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A New Bidirectional Research Chord Method Based on Bacterial Foraging Algorithm

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Abstract. In order to improve mismatching problem between physical topology and the logical topology in traditional Chord, and improve low search efficiency produced by space complexity, we propose a new bidirectional research Chord method based on bacterial foraging algorithm, which combines the advantage of bidirectional research method and bacterial foraging algorithm. This new algorithm regards topology matching problem as one traveling salesman problem, because bacterial foraging algorithm can get optimal solution for TSP, then we use the optimal solution to construct Chord ring, which can solve the mismatching problem. On this basis, we use the bidirectional search method to further accelerate the search speed. The experimental results show that the new algorithm has better performance than the traditional Chord algorithm on the aspect of query path length and finding the hop number. We also make comparison to other latest algorithms with the new method.

Keywords: bacterial foraging algorithm, bidirectional research, chord method, physical topology, traveling salesman problem

1 Introduction

With the development of computer technology and communication network, Internet has been used widely, it plays an important role in people's life [1]. So traditional C/S and B/S model have been challenged. When facing the huge size of networks, the capacity and performance of current center server becomes more and more impotent, so peer-to-peer networks arises.

P2P system divides the topological structure into three forms [2-3]: centralized, unstructured, and structured. Structured topology has several advantages: (a) structural topology network is established based on distributed hash table (DHT), DHT makes the resources index and node one-to-one mapping, which ensures that nodes and resources are uniform distribution form. Finally it achieves load balancing [4]; (b) resource location has high efficiency. Only the searched resource exists in this system, the system finds this resource within $O(\log N)$ hoops. Aiming at physical matching, there are three study trends.

(1) Node ID allocation optimization based on topology.
(2) Optimization based on neighboring router.
(3) Optimization based on neighbor selection.

Based on the basic Chord algorithm, researchers improve it based on the above three optimization methods. Manturov [5] defined a new module M_2 which was generated by chord diagrams on two circles and factored by 4T-relations. Then they constructed a "covering" map from the module of framed chord diagrams into M_2 and a weight system on M_2. But it had long iteration time. Iyer [6] presented a decentralized, peer-to-peer web cache called Squirrel. The key idea was to enable web browsers on desktop machines to share their local caches, to form an efficient and scalable web cache, without the need for dedicated hardware and the associated administrative cost. Manku [7] established lower-bounds for greedy routing for these networks, and analyzed Neighbor-of-Neighbor (NoN)-greedy routing. Wang et al. [8] proposed a Chord bi-directional search algorithm, based on the genetic algorithm, combining,

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which combined the advantages of genetic algorithm and bi-directional routing look-up mechanism. The algorithm combining genetic algorithm regarded the topology matching problem as a TSP. It used the genetic algorithm to find the best solution of the problem, then constructed the Chord ring, which solved the problem of mismatch between physical topology and logical topology. Vatsavai [9] proposed two improvements in a structured P2P resource lookup protocol of Chord-based algorithms. First, the routing information for accurate search of resource was low. Only clockwise direction of resource lookup could be implemented and a unique algorithm was designed for enhancing the finger table in a Chord. A counter-clockwise finger table was also included for generating resource queries in two direction clock wise and anticlockwise increasing the density of neighboring fingers. The proposed model also employed a new functionality of eliminating excess fingers generated by the inclusion of fingers by the suggested model. Jeong [10] proposed an automatic melody composition system that could generate a sophisticated melody by adding non-harmony tone in the given chord progression. An overall procedure consisted of two steps, which were the rhythm generation and melody generation parts. In the rhythm generation part, he designed new fitness functions for rhythm that could be controlled by a user setting parameters. In the melody generation part, he designed new fitness functions for melody based on harmony theory. He also designed evolutionary operators that were conducted by considering a musical context to improve computational efficiency. However, they could lose some topological adjacent members. And the convergence time is very long. Efficiency is very low. Therefore, we propose a new bidirectional research Chord method based on bacterial foraging algorithm.

At last, our scientific contributions of this research work can be summarized as:

(1) we analyze the typical Chord algorithm in P2P. Topology matching problem can be considered as traveling salesman problem (TSP).

(2) And we use bacterial foraging algorithm (BFA) to find the optimal solution, then we construct Chord ring based on the optimal solution, which can solve the mismatching problem between physical topology and the logical topology.

(3) The next step is that we use the bidirectional search method to further increase the search speed and find the resource.

(4) Finally, we make experiments to demonstrate that the new algorithm has better performance than the traditional Chord algorithm.

The following is the structure of this paper. In section2, we introduce the chord algorithm, TSP and bacterial foraging algorithm. New bidirectional research chord method is detailed explained in section3. We make experiments to verify the performance of new algorithm in section4. Section5 conducts a conclusion for this paper.

2 Preliminaries

2.1 Basic Chord Algorithm

Chord algorithm [11] is as one of distributed look-up algorithms, it can make all the resources and nodes get their own unique ID through hash operation. If the length m of hash value is long enough in hash function, it can ensure that node ID will not be repeat mapped. Chord algorithm uniformly distributes all resource and nodes to network by consistent hash. And Chord algorithm clockwise constructs a ring from small to large order of the node ID. Each node maintains rout information in a predecessor node and a subsequent node. Algorithm allocates resources ID along the clockwise direction to ensure that the node ID is greater than or equal to the object ID, this node is called subsequent node of k written as $successor(k)$ [12]. In Fig. 1, Chord algorithm has eight positions, where three nodes are there, namely $m = 3$. Nodes ID are 0, 1, 3 respectively. Subsequent node keeps the index of object 1, $successor(1) = 1$. So $successor(2) = 3$, $successor(6) = 0$.

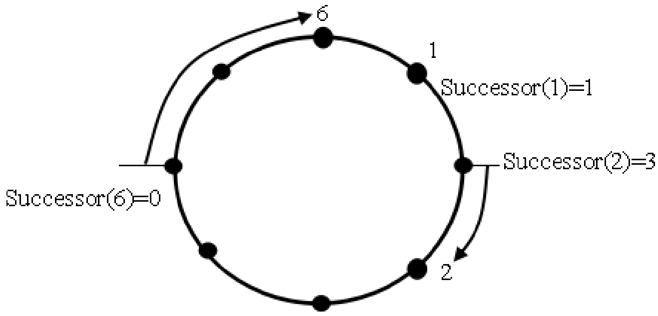

Fig. 1. Framework of chord ring

Each node in Chord maintains only one finger table. It can rapidly and efficiently look for resources through finger table. In order to guarantee the real-time accuracy of Chord network, when a new node n joining, part of rout information maintained by subsequent node will be transferred to node n. Similarly, when all nodes in Chord leaving, rout information will be transferred to subsequent node. For example, if node 7 joins, the route information of resource 6 will transfer from node 0 to node 7 in Fig. 1, namely $successor(6) = 7$.

Because of the subsequent relationship, it can guarantee that local ring in chord works normally. There are m route information in finger table, i-th information leads to node s, $s = successor(n + 2^{i+1})(1 \le i \le m)$. Node s is at least 2^{i-1} apart from first node n along with clockwise direction, written as $n.finger[i].node$. Finger table records node ID, IP and other information, so $n.finger[1].node = n.successor$.

To determine $successor(k)$, node n needs to find the node nearest to k. In that the distance apart from k is closer, the route information is more. According to this finding rule, n will be gradually close to k by continuously recursive search until finding the predecessor node of resource k, written as $predecessor(k)$.

2.2 TSP and Bacterial Foraging Algorithm

TSP is one of the famous mathematics questions. It requires to find a loop through all the cities, but the path is the minimum. In fact, all the nodes in Chord can form a loop ring. On the other hand, it is actually a problem of solving physical path. Through the analysis of the existing algorithms, the essence of which is the nearest neighbor, that is to say, it searches the nearest node in each iteration. But it lacks global topological consideration, which results in a poor local solution. When inquiring Chord ring, it actually makes a traversal for all nodes alike TSP. Therefore, it considers global TSP to get better effect. Theory has been proved that the optimal retention bacterial foraging algorithm (BFA) can find global optimal solution for TSP, so we choose BFA to solve the Chord ring TSP. The main characteristic of BFA is group search strategy and information exchange among individuals, searching does not dependent on the gradient information. BFA builds three steps: chemotaxis, reproduction and elimination-dispersal based on foraging behavior. It establishes individual information sharing mechanism and weeds out poor solution in each iteration, keeps better fitness (solution). It effectively uses a lot of historical information, makes search towards to the best direction every iteration. In actual network, due to the limit of network communication efficiency and computational cost, it is difficult to get optimal solution for TSP of large size nodes. However, BFA is as heuristic algorithm, its aim is to find good or close to the optimal solution with relatively low computational cost.

3 New Bidirectional Research Chord Method

3.1 BFA-Chord Method

Assuming that the number of stored nodes is n, population size is m. Importing the network topology, it can get communication latency (i.e., the path length between nodes) between nodes through node broadcasting and will be stored in matrix $dis[n][n]$. $dis[i][j]$ denotes the path length from node i to j. Its value is as (1),

$$dis[i][j]=\begin{cases} v_{delay} & i \neq j,(i,j)\in[0,n-1] \\ 0 & i=j \end{cases}. \tag{1}$$

Chemotaxis operation. It mainly simulates the movement process of bacteria including two processes: move forward and turn to move as shown in Fig. 2.

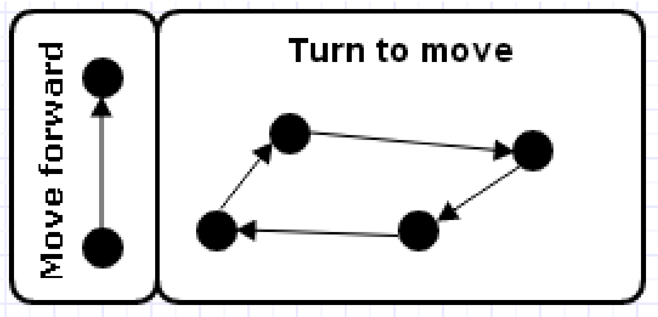

Fig. 2. Bacteria movement

Supposing that $P^i(j,k,l)$ is the position after j-th chemotaxis operation, k-th copy operation, l-th migration operation of i-th bacteria.

$$P^i(j+1,k,l)=P^i(j,k,l)+C(i)V(j). \tag{2}$$

Where $C(i)$ is step length vector after move forward or turn to move. $V(j)$ is randomly generated direction vector.

Copy operation. When the bacteria completes number of settings, bacteria will be divided, this process mainly simulates the breeding process of bacteria individual with fittest survive rule. Setting bacteria population size N, $F^i(j,k,l)$ is the fitness value. First it makes descending order for fitness of whole population. The top N/2 individual with bigger fitness are kept and they become to divide. The rest N/2 individual with smaller fitness are given up. So the bacteria population will be unchanged after one copy operation.

Migration operation. From the perspective of the bacteria foraging behavior, actually there is no behavior in its real movement, it is introduced into the process in order to improve the global search ability of the algorithm. Because when solution space of a problem has several extremum points, it will make the algorithm easily fall into local extremum duo to the bacteria clustering. This process is to use new individual instead of the original individual, which is different from the copy operation, the migration occurs with a certain probability p. When one bacteria meets the requirements of migration, the bacteria will be randomly assigned to the solution space.

Finishing iteration processes. According to the best position obtained by the above processes, it constructs Chord ring after combining all the nodes (best position).

3.2 Bidirectional Resource Location

Chord algorithm uses a compatibility hash function to map all nodes as a virtual logical topology. The logical topology is a ring structure. Then it adopts one-way search mechanism based on ring logical topology, i.e,. the node received inquiry request starts to search resource along clockwise direction of the ring. But there is a question that the nodes far apart from each other will be found through multiple hops. Based on the improved Chord physical topology, we introduce bidirectional resources location. Improved two-way Chord algorithm, each node in the ring maintains two pointers routing table (clockwise and anticlockwise pointer routing table). When a node receives a query request, the node in the ring will make resource location along with clockwise or counterclockwise direction, until it finds the target node.

3.3 Route Table Establishment

In a single direction clockwise resource searching process, if the target node is close to starting node in anticlockwise direction, which means that the query process needs to search the entire Chord ring. If the two nodes are in the same physical domain, resources location could be through multiple domains, delay will greatly increase and the performance will decline substantially [13]. Therefore, we propose resource bidirectional search algorithm based on the physical topology and adopt bidirectional location mechanism to search resource. Bidirectional location requires that each node maintains two pointers route table to store part nodes information in clockwise and anticlockwise direction in Chord ring. The different from directional searches is that one pointer route table (length is m) is expanded as two pointers route table (each length is $m-1$) which is responsible for clockwise and anticlockwise direction search.

Clockwise route table is similar to single search. In $[(n+1)\bmod 2^m,(n+2^{m-1})\bmod 2^m]$, there are $m-1$ nodes, the divided interval is $[(n+1)\bmod 2^m,(n+2)\bmod 2^m]$, $[(n+2)\bmod 2^m,(n+4)\bmod 2^m]$, $\cdots$, $[(n+2^{m-2})\bmod 2^m,(n+2^{m-1})\bmod 2^m]$. Anticlockwise route table is built in anticlockwise direction of Chord ring. In $[(n-1)\bmod 2^m,(n-2^{m-1})\bmod 2^m]$, there are $m-1$ nodes, the interval is $[(n-1)\bmod 2^m,(n-2)\bmod 2^m]$, $[(n-2)\bmod 2^m,(n-4)\bmod 2^m]$, …, $[(n-2^{m-2})\bmod 2^m,(n-2^{m-1})\bmod 2^m]$.

3.4 Search Process

Traditional Chord algorithm is signal direction search process, its disadvantage is that when there is a big distance between the resource needed to search and the node received search request, it needs bigger hop count. As shown in Fig. 3, node N3 receives search request and its target node is N38, it nearly searches all the Chord ring.

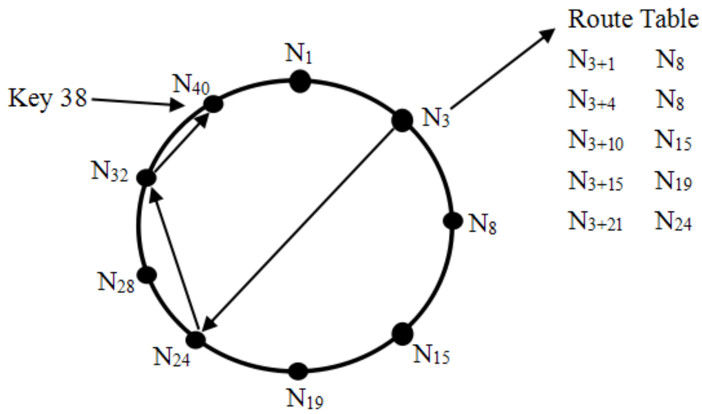

Fig. 3. Single direction search

Bidirectional search not only searches in a clockwise direction, but at the same time can search in a anticlockwise direction. When a node receives a query request, first it determines whether the local has the resource. If NOT. According to the condition, it judges that whether the query belongs to which direction search or not.

Detailed bidirectional search process is as follows:

(1) Step1. After receiving the inquiry request, it judges whether the local has the resource. If YES, search finishes. Otherwise return to step 2.

(2) Step2. Judge the value of $key-NodeID$. If $key-NodeID \geq 0$, return to step 3. Otherwise return to step 4.

(3) Step3. If $key-NodeID \geq 2^{m-1}$, then it chooses anticlockwise direction to search. According to anticlockwise route table, it continues next hop. Otherwise, it chooses clockwise direction to search. According to clockwise route table, it continues next hop.

(4) Step4. If $key-NodeID+2^m \geq 2^{m-1}$, then it chooses anticlockwise direction to search. According to

anticlockwise route table, it continues next hop. Otherwise, it chooses clockwise direction to search. According to clockwise route table, it continue next hop.

In Fig. 3, if it adopts bidirectional search, it only needs 1 hop and finds the target node.

3.5 Node Join and Exit

Chord ring constructed by BFA-Chord algorithm can be explained that it is a best path passing each node in iteration process. Due to node join and exit, this free behavior will make the the whole network physical topology structure different from real network physical topology. Therefore, it is very important to keep the largest matching degree of physical topology and logical topology under the condition of node join and exit.

We propose grouping idea based on physical topology Chord search algorithm. Grouping divides the network into several groups, each group chooses a node with a better performance as reference node. If one node needs to join Chord ring, this node must send round-trip time (RTT) to all reference nodes. Assuming that the node in minimum RTT is nearest reference node, it will be joined in this group. The reference node here is not the same as the traditional super node, just as the reference of the physical location, provides topology information, it does not affect the performance of DHT, The nodes in same group have the nearest physical location. Constructed Chord ring is divided into three groups as Fig. 4.

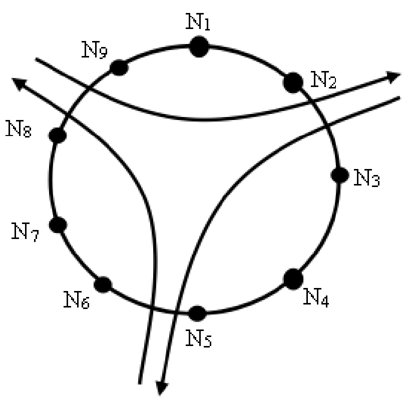

Fig. 4. Three groups in Chord ring

When there is a new node joins, firstly it needs to calculate RTT value of the node and each reference node, and selects the minimum RTT as the joining group (i.e., Determine physical location). After joining Chord ring, it updates other existed nodes information. New node will share its own information with other nodes. Other nodes update their own bidirectional route table information in time.

In the new Chord ring, if the node actively exits Chord ring, it will transfer the keywords to the subsequent nodes, and inform the other nodes pointer to update route table, ensure that the data is not lost. In order to guarantee the maximum matching degree between logical topology structure and the physical topology in Chord ring, it must periodically update the logical topology structure of the whole system Again it constructs a new Chord ring through the BFA-Chord algorithm. Meanwhile, in order to keep that the system still would be able to locate resources when the node status changes, it must timely update bidirectional route table of each node.

4 Experiments and Result Analysis

We use MATLAB platform to randomly generate 1024 nodes. Population size is 100, simulation time 5h. Data package sending interval is 1s. Iteration of experiments is 100. We make comparison with traditional Chord algorithm as Fig. 5.

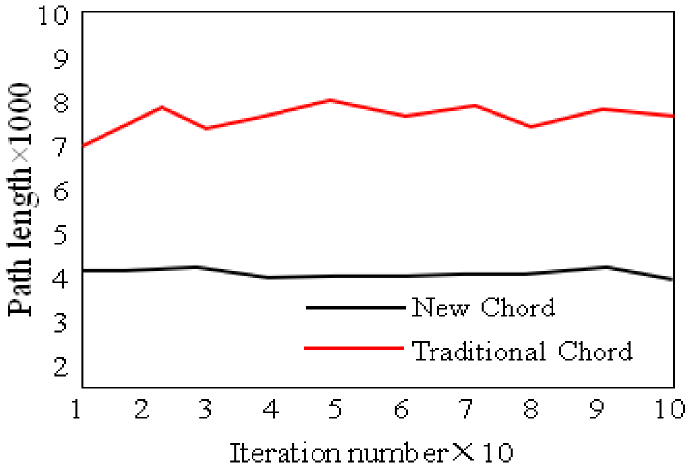

Fig. 5. Comparison of path length

From the experimental results in Fig. 5, it shows that the traditional path length based on Chord search algorithm is far greater than the improved Chord search algorithm path length. Proving that the improved Chord search algorithm on path length has more efficient performance. We select 1000 nodes in data set to search 20 key value. Original node is N_{20} . Select top of 10 key values, and satisfy $0 \le key - NodeID \le 2^{m-1}$. Select latter 10 key values, and satisfy $key - NodeID \ge 2^{m-1}$. Calculate hop count with different key values. Fig. 6 shows the comparison between improved Chord search algorithm and original Chord search algorithm.

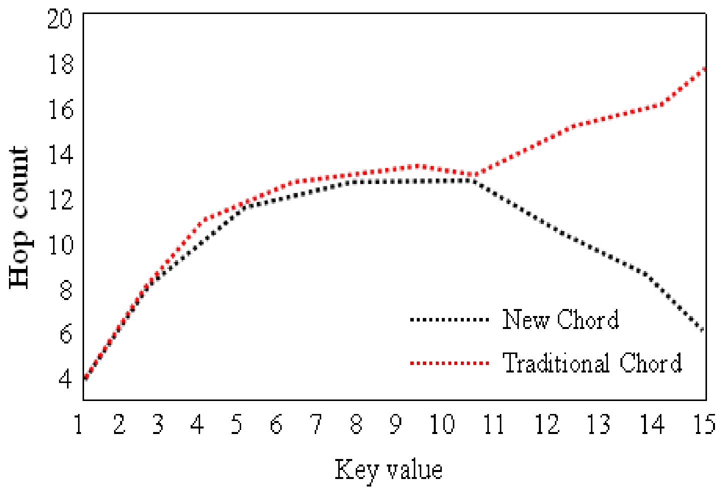

Fig. 6. Comparison of hop in same range

From Fig. 6, we can know that the hop of improved Chord algorithm is superior to the traditional Chord search algorithm and the its effect is obvious at the top 10 inquiries. In the latter 10 inquiries, improved Chord algorithm adopts anticlockwise search and traditional Chord algorithm uses clockwise search. The average search hop value using new Chord method nearly is half of that using traditional Chord algorithm. Results show that the improved Chord bidirectional search algorithm based on BFA on the hop count performance is superior to the traditional Chord search algorithm.

In order to verify the performance of our new method, we calculate the average hop as Fig. 7. Experiment result is obvious, the range of key value is below 50, overall hop value of improved Chord algorithm is less than traditional Chord algorithm. With the increase of network scale, the total hop of search resource is growing too. But the average search hop count of the improved Chord algorithm in this article grows slowly, significantly it is less than the traditional Chord algorithms. It further proves that the performance of proposed Chord bidirectional search algorithm based on BFA is superior to the traditional Chord search algorithm on finding the hop.

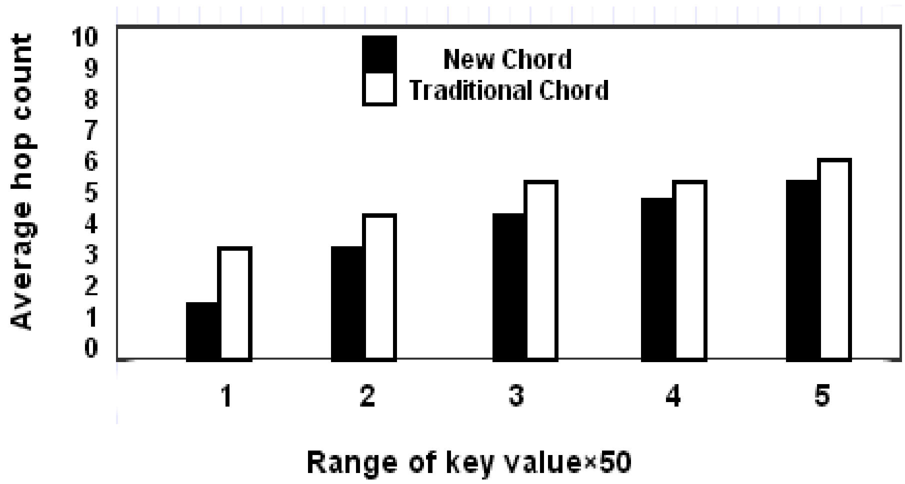

Fig. 7. Comparison of average hop count

To illustrate the effectiveness of our new method, we select modified particle swarm optimization (MPSO) algorithm [14] and temporal correlation support vector machine algorithm (TCSVM) in [15] to make comparison with our new method BFA. Under the same population quantity condition, set the maximum iteration number 27. Fitness evaluation function determines the space distribution of solutions. For the support vector machine, it needs to find the optimal generalization performance solution. In practical application, support vector machine requires to optimize penalty factor C and kernel function parameter γ . We assume that the fitness function in this paper is $fitness = f(C,\gamma)$. S_1 is training sample, S_2 is testing sample. The precision value obtained by testing is as the fitness value. $2^{-5} < C < 2^{15}$ and $2^{-5} < \gamma < 2^{5}$. Fig. 8 is the graph of population's fitness value with iteration change.

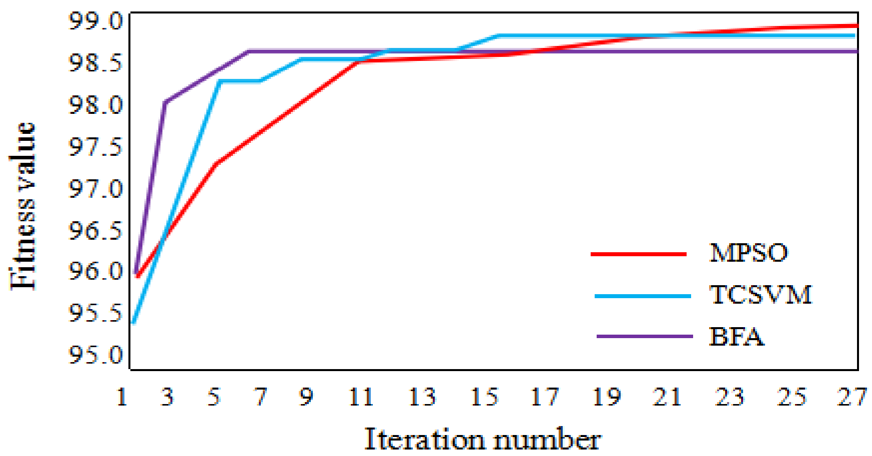

Fig. 8. Comparison of Fitness value with different methods

From Fig. 8, we can know that the fitness value will increase when iteration number increasing. When the iteration reaches to a constant value, the fitness value stops at a certain level. In fact, migration operation is introduced into BFA, so the convergence time is shortened. Clearly, MPSO method needs nearly 20 iterations, when fitness value reaches to the biggest, which has the slowest evolution speed. Followed by TCSVM method, it needs about 15 iterations. However, the new method only needs 7 iterations. It obviously improves the convergence time.

In Table1, it shows the optimal fitness value, stop iteration number and convergence time under same running environment. Compared to the two methods, our method needs the least running time. Therefore, it is the best choice for Chord algorithm.

Table 1. Experiment results with different methods.

C	γ	Fitness value	Iteration	Time/s
2.5834	1.0672	98.7879	20	15.3894
18.1257	0.0112	98.7879	15	7.6187
2.7618	0.0673	98.7879	7	2.3468

4 Conclusions

In order to solve the inconsistent problem between physical topology and logical topology caused by ignoring the physical location in traditional Chord algorithm, we use BFA method and regard topology matching problem as a traveling salesman problem (TSP) in this paper. By using the BFA to find the optimal solution of the problem, then it is used to construct Chord ring, which not only effectively solves the problem, but uses bidirectional search strategy on the basis of the traditional single direction search to further improve the search efficiency. Through experiments simulation, it shows that the improved algorithm has more advantages than the traditional Chord algorithm on the querying path length and finding the hop. The limitation of the work is that calculation amount is very huge. In the future, we will study more advanced Chord algorithms to apply them into practical engineering applications and reduce our disadvantage.

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