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A Replica Selection Algorithm in Data Grid

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Abstract: Data grid is an ideal platform for the data-intensive and computing-intensive computing, which coordinates resources sharing in large scale environment. Replica is an important key technology in data grid. It improves the efficiency of data access and reduces the delay of data transfer. Replica selection is to choose the most appropriate replica among nodes. A replica selection strategy based on ant algorithm is proposed within this study. And then implementation and performance analysis of the algorithm are studied in the grid simulator Optorsim. Experimental results show that the ant algorithm can reduce data access latency, reduce bandwidth consumption and distribute the load of storage site, improve data access speed.

Key words: Data grid, replica selection, ant algorithm, Optorsim

INTRODUCTION

The information explosion has brought about an unprecedented demand in the speed of data storing and accessing. At the same time, large amount of data-currently terabytes and soon pet bytes-could be stored in geographically diverse grid sites (Foster and Kesselman, 1999; Foster *et al*., 2001). Therefore, the storage scale is growing larger and the job of management is becoming more complex. All of these problems have caused the greater challenges to the storage scalability and reliability (Foster, 2002a). In order to solve these problems, a deep acknowledge of the data grid technology is needed.

In data grid, a file may have more than one replication of data. When a user need to access files, the key is to know how to select a node which has the requested data to fulfill the user's demand. This kind of choice depends on many different factors, such as the size of data, the data replacement and the bandwidth of the network. In addition, the load condition of the node where the replica in and the read speed of the disk when it is input/output must also be taken into account (Foster, 2002b).

In this study, the replica optimization is the main problem to be solved, which aims to choose an appropriate set of replicas from many distributed nodes. The ant algorithm has the characteristics of positive feedback and the implicit parallelism (Watkins, 1989). All the characteristics make it applicable to distributed system. And its scalability makes it ideal for network structure and the data grid environment. In addition, the ant algorithm uses feedback to adjust the self-dynamic interaction with the environment in order to gradually obtain the optimal solution. In data grid, selecting one of the best replicas is also an optimization problem. Therefore, this study has proposed a method for replica selection based in ant algorithm. It can choose the best replica from multiple copies of the grid system in order to achieve the global optimality of the replica management system.

RELATED WORK

Data replication technology can effectively improve the system performance and reliability. Therefore, it is widely used in distributed environment, such as distributed databases, data grids, content distribution networks, cloud computing and so on. The problem about data selection caused by the replication of data is one of the hot topics of data management (Sun *et al*., 2006; Chang and Chen, 2007). How to determine the best replica to meet the quality of service requirements of the application, which is the core of the problem if replica selection. Currently, most of the replica selection strategies think time as the main factors. As data-intensive applications require access to large-scale data sets, reducing the time of the transmission data sets as much as possible will help reduce the total execution time. And then the best data set can be selected successfully.

Generally speaking, the replica selection strategies can be summarized as the following:

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- Access the best replica from the request site whose has least hops (Vazhkudai *et al*., 2001)
- Using the reverse neural networks and supervised learning methods to predict the transmission time accessing to replica from each site and then choose the replica on the site which has the shortest transmission time as the best replica (Rahman *et al*., 2007)
- Thinking the replica selection as a classification problem and then use the K-Nearest Neighbor (KNN) algorithm to determine the best replica (Rahman *et al*., 2008)
- Thinking the replica selection as a set covering problem and use the tree search algorithm to solve the SCP. The algorithm reduces the number of the remote replica transmission. Therefore, it can reduce the total time of replica transmission (Venugopal and Buyya, 2008)
- Make an introduction of the concept of the virtual, and then proposed the best replica selection strategy based on the virtual Token Ring and auction protocols (Chai, 2007)
- Searching the replica from the central node or the nodes on the path from the requesting node to the central node. This strategy is based on the hierarchical network structure. The load of node as well as the path length of the requesting node to the replica node must be taken into consideration after getting the replica from the central node. In a word, the node which selected as the data acquisition place should has a small load and a short path length (Gao, 2008)
- According to analysis the read speed of the storage resources, the bandwidth, the physical distance between two sites and the computing speed of the computing resources, the replica strategy based on the ant algorithm is proposed (Lu, 2006)

The ant algorithm is a simulation of real ant colony foraging behavior of new intelligent optimization algorithm. It was proposed by Italian scientist Gambardella and Dorigo (1995). Through the accumulation and updating of the pheromone and convergence to the optimal path, it has the ability of distributed, parallel, global convergence and has successfully resolved many combinatorial optimization problems.

As a new and promising field about research, ant algorithm has been successfully applied in some combinatorial optimization problem. Besides that ant algorithm applied in research in the field of integrated circuit wiring, network routing, image processing, data mining has been quite extensive (Yin *et al*., 2007), in this study the following applications are enumerated.

Quadratic assignment problem: N devices are assigned to the nth position, to solve how to allocate to gain a minimum of allocating costs. In 1994, someone use ant algorithm in quadratic assignment problem which is called the AS-QAP algorithm. Experiments show that this algorithm has the same performance to the simulated annealing algorithm and the evolutionary computing heuristic algorithm.

Networking routing problem: With the development of network multimedia applications, the transmission quality about multimedia data flow in the network are more attention. The concept of quality of service (QoS) is put forward and routing is the key to achieve QoS issues (Almuttairi *et al*., 2010a). Ant algorithms are used to solve the problems of restricted routing. QoS multicausal routing problem can be solved, such as bandwidth, delay, packet loss rate and minimum spend. It has obvious advantages when compared to the existing link-state routing algorithm.

Ant algorithm in the field of data mining: Ant algorithm in the field of data mining is still in its infancy. But somebody has applied the ant algorithm to the data mining classification problem and proposed the Ant-Miner classification algorithm and the related improvements in the algorithm (Jaradat *et al*., 2009).

In addition, the ant algorithm obtains a wide range of applications in other areas. For example, in Switzerland there are some people thinking that a tanker route can be arranged according to this algorithm. British Telecommunications arrange the top line for the transmission of signals within a communications network and improve the communication efficiency. In short, the ant algorithm has strong robustness and internal distribution of parallelism and scalability. In many areas, the ant algorithm has widely used in a very wide range of applications.

THE PRINCIPLE OF THE ANT ALGORITHM

Ant percept the outside world through the antennae to distinguish objects in the shape and smell, because it has no vision. Ant family will sent a group of ants wandering around their nest when they search for food, if one of them finds the food, it will backtrack to the lair, and marked a path along the way with a chemical substance called pheromones (Almuttari *et al*., 2010b; You *et al*., 2006). And then other ants can smell the pheromones and along the road to find food. The pheromone is volatile, when two ants find the same food and return to the lair in accordance with their respective path, pheromone on the longer path volatile much so that the section on the road leaving the light odor. Therefore, the other ants will tend to handling food along the path which has the higher pheromone concentrations and leave their own pheromone on this road, again and again until all the ants choose the closer path to handling food.

The collective behavior of the ants is a positive feedback phenomenon, the behavior of ants to choose path is called autocatalytic behavior. The principle is a kind of positive feedback mechanism. Therefore, it can be considered as one kind of Reinforcement Learning system. Here, Gambardella and Dorigo (1995) are be referenced to illustrate the principle and mechanisms of how the ants to found the shortest path. The following three figures are building an ant system to simulate ants foraging system which is showed in the Fig. 1a, b and c.

In the Fig. 1a, it is building a simple ant system. The point A and the point E mean the food and the starting point respectively at different time. And assuming that the distance between D and H, B and H and B and D is 1 (through C), C is located in the center of D and B. At the same time, the ant colony system in the each point has the same interval and the same discrete (t = 0, 1, 2...).

In the Fig. 1b, assuming that there are 30 ants run from A to B each unit of time, and the other 30 ants run from E to D and their walking speed is 1 (which means the distance they walk each unit of time is 1). Therefore, when an ant is walking, it can leave the pheromone with the concentration of 1. At the moment of t = 0, there is no any pheromone in the path, but there are 30 ants in B and 30 ants in D waiting for departure. For which path they will choose is completely random, so the ant colony in the two nodes can split into two parts and go in two different directions. However, at time t = 1, the 30 ants walk from A to B in the path leading to H will find the concentration of pheromone is 15, which is leaved by the preceding ants from B to H.

In the Fig. 1c, in the path toward C at the moment of t = 1 they can find a path whose concentration of pheromone is 30, that is the pheromone of 15 ants toward BC add the pheromone of 15 ants from D toward B through C. At this time, the probability of selecting path has a deviation. The number of ants go to C is 2 times as the number of ants go to H. It is the same to the ants from E to D.

This process will continue until all the ants choose the shortest path eventually. In this way, the basic idea of the ant algorithm can be understood: If at a given point, an ant has to make a choice in different paths. Then the path (which have the pheromone darker) selected by those preceding ants will have greater probability of being selected. More pheromone means that a shorter path,

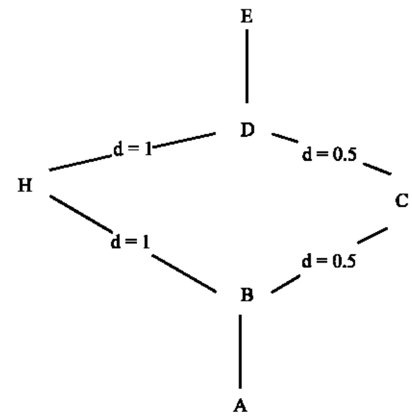

Fig. 1a: Building a simple ant system

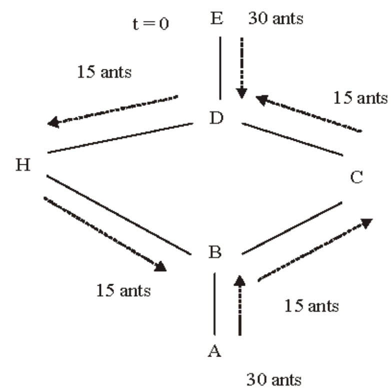

Fig. 1b: The situation for simulating ants foraging at the moment of t = 0

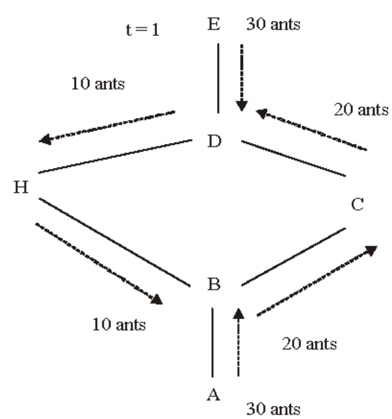

Fig. 1c: The situation for simulating ants foraging at the moment of t = 1

which means a better answer. In general, the ant algorithm for solving some optimization problem (such as TSP, production scheduling problem) is always follow the unified algorithm framework as followed.

Algorithm 1: Ant algorithm for solving combinatorial optimization problems

```
Setting parameters and make initialization of the pheromone
While (the condition is not satisfied) do
for each ant in the ants colony
for each solution construction step (until construct a feasible solution)
    (1) ants construct the solution for one-step problem according to the
    guidelines of pheromone and heuristic information;
    (2) partial update of pheromone. (Optional)
end for
end for
    (1) take some point obtained the solution as a starting point for the
    neighborhood (topical) search; (Optional)
    (2) based on the quality of obtained solution to make global
    pheromone update.
end while
end
```

The ants construct a feasible solution of the problem gradually in the algorithm 1. After that the ants will select the arc which has strong pheromone and higher heuristic factor to the next node. At this time, the path traversed by all of the ants corresponds to a feasible solution of the problem. The local pheromone update is according to the pheromone on the path ants walked. The global pheromone update is to update the pheromone according to the quality of the solution or the best solution after all the ants find the feasible solution.

REPLICA SELECTION BASED ON ANTS ALGORITHM

Factors for replica selection: Replica selection is one of the most important technologies in replica management. Suitable replica selection strategy can improve the efficiency of the entire system greatly (Nan and Youn, 2004). In order to find the appropriate strategy of the replica in data grid, the main factors which affect the performance of the system must be determined firstly. The parameters based on dynamic network are mainly about dynamic monitoring host distance, link bandwidth, hardware parameters and so on.

The basic principles of the ant algorithm are to imitate the behavior of ants foraging. According to the selection of pheromone adjustment solution, it can converge to the global optimal solution gradually. In the ant algorithm model of this study, the access speed of the Storage Element (SE) and the calculation speed of Computational Element (CE) will be taken into consideration. Besides that the load status of the replica nodes, the bandwidth and the physical distance between nodes are also the important factors. And now the value of these characteristics will be analyzed individually.

The access speed of the storage elements: For replica selection strategy, it mainly refers to the access time of the disk. Low accessing time can reduce the remote access time of data replica. When it needs to transfer files, the file should be read out from the site which stored the replica of it firstly. Since the storage format of the replica on different storage is different, it will affect the read speed of the data. Here, the differences on the time caused by different storage way will be ignored and thinking that the entire file storage format are the same. In addition, in the case of the same storage format, the factor which affects the read speed of data includes the hard disk number of revolutions. The read speed will be different because of the different number of revolutions of the hard disk. The number of the revolutions of the hard disk in the configuration file of the SE will be considered as a characteristic value of the SE.

The bandwidth between the request node and the replica node: The traditional replica selection algorithm is based on the maximum available bandwidth between these two points for the selection criteria. And the available bandwidth is the main factor determining the speed of data transmission. Therefore, it is possible to be a reference for replica selection. And the available bandwidth of replica can help replica manager to analyze the read status for replica. The data transmitted unit time if available bandwidth larger and the speed will be faster. Therefore, in the case of other factors, the algorithm will tend to select the replica on the node whose available bandwidth value larger.

The physical distance between the request node and the replica node: Physical distance will affect the propagation delay directly and it will also affect the transmission speed of the replica. Grid is based on a distributed system in the internet, the physical distance between sites maybe very far. If the physical distance is close, the propagation delay can be ignored. However, in the case where the physical distance is large, the propagation delay will be much greater than the transmission delay and it cannot be ignored. In the actual network environment, the connection between the two sites may have to pass more than one router. Therefore, there are multiple hops. And there is no way to get the physical distance between the two points, so the distance can be expressed with the number of hops. Assuming that the physical distance of each hop is the same. The greater the number of hops the greater physical distance and the node is less likely to be selected by the algorithm.

Calculation speed of computing elements: The calculation speed of CE in the calculation of the grid is an important reference factors in the design task scheduling algorithm. It can reflect the speed of the CE processing tasks. The data need to be read out from the SE at first before sending a replica in the data grid and then it can be sent to the request site according to the CE. Therefore, the calculation of CE will affect the read speed of the file. However, the scale for data replica of the grid is always very large. The replica transmission time will be much larger than the CE processing time. Therefore, the calculation speed of CE will less affect the read speed of the replica. And the calculation speed of the CE can be ignored.

The load condition of replica nodes can store multiple copies of SE in the data grid system. The load of the storage element will be relatively large if multiple copies of SE are selected in the implementation of the transmission job. The replicas stored in SE should not be selected again when the load pressure is large. Otherwise, it will continue to increase the load of SE and influence the transmission speed of ongoing replicas. The load condition of the replica node is also the key factor of affecting the remote data accessing time.

In this study, the several characteristics above are taken into consideration firstly. And other characteristic factors will be ignored, such as reaction time, the delay time and so on.

Model of the algorithm: According to the ant algorithm principle in the third part, it is known that when the ant finds the best path, it will take the concentration of the pheromone into account to determine which way to reach the food source. And then the principle in the replica selection of data grid replica management will be applied to build model. When the site of the grid needs to select the desired data file from the replicas stored in the other sites, it will compare the replica's characteristics in different sites to choose the most advantageous replica.

Each user site can be looked as the ants of the pathfinder and the replica is the path which ant to choose. The information eigenvalue of a replica will affect the choice of user site and at the same time, the choice of the user site for a replica or abandoned will affect the pheromone value of the replica. Local site will determine which replicas of documents to be used depending on the concentration of pheromone. After ants determining the selected path, the ants also leave their own pheromone to increase the concentration of pheromone in this path. And then the ants come later will tend to choose this path. After determining the selected replica site, pheromone value of the selected site also needs to be modified to make the increase of the concentration of pheromone.

In the model of data grid, there is a node monitor responsible for site management. All nodes in this system need to report to the node monitors the node Computing Element(CE) and Storage Element (SE) usage situation regularly. When site A contains a replica of file B, it needs

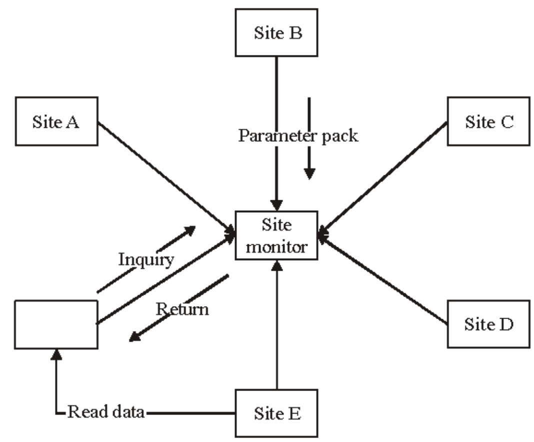

Fig. 2: Model of site distributed situation for site management in data grid

to send parameters packet to the site management and submit the relevant information of the replica. All of this information is not pheromone, but is the eigenvalue of replicas and sites. Then site manager will calculate the pheromone using relevant formula based on these eigenvalues. Site monitor should contain all documents and the eigenvalues and the pheromone of all replicas, because all sites should submit the related information to the site monitor (Wu *et al*., 2008). When site C requires data file B, it will search for all replicas of the file B in site monitor to do replica placement. Therefore, the logical location and the physical location of the replica which is appropriate can be found. In these replicas, the best replica can be selected according to the concentration of replica pheromone. And the site distributed map is showed in Fig. 2.

Replica selection method based on ant algorithm: In this study, the ant algorithm is used to solve the grid replica selection problem and design the replica selection strategy based on ant algorithm. This strategy is based on the eigenvalues of replica and the parameters of network environment to calculate the pheromone of replica. An optimal replica can be selected by comparison of the pheromone values of all the replicas.

In the replica selection strategy based on ant algorithm, the pheromone determines the good replica or the bad replica. The pheromone value is decision by some important factors, such as the disk read speed of storage nodes, the network bandwidth between nodes, the physical distance, the CPU computing power and the load on the replica storage node.

Pheromone initialization: When there is a new replica j generated in data grid, initialization of its pheromone will be done according to the Eq. 1. In the Eq. 1, r is the disk read speed, f is the size of the replica and s_j is the size of parameters packet:

$$\tau_j(0) = \frac{r}{f} + s_j \quad (1)$$

Pheromone update: When the pheromone of replica changes, it should be adjusted according to the Eq. 2. In the Eq. 2, A_{ij} is the change amount of pheromone, $0<\rho<1$ is the maintain factor of the pheromone, $1-\rho$ is the evaporation of the pheromone:

$$\tau_j^{new} = \rho \cdot \tau_j^{old} + \Delta\tau_j \quad (2)$$

- **Update rule 1:** When someone accesses the replica j remotely, the pheromone will reduce. $\Delta\tau_j = -k$, $k = f/bw$, where, bw is the bandwidth. That is, when a replica has been selected to provide services and the probability of other task to select the replica will be reduced
- **Update rule 2:** When successfully access the replica j, the pheromone will increase. $\Delta\tau_j$, $= c_e.k$ $0<c_e<1$ is the reward factor
- **Update rule 3:** When accessing the replica j fails, the pheromone will reduce. $\Delta\tau_j = -c_p.k$, $0<c_p<1$ is the penalty factor

Selection probability of replica: When the pheromone of replicas changes, the probability of the replica being selected will also changes. The probability values can be calculated according to the Eq. 3. $\tau_j(t)$ is the pheromone of replica j, $\eta_j(t)$ is the inherent properties of replica, that is initialing pheromone. α and β is the weighting factor of replica's pheromone and its inherent properties:

$$p_j^k(t) = \begin{cases} \dfrac{[\tau_j(t)]^\alpha[\eta_j]^\beta}{\sum_{u=1}^{n}[\tau_u(t)]^\alpha[\eta_u]^\beta} & j,u \in \text{datareplica} \\ 0 & \text{others} \end{cases} \quad (3)$$

Roulette probability method: Replica selection is determined according to the probability of replica selection. But the load balancing problem of replica node must be taken into account, the large probability replica do not always be selected. Then the roulette probability will be used to determine commonly. Assuming that if there are k replicas can be selected and the probability of each replica being selected is p(i) ($i\in Z^*1 \le i \le k$). $p(0) = 0$, $ps(j) = p(0)+p(1)+\ldots+p(j)$ ($j\in Z$, $0\le j\le k$). If $ps(j-1)\le rand \le ps(j)$, then select the j-th replica. Because rand is a random number which meets 0-1 uniformly distributed, therefore the probability between ps(j-1) and ps(j) depends on the value of ps(j). In long-term running, the probability of the replica being selected is consistent with probabilities calculated by Eq. 3. That conforms the principle of selecting the larger probability replica.

The algorithm flow:

Step 1: Using Eq. 1 to initialize the pheromone of each replica
Step 2: Using replica positioning strategies to identify all available replicas which have the data sets users' requests. And then match the probability according to the replica selection probability and roulette probability method to determine the best replica
Step 3: Update the pheromone of the selected replica according to the Update Rule 1 and then establish a connection with the node where the selected replica in and to transfer the replica. If the transfer is successful, it needs to update the pheromone of the replica according to the Update Rule 2. If the transfer fails, it needs to update the pheromone of the replica according to the Update Rule 3
Step 4: If meets the termination condition, the algorithm terminates. Otherwise, then go to step 2

SIMULATION EXPERIMENTS AND RESULTS ANALYSIS

Grid system is mainly for the massive data in large-scale network environment. Thus all of the expected performance of the system must be completely correct before actual operation. Therefore, it needs to use the grid simulator to assess these properties. Grid simulator can simulate the operation of the grid system and it can be adjusted in time before put into practical operation through simulation analysis results.

Optorsim simulator is mainly to study the effectiveness of algorithm for replicas in a particular environment (Bell *et al*., 2003). The simulator is a grid simulator which is extension, simple and easy to configure, easy programming. In addition, all the source code in it is free of charge and it has better open architecture and it is scalability (Dogan, 2009). In this study, Optorsim simulator is used to analyze the advantages and disadvantages of ant algorithm in the data grid.

Experimental environment and emulation configuration: In this study, the simulation experiments are completed using the configuration file about CMS Testbed in Optorsim (Sulistio *et al*., 2005). The input of Optorsim is using the configuration files to control, including the grid configuration file (grid.conf), the job configuration file (job.conf), the simulation parameters configuration file (parameters.conf), the network bandwidth configuration file (bandwidths.conf) and so on

- **grid.conf**

The grid configuration file is mainly used to described the state of the resources of the grid nodes and the topologies of grid.

- **job.conf**

The job configuration file contains the information of files in grid system and the information of the job submitted by the user during the simulation.

- **parameters.conf**

The parameters configuration files simulate the needed parameters in the means of "key to value".

- **Add the ant algorithm to the configuration file**

If someone wants to know the situation of ant algorithm in Optorsim, it is need to add the algorithm into the configuration file.

RESULTS AND DISCUSSION

In this study, the replica selection strategy based in ant algorithm is achieved in grid simulator Optorsim. After the expansion of the optimization module for the replica in the emulator, the replica selection algorithm based on ant method can be achieved in the module. Due to that there are multiple replica selection methods in optimization module of Optorsim, it is more convenient to make a comparative assessment of the results of the new algorithm on this basis. By rewriting the interfaces between modules, the new algorithm can run successfully in the emulator.

Here the configuration of sites and tasks in grid system in the previous section is used to do experiments based in SimpleOptimiser algorithm and Ant algorithm. In each experiment there are 200 job tasks need to be processed. And there are 10 calculating sites and 18 nodes in the experiment. The following Fig. 3 shows the average operation time for executing 200 jobs using SimpleOptimiser and Ant algorithm.

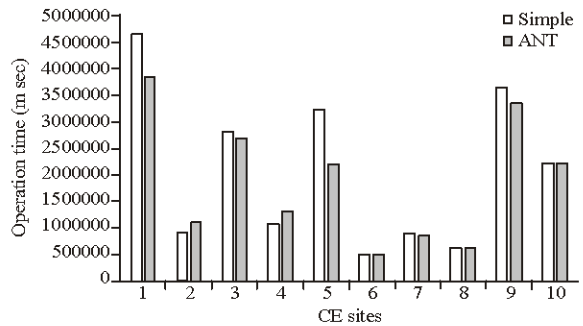

Fig. 3: Average operation time for executing 200 jobs using SimpleOptimiser and Ant algorithm

From Fig. 3, it is clearly that the average operation time using Ant algorithm is longer than using SimpleOptimiser at CE2, CE4, CE8 these three computation nodes. And other seven nodes are shorter. Therefore, the average operating time of these 10 nodes need to be calculated according to the Eq. 4 as follows.

$$\text{Total average operating time} = \sum_{i=1}^{10} CE_1 \text{ average operating time} \tag{4}$$

Therefore, the answer calculated by the Eq. 4 which means the total average operating time is 2073734 m sec after using SimpleOptimiser algorithm. And the total average operating time is 1894774 m sec after using Ant algorithm. It is clearly that the later algorithm saves about 8% of the time. It can be summarized from the experiment, the time for handle all the jobs in grid system shortened greatly after introducing the replica selection strategy based in ant algorithm.

In order to give better understanding in this study, the data comparison to conclude the efficiency of the ant algorithm and the other algorithm is needed. Here the genetic algorithm is proposed to make a comparison with the ant algorithm for replica selection in data grid. It is known that the genetic algorithm is a global optimization search algorithm, which is simple, universal, and is suitable for parallel processing. All the characteristics of the genetic algorithm are suitable for replica selection. Therefore, the experiment is done for these two algorithms in Optorsim simulator to verify the actual results of the replica selection strategy based in the ant algorithm. In the experiment, the number of jobs is 10. And the grid mean job time for the two algorithms is as the following Table 1.

From Table 1, it is clearly that the difference of the two algorithms is becoming more obvious with the passage of time in Optorsim simulator. The access time of the replica selection strategy based in the ant algorithm is

Table 1: Grid mean job time for the ant algorithm and the genetic algorithm

Time (1000 sec)	1	2	3	4	5	6
Genetic	0	1785	3864	6826	9024	11746
Ant	0	2357	3835	6629	8946	10835
Time (1000 sec)	7	8	9	10	11	12
Genetic	13646	16924	19638	21837	22745	26256
Ant	13475	16583	17684	21253	22253	23745

always less than the genetic algorithm in the later period. That means the ant algorithm proposed in this study is better than the genetic algorithm for the replica selection in data grid.

Besides that, in order to obtain the sufficiency of the replica selection algorithm based on the ant algorithm, it is need to make the comparative analysis between the execution of this algorithm and the SimpleOptimiser algorithm in Optorsim simulation. Because SimpleOptimiser algorithm will not create the replica dynamically, then it can exclude the impact of the replica selection strategy caused by creating replica. In addition, SimpleOptimiser algorithm will always dynamically select the replica whose accessing cost is the least. Each client request will to assess the consideration of the replicas in data grid. And then it will select the replica whose overall access cost is the smallest as the replica need to be accessed. It is clearly that this strategy is a typical in many other replica selection algorithms. SimpleOptimiser algorithm will select the best replica according to the prediction time of accessing replica. It will record the size of file and the bandwidth between two points, these two values can calculate the expected reading time. The Eq. 5 is as follows:

$$\text{Access time} = \frac{\text{File size}}{\text{Band width}} \quad (5)$$

During the experiment, the client who requests the access of replica is randomly distributed in the grid. And the request from the individual client will execute in a parallel manner. Since, the same replica can only accept the request from one client at a particular moment, if multiple clients request the same replica simultaneously, then there must be some clients to wait until the replica available. Therefore, three scenarios are designed to assess the results of the algorithm. In these three scenarios, the average access time is considered as the evaluation of the performance of the algorithm.

The experiment contains a total of 18 sites, which are distributed in different countries and regions. The allocation of SE in each site is proportional of the performance of CE. The site without SE and CE will be looked ad a router.

- **In the first scenario**

Initializing site Site8 only, whose size is 100 million. Site8 is large enough to set all the files inside and all the other Sites is empty. In this case, the file only has one replica, which is the master. SimpleOptimiser will read the file in Site8 no matter how to choose. And it is the same in ant algorithm. Therefore, the performance of these two algorithms should be the same basically. Figure 4a shows the details of the results for two different algorithms.

From Fig. 4a, it is clearly that the curve of remote files reading times with SimpleOptimiser and ant algorithm are very similar. It shows that the performance of these two algorithms is the same in the case of there is only one replica in the same site.

- **In the second scenario**

The number of initializing Site will be increased as: Site0, Site3, Site7, Site8, Site12, Site13 and Site15. At the same time, the size of these sites will be reduced. The size of Site8 remains unchanged so as to store all the files. Figure 4b shows the result of the experiment.

From Fig. 4b, it is clearly that the two curves are fluctuations to reach a peak and then stabilizing. This is in line with the trend of performance analysis. In addition, using ant algorithm is faster than using SimpleOptimiser algorithm. This demonstrates the superiority of ant algorithm. Ant algorithm is mainly to balance the network load and reduce network congestion, thus, reducing transmission time.

- **In the third scenario**

Initialization will be done for all sites containing SE and the size of Site8 remains unchanged. The purpose is to expand the range of storage. If the range of grid becomes greater, the topology will be more complex. And then the advantage of ant algorithm will be more obvious. Figure 4c shows the results of experiment.

From Fig. 4c, it is clearly that the time of using ant algorithm is much faster than using SimpleOptimiser. Curve tend are first fluctuations, the later go to steady as system automatically adjusting. This shows that with the increase of replica in grid, the topology becoming more complex, the ant algorithm shows more superiority.

The results can be concluded from the three Figures: In the first scenario, there is no significant difference in the performance of the two algorithms. The two algorithms will always choose the same replica due to the small number of replicas in the data grid. With the increase of the number of the replica in data grid, the ant algorithm shows its superiority gradually, especially in the

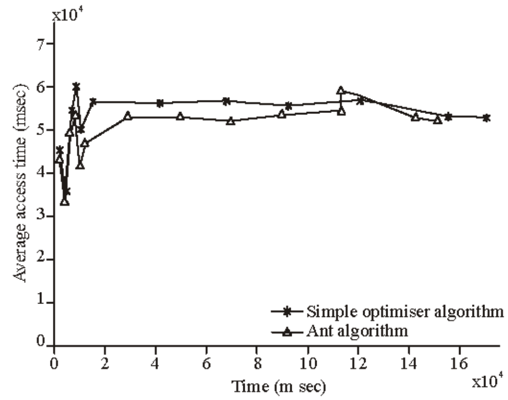

Fig. 4a: The average access time for ant algorithm and SimpleOptimiser algorithm in the first scenario: initialize only one replica in Site8

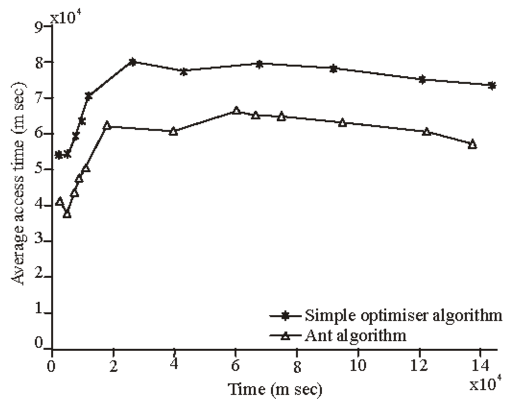

Fig. 4b: The access average time for ant algorithm and SimpleOptimiser algorithm in the second scenario: initialize seven replicas for different sites randomly

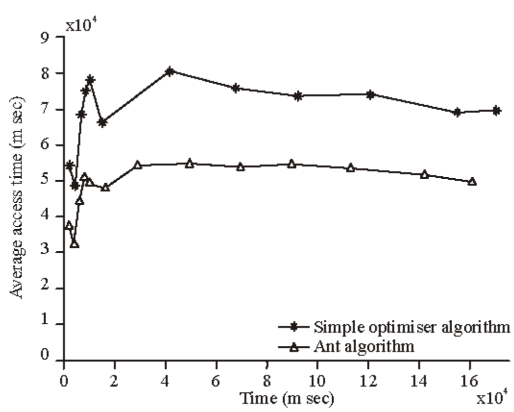

Fig. 4c: The average access time for ant algorithm and SimpleOptimiser in the third scenario: initialize all replicas for all sites

case of multiple clients request the same replica. The results also confirmed that the new algorithm is in the best performance in the third scenario and reducing the average accessing time at the same time.

CONCLUSION

In this study, an ant algorithm that aims to select the most appropriate data file replica in data grid is proposed. At the same time, the simulator Optorsim is used to evaluate the new algorithm. The experimental results show that the algorithm has a good performance in data-intensive data grid. It can reduce the average accessing time of the replica, reduce the network bandwidth consumption and make the load balance between nodes effectively.

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