

TSP-Chord: An Improved Chord Model with Physical Topology Awareness

Zhen He¹⁺, Jianping Wang¹ and Si Liu²

¹ Department of Communication Engineering, School of computer and Communication engineering, University of Science and Technology Beijing, Beijing 100083, China

² Zhengzhou Normal University, Zhengzhou, 450044, China

Abstract. A physical topology aware Chord model (TSP-Chord) which based on ant colony algorithm is proposed in this paper. The idea of TSP-Chord is regarding the storage nodes in the whole Chord as a TSP problem and solving the TSP problem quickly by using the ant colony optimization algorithm, then building the Chord with the obtained TSP solution. The model is simple and easy to implement, which has small changes within the original Chord model. Simulation results show that TSP-Chord has obvious advantages in routing delay in comparison with other Chord models.

Keywords: Chord, TSP, ACO, Physical topology awareness

1. Introduction

Chord[1] is a classic structured P2P network model, which is characterized by being implemented simply and having relatively efficient routing hops whose average hop count is $O(\log N)$, so the query efficiency of Chord is high as shown in Fig.1. However, as a logical topology model, Chord lacks the use of information of the physical network topology, so two logical adjacent nodes are often not adjacent in the physical layer, and then a logical short path will not be a physical short path. The difference on performance of query and location between the logical layer and physical layer greatly reduced the practical efficiency of resource query in Chord. Therefore, if the mismatch problem between the Chord and underlying physical topology could be solved, it will further increase the application prospects of Chord.

On the base of research in related physical-matched methods, an improved Chord model (TSP-Chord) is proposed in this paper based on ant colony optimization (ACO) algorithm [2]. The idea of TSP-Chord is to regard the storage nodes in the whole Chord as a global TSP problem and obtain the approximate optimal solution of the TSP problem by using the ACO algorithm, and then quickly build a physical topology-aware Chord. OPNET simulation result shows that, TSP-Chord has obvious optimizations in the routing delay of resource discovery.

2. Related Work

2.1 Typical Physical Topology Matching Chord Algorithms

At present the research on the physical topology matching has formed three main ideas within the P2P network [3]: (1) the optimization of node ID assignment based on topology, whose basic idea is to map the ID space of the logical network to the physical network, so that two nodes adjacent on the ID space are physically close too. However, this method will lead to uneven node distribution in the ID space and intensify the load imbalance. (2) Optimization based on proximity routing: building the overlay network

⁺ Zhen He. Tel.: + 86-18810482513; fax: + 86-10-62333498.
E-mail address: zhenhe688@163.com.

without regard to the underlying physical network, when it is routing, and then selecting the nearest node to destination node from the routing table as the next transit node. The effect of this idea depends on the number of candidates provided by the routing table, the more candidates, the better, but also increased the burden on the routing table. (3) Optimization based on proximity neighbor selection: the node ID space is divided into several regions and the nodes with similar or close node ID are in the same region, when a node N want to communicate with other neighbor regions, the routing table will select the nearest node to N in the destination region as the neighbor of N, and in accordance with this to build the overlay network. Aimed on basic Chord model which based on the structured P2P technology, some researchers proposed improved Chord Model based on the above three methods.

In [4] the ChordPNS algorithm is proposed, in which each routing table maintaining a set of candidate nodes and selects the proximal node from the candidate nodes to route the query request. The algorithm reduces the query delay, but ChordPNS bring heavy network traffic overhead in the process of proximal node discovery and routing table maintenance.

In [5] the authors use the proximity list to obtain a better network approximation than the standard Chord model. Proximity list stores a set of nearby nodes of a node which discovered in a life period, next hop is decided by the proximity list and finger table jointly. Although this method gets a better routing efficiency than basic Chord, it has the problems of slow convergence and low efficiency when nodes frequently enter and exit the network, which will lead to the relative reduction of life period in nodes and rapid changes in dynamic network topology.

In [6] the authors propose the Chord6 which making use of the addresses hierarchical nature of IPv6 to generate the node ID, so that each node in the same domain with more approximate ID, and the average path length is reduced from $O(\log N)$ to $O(\log M)$ by this method, where N is the number of network nodes, and M is the number of network domains. However, nodes between two approximate domains may be very far, which is determined by the nature of Hash function.

2.2 TSP and ACO Algorithms

Traveling Salesman Problem (TSP) [2] is well-known in the field of mathematics, which supposes there is a traveling salesman want to visit N cities, so he must choose a path to go, the restrictions of the path are that he have to visit each city only once, and at last go back to the original departure city. TSP is the problem asking the shortest path among all possible paths, which is a NP hard problem.

The reasons why we introduce the TSP problem to Chord, on the one hand because all the nodes in Chord can form a closed loop ordered by their IDs, on the other hand because the problem we want to solve in Chord is also a physical path length problem. According to the analysis of existing algorithms in 2.1, adding proximity routing table and dividing proximity physical region is the two main ways to achieve physical topology match. Adding proximity routing table has the minimum changes with the Chord structure, but increases the routing table overhead. Dividing proximity physical region as shown in Fig.2, on the one hand needs to solve the balances between the number of regions and the number of nodes within a region, on the other hand it is opaque between each regions, so the efficient of inter-domain communication is not ideal.

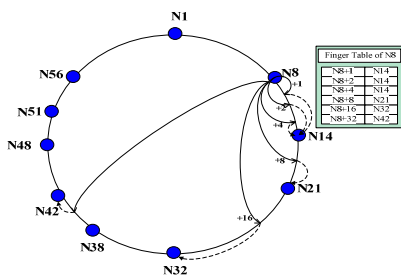


Fig.1: Example of Chord query process

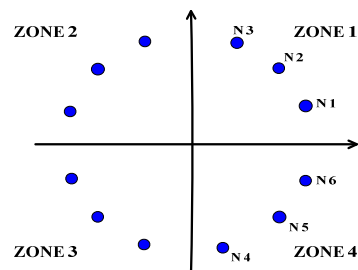


Fig.2: Proximity physical region division method

As a widespread concerned academic issue, TSP problem has been researched for a long time and is also a standard test platform for lots of new algorithms. Meta-heuristic algorithm is very successful in solving TSP problem and ant colony optimization (ACO) is one of the classic meta-heuristic algorithms. In fact, the

first ACO algorithm -- ant system, and a number of the subsequent proposed ACO algorithms, were all first tested by the TSP problem. So far, ACO algorithm has become a very sophisticated algorithm in solving TSP problem, therefore, we choose ACO algorithm to solve the TSP problem within Chord.

In a real network, we can not previously or immediately know its TSP optimal solution, thus unable to confirm the solution obtained by ACO algorithm is the optimal solution. At the same time, because of the constraints of network communication efficiency and computational cost, so to quickly get a TSP optimal solution with large-scale nodes becomes very unrealistic. As a meta-heuristic algorithm, ACO is in pursuit of a good solution or approximate optimal solution in a relatively low computational cost, but the algorithm does not guarantee to find the optimal solution. So our actual purpose of choosing the ACO algorithm is to quickly obtain the approximate optimal solution of TSP problem, not the optimal solution itself. The simulation in Section 4 will prove that the approximate TSP optimal solution which quickly obtained by ACO, its performance is satisfactory.

3. TSP-Chord algorithm

In order to quickly solve the TSP problem within TSP-Chord, this paper used the ant colony system (ACS) algorithm with some simplifications and made corresponding adjustments and optimizations according to Chord features.

TSP-Chord algorithm is described below, set the number of storage nodes in Chord is n ; the number of ants is m .

(1) Data initialization

Step1 Import network topology and get the communication delay(indicate the path length between nodes) between nodes by node broadcast, then save the information in the distance matrix $dist[n][n]$, where the value of array element $dist[i][j](i,j \in [0,n-1])$ which represents the path length from node i to j is shown in (1).

$$dist[i][j] = \begin{cases} v_{delay} & i \neq j \\ 0 & i = j \end{cases} \quad (1)$$

Step2 Initialize the pheromone matrix $pheromone[n][n]$, where the value of array element $pheromone[i][j](i,j \in [0,n-1])$ which represents the pheromone content of the path from node i to j is set a uniform initial value as shown in (2).

$$pheromone[i][j] = v_{init_pheromone} \quad (2)$$

Step3 Initialize path choice matrix $choice[n][n]$, where the value of array element $choice[i][j](i,j \in [0,n-1])$ is shown in (3), it can be seen, the value of $choice[i][j]$ is proportional to the pheromone content in its path, and inversely proportional to the distance.

$$choice[i][j] = \begin{cases} \frac{pheromone[i][j]}{dist[i][j]} & i \neq j \\ 0 & i = j \end{cases} \quad (3)$$

Step4 Initialize the parameters of ants and algorithm, such as the maximum iterations $epoch_max$, the length of global optimal path $dist_best$, the lower limit of pheromone content $pheromone_min$ and so on.

(2) Iteration

When the iteration number is equal to $epoch_max$, the iteration end; otherwise circulating the following acts:

Step1 Clear the way-finding memory of all ants on the previous iteration;

Step2 All ants were randomly assigned to an initial node;

Step3 Every ant builds a full path: in each step of the path construction, ant $k(k \in [1,m])$ in accordance with the roulette wheel selection method [2] to decide the next node to go. The characteristic of this selection method is that the value of $choice[i][j]$ corresponding to a path is greater, the probability of the path chosen by ant k is greater. So on the one hand ants tend to choose the paths which is considered better currently, on the other hand the other paths are also have the chance of being selected that can avoid algorithm falling into

local convergence prematurely. The probability of an ant in node I will choose the node j as its next visit node is shown in (4), where N represents the set of nodes has not yet visited by the ant.

$$p_{ij} = \frac{\text{choice}[i][j]}{\sum_{l \in N} \text{choice}[i][l]}, \quad j \in N \quad (4)$$

Step4 Ants return to the starting node, and calculate the length of the paths it constructed, then reduce the pheromone content of each path it visited (set the reduction as V_{sub}), so that the probability of other paths chosen by ants in next iteration is increased which could prevent the algorithm falling into a local optimum. If the pheromone content of a path is less than $pheromone_min$, then make it equal to $pheromone_min$, which can avoid the pheromone content of a path is too low so the path can hardly be selected;

Step5 Select the ant which constructed the shortest path in this iteration and increase the pheromone content(set the increment as V_{add}) of this path, which is to reward the best path in this iteration so the probability of this path chosen by ants in next iteration is increased, and V_{add} is significantly greater than V_{sub} . If the length of this path is less than $dist_best$, then use it to replace $dist_best$, and record the node order of this path;

Step6 Go to the next iteration.

(3) Chord construction

Use the path order recorded by $dist_best$ to build the Chord, within the construction of the Chord, the ID of storage nodes consists of two parts, if set the length of ID is L bits, then the front L_1 bits of ID represent the TSP sequence information, and the back L_2 bits is the result of unity hash of the node ID, so that all nodes in accordance with its previous L_1 bits of ID to build an TSP-Chord.

4. Simulations and Performance Analysis

Verification experiments using OPNET 10.0 as the simulation platform, and the experimental topology data is generated by the network topology generator NEM (Network Manipulator) [7] with using the magoni_pansiot_sampling method [8]. We generated two Chords with the capacity of 16,384 nodes and 131,072 nodes respectively, and chose the original Chord (denoted as Random-Chord) and the dividing physical region Chord (denoted as Zone-Chord) for simultaneous simulations, as the experimental references of TSP-Chord. Simulation time was 3 hours, the packet interval is 1 second and the number of ants used in TSP-Chord algorithm is 10.

Fig.3 show the simulation results of the 16384Chord, blue, red and green lines represent the TSP-Chord, basic Chord and the dividing physical region Chord, respectively.

In the delay, we can see the TSP-Chord and the dividing physical region Chord are significantly better than the basic Chord and the TSP-Chord is better than the dividing physical region Chord.

Fig.4 show the simulation results of the 131072Chord, in this simulation, we limited the number of iterations in TSP-Chord so that in each experiment TSP-Chord only obtained an approximate optimal solution of TSP. Meanwhile, in order to facilitate comparative analysis, we also added an additional experiments, which is the the TSP_Chord used the TSP optimal solution (BEST_TSP_CHORD).

Apart from the similar conclusions can be drawn from 4096Chord, we can also see the performance of TSP-Chord and BEST_TSP_Chord is similar. This proved that the idea of to solve the physical topology matching problem through TSP is feasible, on the other hand proved that the approximate optimal solutions of TSP which quickly obtained by ACO algorithm, even if not the best, but because it is still using of the idea of global TSP optimization, so the effect is satisfactory. We compare Fig.3 and Fig.4 can find that with the increase of Chord, the advantages of TSP-Chord on delay become more pronounced than the dividing physical region Chord which using the idea of local optimization.

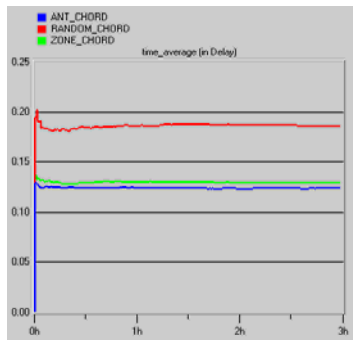


Fig.3: The average delay of 16384Chord

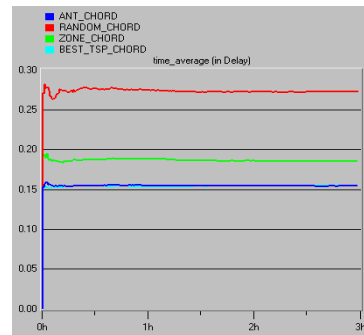


Fig.4: The average delay of 131072Chord

5. Conclusion

This paper proposed to utilize the global TSP problem to achieve the physical topology matching in Chord, then use ACO algorithm to fast obtain the approximate optimal solution in order to meet the requirements of the network communication efficiency. Experimental results demonstrate the feasibility of the TSP-Chord model. For the construction program of new network or even the existing Chord network, and the research of the physical topology matching, TSP-Chord model may provide another idea for reference.

6. Acknowledgment

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