basic algorithm will lead to the increase of transition probability; make the ants choose the shortest path to reach the destination. This algorithm will limit it near the biggest link volume without too much lost packages, also improve the utilization rate of link bandwidth.



(a) Average bandwidth utilization rate



(b) Average packet loss rate

Fig. 2. The experimental results of network balanced performance

Network balanced performance experimental results are shown in Fig. 2, thereinto, the x axis is corresponding to the main route of network, and the y axis respectively represents the average bandwidth utilization and the average packet loss rate. The experimental results show that, different with the basic ant colony algorithm, the two-way feedback ant colony algorithm can put the ants, in other words the data packets of network transmission, reasonably assigned to each path, instead of leading more and more packets into the shortest path DG, to achieve the purpose of network load balance. Comparing with basic ant colony algorithm, it improves the average bandwidth utilization rate from 31% to more than 65%, the network resource utilization rate has very big enhancement; packet loss rate will remain in 8% ~ 15%, which maintains a relatively low level and changes in lower range, this makes the network resources get reasonable balanced distribution.

The quantitative analysis of network performance is shown in Table I, the two-way feedback ant colony algorithm in this paper can effectively achieve the network load balance, make further improve on the comprehensiveness of network. The algorithm in this paper has more effective bandwidth utilization rate (79.25%), and has smaller packet loss rate (11. 25%).

TABLE I: NETWORK PERFORMANCE QUANTITATIVE ANALYSIS (%)

Algorithm	**Utilization rate of band width**	**Packet loss rate**
Basic ant colony	30.75	21.50
Two-way feedback	79.25	11.25

IV. LAST WORD

This article aiming to the flow distribution problem on the links of network, based on ant colony algorithm adding reverse feedback mechanism, proposes an improved algorithm to solve the network load dynamic balance, which takes into account the convergence speed and realizes the network load balance. Simulation results show that this method can judge the flow on the network links, allocate the flow to reach the load balance and improve the network efficiency. Future work will focus on the research of balance performance of complex network simulation.

REFERENCES

[1] M. Dorigo, M. Birattari, and T. Stutzle, Ant colony optimization. *IEEE Computational Intelligence Magazine*, vol. 1, no. 4, pp. 28-39, 2006,

[2] J. J. Pan and D. W. Wang, “An ant colony optimization algorithm for multiple travelling salesman problem,” in *Proc of the 1st International Conference on Innovative Computing，Information and Control,*2006.

[3] C. Y. Yang, and S. P. Chen, “The Network Load Balance Routing Optimization Based on Improved Ant Colony Algorithm,” *Computer Engineering*, vol. 4, no. 8, pp. 4-6, 2010.

[4] J.. Lu, and B. Qi, “Network Load Dynamic Equilibrium Method of Ant Colony Algorithm,” *Computer Applications,* pp. 572-574, 2008.

[5] J. L. Ding, and Z. Q. Chen, “The network resources equilibrium and optimization based on hybrid ant colony algorithm. *Journal of Instruments*,” (ZI): pp.592-598, 2003.

[6] M. Dorigo, and T. Stutzle, Ant Colony Optimization. Jun Zhang, Xiaomin Hu,Xuyao Luo. Beijing: Tsinghua University Press, pp. 69-71, 2007.

[7] Y. Qin, W. J. Xiao, etc. Pareto parallel routing optimization method based on a Qos measure. *Journal of Computer*, pp. 463-472, 2009.

[8] X. H. Wei, Z. J. Zhao, and Y. Y. Ye, “Network Routing Restructuring Based on the Improved Algorithm. Computer Engineering,” pp. 90-92, 2009.

[9] J. G. Vlachogiannis, N. D. Hatziargyriou, and K. Y. Lee, “Ant Colony System-based Algorithm for Constrained Load Flow Problem,” *IEEE Trans on Power Systems*, pp. 1241-1249, 2005.

[10] J. Triay and C.-P. C, An Ant-based Algorithm for Distributed Routing and Wavelength Assignment in Dynamic Optical Networks. *IEEE Journal on Selected Areas in Communications*, pp. 542-552. 2010.

[11] K. M. Sim,and W. H. Sun, “Ant Colony Optimization for Routing and Load-balancing：Survey and New Directions,” *IEEE Trans on System, Man, and Cybernetics-Part A: Systems and Humans*, pp. 560-572, 2003.