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Research on virtual node placement optimization strategy of cloud platform for information acquisition①

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Abstract

A virtual node placement strategy based on service-aware is proposed for an information acquisition platform. The performance preferences and types of services in the information acquisition platform are analyzed as well as a comparison of the running time of services both in virtual node centralized and decentralized placing. All physical hosts are divided into different sub-clusters by using the analytic hierarchy process (AHP), in order to fit service of different performance preferences. In the sub-cluster, both load balance and quality of service are taken into account. Comparing with the heuristic algorithm, the experiment results show that the proposed placement strategy is running for a shorter time. And comparing with the virtual node placement strategy provided by OpenStack, the experiment results show that the proposed placement strategy can improve the execution speed of service in the information acquisition platform, and also can balance the load which improves resources utilization.

Key words: virtual node placement, service-aware, performance preference, analytic hierarchy process (AHP), load balance

0 Introduction

As soon as the concept of cloud computing[1] was put forward, it quickly developed into a new business model. The basic function of cloud computing is based on user needs to allocate cloud resources[2]. Virtualization technology[3] is one of the core technologies of cloud computing, it can virtualize a physical host into multiple virtual machines, which greatly improves the utilization of hardware resources in the data centers[4]. Cloud computing through a virtualization technology, makes computing, network, storage and other resources of the data center form a huge virtualized resources pool. Users can use these resources as easily as using water and electricity. However, virtualization technology allows cloud computing to have a huge amount of processing and storage capacity and at the same time also brings problems. Improper placement of virtual machines will not only make the processing time of service longer for virtual machine mounted but also load imbalance cause the of physical host in cloud computing environment and the lower of resource utilization.

Ref. [5] and Ref. [6] used a heuristic algorithm to optimize the virtual machine placement process, combining with energy constraints, it can effectively minimize the usage of resources, reduce the number of the running servers in data centers, and in line with the concept green cloud[7]. But the strategy does not consider the quality of service, there is no good compliance with SLA (service level agreement)[8] principle. Ref. [5] proposed a virtual machine placement strategy based on particle swarm optimization (PSO). Ref. [6] put forward an algorithm named GASA that combines genetic algorithm (GA) with simulated annealing (SA) which can lower the energy consumption of the cloud platform. Ref. [9] presented a virtual machine placement scheme based on migration, which makes the cluster achieve the dual goals of load balancing and energy saving. However, virtual machine migration will have a certain probability of malfunction,

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and migration takes up a lot of bandwidth, bringing additional resources consumption and impacting the normal service of the cloud platform.

At present, most of the current research of virtual machine placement is mainly aimed at energy saving or load balance, and these strategies cannot meet the requirements of the information acquisition platform for service running speed as well as cluster load balance. What's more, the running time of heuristic algorithms like PSO and GASA is too long and does not meet the demand for the virtual machine placement speed of the information acquisition platform. The purpose of virtual machine generation is to deal with the services, and different kinds of services focusing on consumption of hardware resources are different, which is called performance preference. Placing the virtual machine on the physical host whose hardware resources are consistent with the preference of the service that the virtual machine mount can not only shorten the running time and improve the service quality, but also improve the utility ratio of resource. Aiming at these problems, this paper proposes a service aware based strategy (SABS) for the information acquisition platform, which can not only improve the services processing speed in the platform but also balance the cluster load.

1 The overview of information acquisition platform

The information acquisition platform is for information crawling and analyzing. There are two kinds of services on the platform, one is crawling service and the other is analysis service, in which the crawling service uses a web crawler to collect specified information and store it, and analysis service is based on the emotional dictionary to classify the information. The running status of the two types of services in the platform is recorded, and both the load resource and type of the services are analyzed. The resource utilization when the service is running as shown in Fig. 1, Fig. 2, Fig. 3 and Fig. 4. In the graphs, 0s – 15s and 50s – 70s are the service suspension period, 15s – 50s is the service running period.

Fig. 1 and Fig. 2 reflect the CPU and memory usage rate during the crawling service running process that is basically the same as the service pause state, but the network I/O speed increases by a large margin. The main manifestation of the crawling service is the increase of network I/O while the utilization of other resources changes little. The performance preference of analysis service is network card, and crawling service is the I/O-intensive service.

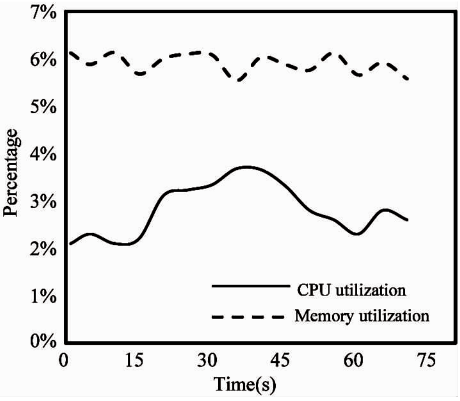

Fig. 1 The utilization changes of CPU and memory when crawling service running

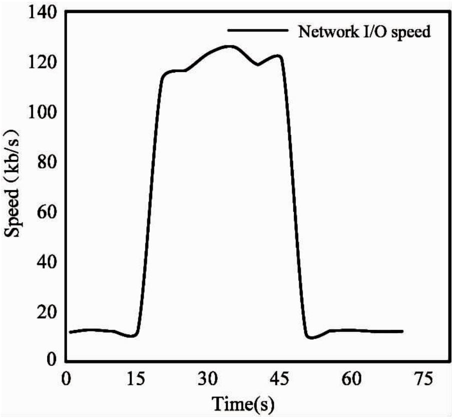

Fig. 2 The network I/O speed changes when crawling service running

Fig. 3 and Fig. 4 reflect the memory usage and network I/O speed during the analysis service running process that is basically the same as the service pause state, while a substantial increment in CPU utilization, the main manifestation of the analysis service is the increase of CPU utilization while the utilization of other

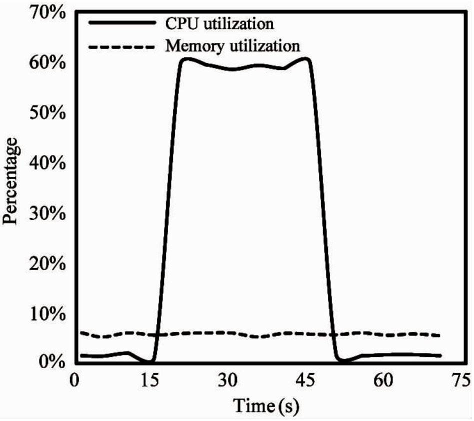

Fig. 3 The utilization changes of CPU and memory when analysis service running

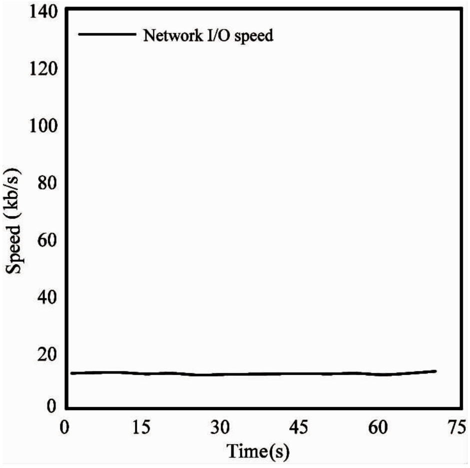

Fig. 4 The network I/O speed changes when analysis service running

resources changes little. The performance preference of analysis service is CPU. Therefore, the analysis service is the computing-intensive service.

Fig. 5 and Fig. 6 show the comparison of the average response time of service when placing all virtual machines on one physical host and all virtual machines are placed on two physical hosts of same configuration. It can be seen that the distribution of virtual machines to multiple physical machines can effectively improve the running speed of services and reduce the execution time.

Different kinds of service in the process of running focusing on resource consumption are quite different. In the information acquisition platform, the main responsibility for the resource load of computing-intensive service is CPU and the main responsibility for the resource load of I/O-intensive service is the network card. What's more, the running speed when decentralizing virtual machines on physical hosts is faster than centralized. Therefore the process of placing virtual machine should be fully considered in the performance preference of services, according to the preference to place virtual machines on proper physical host cluster and keep load balance in the cluster, so as to make the service run faster and reduce running time.

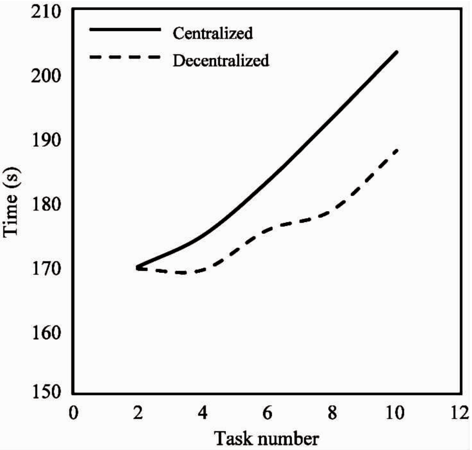

Fig. 5 Analysis service centralized and decentralized processing time comparison

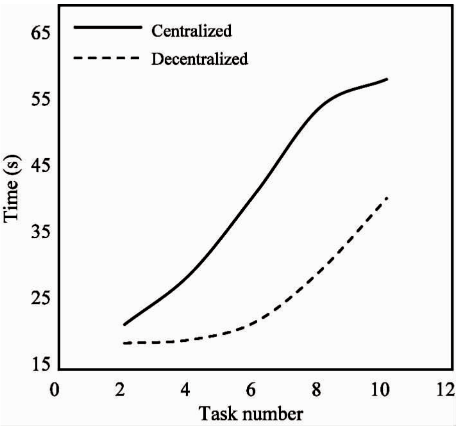

Fig. 6 Crawling service centralized and decentralized processing time comparison

2 Virtual node placement strategy design

This study investigates a virtual node placement strategy based on information acquisition platform and the proposed strategy is based on service-aware. However, the virtual machine placement algorithm provided by OpenStack like Chance (randomly select physical host) and Simple(select the physical host which available memory is largest) is too simple and has drawbacks which cannot meet the requirements for service running speed and load balance.

All virtual machines on a single physical host share the CPU, memory and network cards, so the virtual machine's hardware performance is determined by the physical host. All physical hosts according to its hardware performance are divided into the computing-intensive cluster which is suitable for processing computing-intensive services and I/O-intensive cluster which is suitable for processing I/O-intensive services.

In general, there are two steps contained by the strategy, the first step which is called sub-cluster partition divides all physical hosts into sub-clusters, and the second step which is called the virtual node placement view generation chooses the most proper physical host to place the virtual machine.

2.1 Sub-cluster partition

There is a great relationship between the running speed of service and the hardware performance of the physical host. So it is important to choose the physical host to place the virtual machine. The process of sub-cluster partition divides all physical hosts into different sub-clusters according to their hardware performance. Zivkov pointed out that MIPS was a true measure of CPU performance indicators[10]. MIPS (million instructions per second) refers to the processing of millions of machine language instructions per second. In this paper, MIPS, memory size, network bandwidth are chosen to represent the performance of CPU, memory and network card. The capacity value of the physical host is calculated according to

$$C = N_{MIPS} \times W_{MIPS} + N_{Mem} \times W_{Mem} + N_{Bw} \times W_{Bw} \qquad (1)$$

N_{MIPS}, N_{Mem} and N_{Bw} are the value of the MIPS, memory size and bandwidth of the physical host after beeing normalized. W_{MIPS}, W_{Mem} and W_{Bw} are the weights calculated according to AHP[11]. The normalized calculation method of the physical host hardware is shown as

$$N_{MIPS} = \begin{cases} \dfrac{MIPS - MIPS_{\max}}{MIPS_{\max} - MIPS_{\min}} & MIPS_{\max} \neq MIPS_{\min} \\ 1 & MIPS_{\max} = MIPS_{\min} \end{cases} \qquad (2)$$

$$N_{Mem} = \begin{cases} \dfrac{Mem - Mem_{\max}}{Mem_{\max} - Mem_{\min}} & Mem_{\max} \neq Mem_{\min} \\ 1 & Mem_{\max} = Mem_{\min} \end{cases} \qquad (3)$$

$$N_{Bw} = \begin{cases} \dfrac{Bw - Bw_{\max}}{Bw_{\max} - Bw_{\min}} & Bw_{\max} \neq Bw_{\min} \\ 1 & Bw_{\max} = Bw_{\min} \end{cases} \qquad (4)$$

$MIPS$ (unit, million instructions/s) is the MIPS value of the physical host, Mem (unit, GB) is the memory size of physical host, Bw (unit, Mb/s) is the bandwidth of physical host, $MIPS_{\max}$, $Mem_{\max}$ and $Bw_{\max}$ are the maximum MIPS, memory and bandwidth in the cluster, $MIPS_{\min}$, $Mem_{\min}$ and $Bw_{\min}$ are the minimum MIPS, memory, and bandwidth in the cluster.

And then the analytic hierarchy process is used to determine the weight to divide the host, and the process is shown as follows.

1) Establish a hierarchical model. In the classification of physical hosts to consider the indicators include MIPS, memory size, and bandwidth. The hierarchical model is shown in Fig. 7.

2) Constitute a contrast matrix. The importance of each factor is compared and the importance is determined. The matrix $\boldsymbol{A} = (a_{ij})_{n \times n}$ represents the importance comparison between factor i and j. The value of items in the comparison matrix can be set referring to the recommendations of the Satty, between 1-9 and its reciprocal value, as shown in Table 1.

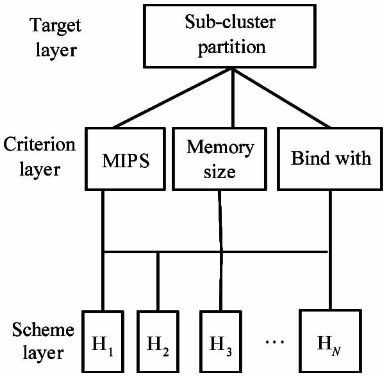

Fig. 7 Sub cluster partition hierarchical model

Table 1 The reference value of comparison matrix element

a_{ij}	Meaning
1	factor i and factor j have the same importance
3	factor i is slightly more important than factor j
5	factor i is more important than factor j
7	factor i is much more important than factor j
9	factor i is extremely more important than factor j
$2n$ ($n = 1,2,3,4$)	the importance between $2n - 1$ and $2n + 1$

Defining the element a_{ij} of contrast matrix, i and j represent the MIPS size, memory size, and bandwidth respectively, a_{ij} is the result of the comparison of the importance of factor i and factor j.

For computing-intensive sub-cluster, the physical hosts in this cluster will be responsible for placing the virtual machines which contain computing-intensive services. And the resource that is primarily responsible for computing-intensive service load is CPU, the utilization of CPU increases largely and the utilization of memory and network I/O speed is basically unchanged in the running process of compute-intensive services. But if the memory is sufficient, the speed of CPU processing data can be faster. Therefore, for computing-intensive sub-cluster MIPS is much more important than bandwidth and memory size. Memory size is more important than bandwidth. So the contrast matrix of computing-intensive sub-cluster is shown as

$$\boldsymbol{A} = \begin{bmatrix} 1 & 5 & 7 \\ \dfrac{1}{5} & 1 & 3 \\ \dfrac{1}{7} & \dfrac{1}{3} & 1 \end{bmatrix} \qquad (5)$$

3) Consistency test. Ideally, $\boldsymbol{A}$ is the comparison matrix perfectly and satisfying:

$$a_{ij} \times a_{jk} = a_{ik} \quad 1 \leqslant i, j, k \leqslant n \qquad (6)$$

But it is difficult to satisfy Eq. (6) in reality , and redefining the consistency index CI like Eq. (7) shown is needed.

$$CI = \frac{\lambda_{\max}(\boldsymbol{A}) - n}{n - 1} \tag{7}$$

where $\lambda_{\max}$ represents the largest eigenvalue of the matrix. When $CI = 0$, matrix $\boldsymbol{A}$ is completely consistent; the smaller of CI, the better the consistency of matrix $\boldsymbol{A}$. What's more, the average stochastic consistency index RI is also used to measure CI, which is only related to the order of the matrix. For the judgment matrix of the order 1 - 6, the value of RI is shown in Table 2.

Table 2 The values of stochastic consistency index *RI*

Order	1	2	3	4	5	6
RI	0	0	0.52	0.89	1.12	1.26

Defining the consistency ratio $CR = CI/RI$, when $CR < 0.1$, it is assumed that the inconsistency of matrix $\boldsymbol{A}$ is within the allowable range. Otherwise, the contrast matrix needs to be adjusted until the inconsistency is within the allowable range.

By calculating, $\lambda_{\max}$ of matrix $\boldsymbol{A}$ is 3.065, $CI = (\lambda_{\max}(\boldsymbol{A}) - n)/(n - 1) = (3.065 - 3)/2 = 0.0325$, looking at Table 2 can get that $RI = 0.52$, $CR = CI/RI = 0.062 < 0.1$. It is indicated that the inconsistency of the contrast matrix $\boldsymbol{A}$ is acceptable and there is no need for $\boldsymbol{A}$ to be adjusted. At last, $W_{MIPS} = 0.731$, $W_{Mem} = 0.188$ and $W_{Bw} = 0.081$.

Similarly, for I/O-intensive sub-cluster, the physical hosts in this cluster will be responsible for placing the virtual machines which contain I/O-intensive services. And the resource that is primarily responsible for I/O-intensive services load is the network card. In the process of running I/O-intensive service, the speeds of network I/O increases largely and the utilization of CPU will increase slightly but the memory utilization is stable. Therefore, in the I/O-intensive sub-cluster, the network card bandwidth is much more important than the memory size and more important than MIPS. As the memory utilization is basically the same and the CPU utilization increased slightly, MIPS is slightly more important than the memory size. So the contrast matrix $\boldsymbol{B}$ of I/O-intensive sub-cluster is shown below:

$$\boldsymbol{B} = \begin{bmatrix} 1 & 3 & \frac{1}{5} \\ \frac{1}{3} & 1 & \frac{1}{7} \\ 5 & 7 & 1 \end{bmatrix} \tag{8}$$

By calculation can get that $CR = 0.062 < 0.1$, which means the inconsistency of $\boldsymbol{B}$ *is also acceptable and there is no need for matrix B* to be adjusted. At last, $W_{MIPS} = 0.188$, $W_{Mem} = 0.081$ and $W_{Bw} = 0.731$.

In summary, the sub-cluster partition process is shown as follows.

1) Traverse all the physical hosts U of the cluster, and calculate the computing capacity and I/O capacity of each host according to the above formula;

2) According to the descending order of computing capacity value, hosts in top ω_1 are added into the computing-intensive sub-cluster $\boldsymbol{A}$;

3) According to the descending order of I/O capacity value, hosts in top ω_2 are added into I/O-intensive sub-cluster $\boldsymbol{B}$;

4) Multiple iterations until sub-cluster $\boldsymbol{A}$ and sub-cluster $\boldsymbol{B}$ contain all hosts in cluster U.

In addition, the value of ω_1 and ω_2 can be set according to the specific situation.

2.2 Virtual node placement view generation

The selection of the first step can exclude physical hosts that can not meet virtual machine's service performance preference. And then in the remaining physical further screening of host, this can avoid the situation that some physical hosts resource utilization is too high while other hosts are idle. Due to heterogeneous of the physical host, choosing the resource utilization as the standard is necessary to calculate the load balance degree of all physical hosts. The method used to compare differences is the statistical variance, the smaller the variance is, the more the resource occupancy rate is close to, and the allocation of resources is more balanced.

Through Eq. (9) to calculate the load of a single resource $L^i(t)$, Eq. (10) is used to calculate the overall load of host $H^j(t)$, Eq. (11) calculates the average load $Avg_{cl(t)}$ of the cluster, and Eq. (12) is used to calculate the variance $\delta_{H^j(t)}$ of each physical host. At last, select the physical host with minimum load variance to place virtual machine.

$$L^i(t) = \frac{1}{R^i}[P^i(t-1) + U^i(t)] \tag{9}$$

$$H^j(t) = \frac{1}{m}\sum_{i=1}^{m} L^i(t) \tag{10}$$

$$Avg_{cl(t)} = \frac{1}{n}\sum_{j=1}^{n} H^j(t) \tag{11}$$

$$\delta_{H^j(t)} = (H^j(t) - Avg_{cl(t)})^2 \tag{12}$$

where, $P^i(t-1)$ is the total usage of resource i in $t-1$ time units, $U^i(t)$ represents the usage of resource i at time t, and R^i is the total amount if resource i, m is the total number of resources. In the strategy this paper proposes $m = 3$ and N as the number of physical hosts in the cluster.

The pseudo-code of the concrete implementation process is as follows:

```
Initialization, dividing all physical hosts into computing-intensive sub cluster $U_A$ and I/O-intensive sub cluster $U_B$
while true do
    polling the request queue Task of virtual machine placement
    if there is a new placement request
        Read the service type Type in the placement request
        if Type == computing-intensive
            Scheduling domain $U_S = U_A$
        endif
        if Type == I/O-intensive
            Scheduling domain $U_S = U_B$
        endif
        for $i = 0$ to $U_S$.length do
            Calculating the load variance $\delta_i$ of the physical hosts in the Scheduling domain, record the minimum load variance.
        endfor
        return the physical host with the minimum load variance
    endif
endwhile
```

3 Experiment and analysis

In order to test the validity of the virtual node placement strategy, different test cases are designed for different indicators. Aiming at the Chance and Simple algorithms provided by OpenStack as well as heuristic algorithms PSO and GASA, three sets of tests are designed. Firstly, compare the time that the service aware based strategy (SABS) as well as Chance algorithm and Simple algorithm to complete the same type and number services. Secondly, respectively use the placement strategy SABS as well as the heuristic algorithm PSO and GASA to place 5, 10, 15, 20, 30 virtual machines and compare the running time of each strategy. Thirdly, respectively use the placement strategy SABS as well as Chance algorithm and Simple algorithm to place the virtual machine, compare the mean value of all physical host's load variance when the cluster gets into a stable state.

The testing process is based on OpenStack to build a platform with 4 physical hosts. Table 3 shows the virtual machine configuration parameters, which are used to describe the configuration information of the virtual machine. Table 4 is the physical host configuration information contained in the platform.

Table 3 Virtual machine configuration parameters

ID	CPU core number	RAM (GB)	Disk size (GB)
1	1	1	50
2	1	2	50
3	2	1	50
4	2	2	50

Table 4 Physical host configuration parameters

ID	CPU cores	CPU MIPS	RAM (GB)	Disk size (GB)	Bandwidth (Mb/s)
1	4	6385	4	300	100
2	4	6385	8	300	100
3	4	4191	4	300	1000
4	4	4191	8	300	1000

In the experiment of service completion time comparison, virtual machines with specific intensive service are generated according to Table 3. And 2, 4, 6, 8 and 10 virtual machines are generated, where respectively, the ratio of crawling service and analysis service is 1:1. What's more, virtual machine placement requests are randomly generated and both values of ω_1 and ω_2 are 0.5. Then start the service and record the completion time. In the experiment of calculating the mean value of all physical host's load variance, respectively generating 5, 10, 15, 20 and 30 virtual machine placement requests according to the virtual machine configuration provided in Table 3. Then the mean values of all physical host's load variance are recorded after all physical hosts enter into steady state status. In order to make the data more accurate, each group of test does 5 times, the experiment results take the average of 5 times.

Fig. 8 shows the comparison of task completion time

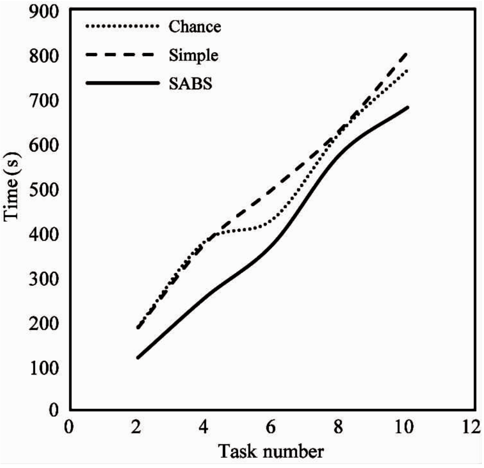

Fig. 8 Services completion time comparison

between the strategies studied in this paper and the Chance and Simple algorithms provided by OpenStack. The task completion time is increasing with the number of tasks increasing, but the task completion time of this paper studied strategy is lower than that of the Chance and Simple algorithm.

Fig. 9 shows the reduction percentage of task completion time when using the placement strategy proposed in this paper. Because of adopting the placement model based on service performance preference, when the physical host is selected to place the virtual machine, it can select the physical host which can satisfy the performance preference of virtual machine mount service, thus reducing the execution time of the service.

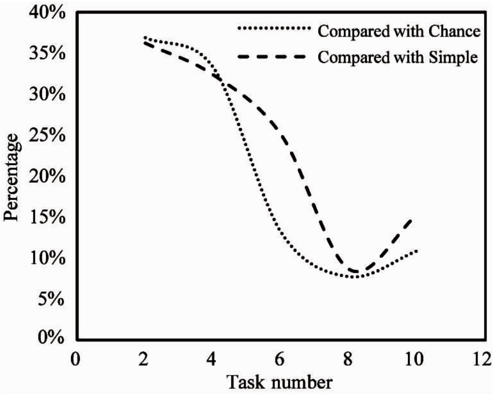

Fig. 9 Task running time reduction ratio comparison

Fig. 10 shows that the running time of the placement strategy proposed in this paper compared with the heuristic algorithms PSO and GASA. From the experimental results, it can be seen that the proposed placement strategy in this paper runs faster and can provide faster virtual machine decision for the platform.

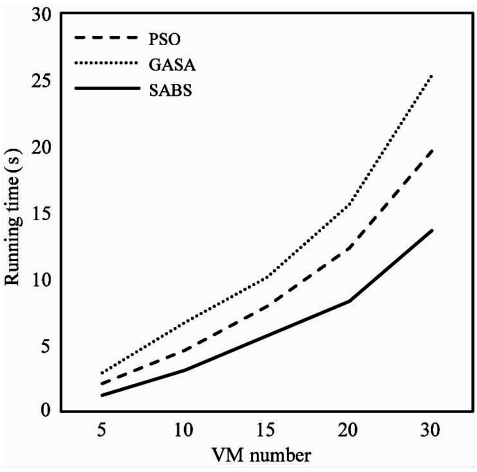

Fig. 10 Running time comparison with the heuristic algorithms

After respectively using the virtual machine placement strategy proposed in this paper as well as Chance strategy and Simple strategy to place virtual machines, the comparison of the mean value of the load variance for all physical hosts is shown in Fig. 11. It can be seen from Fig. 11 that after using the virtual machine placement strategy proposed in this paper, the variance fluctuates in a small range is smaller than that of the Simple strategy and the Chance strategy. It also can be seen from the experimental data, resource utilization of virtual machine placement strategy proposed by this paper is balanced. Because the proposed strategy will take the running status of the physical host into consideration when placing the virtual machines, and select the physical host with minimum load imbalance to place the virtual machine. Thus the resources usage of physical hosts in the cluster is similar.

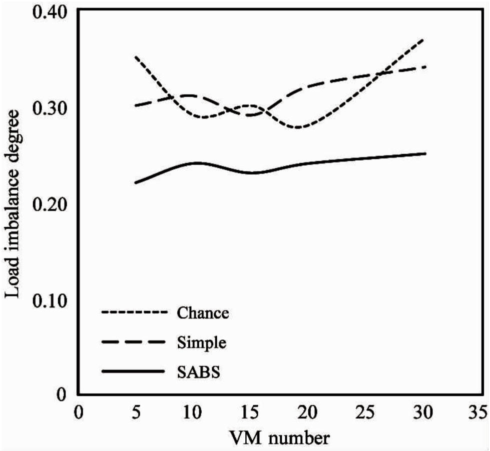

Fig. 11 physical hosts' load variance comparison

4 Conclusion

The types and performance preference of services in the information acquisition platform are analyzed in this paper. Through the study of virtual machine placement strategy provided by OpenStack, a virtual node placement strategy based on service-aware is proposed for the information acquisition platform. By means of AHP, all physical hosts are divided into different sub-clusters according to hardware configurations, in order to fit services of different performance preferences. In the sub-cluster, the load variance of each physical host has been calculated and the physical host with minimum load variance is selected to place the virtual machine, which can balance the load among the physical hosts. Comparing with the heuristic algorithm, the placement strategy proposed in this paper is running for a shorter time. And comparing with the virtual machine placement algorithm provided by OpenStack, the experiment results show that the proposed virtual node placement scheme can not only reduce the completion time but also improve the quality of service and balance the resource load of the cluster.

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