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Energy Consumption Measurement and Management Method Based on Cloud Computing Environment

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Abstract: Cloud computing has become a popular network computing model. It does not need to perform complex computing and avoid the purchase of a large number of hardware facilities. As long as the application program is used, it can directly perform computing and obtain service resources. Cloud computing providers are on the rise, and at the same time, energy consumption is starting to raise suspicions. The main purpose of this paper is to analyze and improve the measurement and management methods of energy consumption based on the cloud computing environment. This paper mainly proposes a resource scheduling algorithm through the problem of system resources and task scheduling allocation, so as to reduce unnecessary consumption. Experiments show that with the gradual increase of the constraint cost in the scheduling process of random tasks, the average total execution energy consumption of the cloud system and the amount of mobile data in the system are both declining, indicating that the scheduling process of tasks is gradually decreasing.

1. Introduction

Cloud computing has high availability, easy expansion, and can provide corresponding services according to user needs. Therefore, it is widely used and develops rapidly. However, the energy consumption management of cloud computing is also a big challenge. Effective resource allocation can optimize the management of server nodes in the data center resource pool, and the energy-saving task scheduling method can effectively combine the original scheduling method and emerging energy-saving technology to improve the utilization rate and service quality of cloud computing systems, whether it is service Either the provider or the requester can obtain the maximum benefit to the greatest extent, thereby realizing a win-win situation of resource supply and resource consumption [1, 2].

For cloud computing, a large number of scholars have conducted research on it, and the research results are also considerable. For example, Jamali IA proposed that cloud computing is not to spend a lot of money to purchase required software and hardware resources or required skills, but to obtain these available services through web login [3]. Ismail L proposed to convert computing power into a market, so that each user can obtain computing power according to their own needs [4]. It can be seen that it is imminent to improve resource allocation, improve resource utilization, and reduce energy consumption.

The main purpose of this paper is to study the measurement and management methods of energy consumption based on cloud computing environment. To reduce energy consumption, to optimize. For the optimization strategy, an optimization algorithm is proposed, one is for virtual machine placement, and the other is for task scheduling. On the basis of the research results, improve the algorithm and reduce the energy consumption target.

2. Design and Research of Energy Consumption Measurement and Management Method Based on Cloud Computing Environment

2.1. Features and Advantages of Cloud Computing

Cloud computing concentrates resources, provides services for users, users obtain on-demand, self-service, convenient and fast. This model of cloud computing can provide services elastically and has high scalability. Combined with the research status, the characteristics and advantages of cloud computing are summarized as follows:

2.1.1. Very Large Scale

In order to provide users with better services, cloud computing service providers need to establish a large-scale resource pool. The resource pool is composed of a large number of servers, which can reach more than 10,000 levels. Google's data center is composed of millions of servers, and its scale is huge, and the servers owned by some well-known cloud companies in China have reached more than 100,000. The huge scale also means that cloud computing has powerful computing power [5, 6].

2.1.2. Virtualization

The most representative feature of cloud computing is virtualization. In cloud computing, virtualization technology is mainly reflected in the sharing of resources. When users acquire resources, they can flexibly allocate jobs to different physical machines, providing users with great convenience. Users who want to obtain computing services only need to use network services through various terminals to achieve their goals, and are not limited by time and place.

2.1.3. High Reliability

Cloud computing will take a series of typical measures to ensure the high quality of services and provide users with high-quality services. In this way, users can use cloud computing resources with confidence. The cluster in cloud computing will not cause the entire system to collapse due to the failure of some servers. Once a server in the data center fails, it will be terminated and another server will be started, thus ensuring the normal progress of cloud tasks.

2.1.4. On-demand Service

Users can buy according to their own needs, and they are billed according to the usage. It is easy to use and low in cost. The cloud data center is like a black box. Users can use it according to their own needs, which are convenient and fast, and does not need to pay attention to internal implementation.

2.1.5. Cheap

Extremely cheap, and the cost-effectiveness of cloud computing is very high. The automated management of data centers can reduce management costs and improve the efficiency of resource use. Cloud data centers are generally built in areas with small populations, low temperatures, and abundant water and electricity resources, thereby further reducing energy costs..

2.1.6. High Scalability

The "cloud" in the data center can be dynamically scaled, for example, by expanding the number of data center servers to meet the growing needs of cloud users and cloud applications, and by optimizing the quality of data center servers to meet the needs of cloud users and cloud application service quality.

2.2. Key Technologies of Cloud Computing

The rapid development of cloud computing also depends on the improvement of technology. The most important key technologies in the cloud computing platform are listed below.

2.2.1. Virtualization Technology

Through virtual operation, software and hardware are isolated, resources are divided into multiple or integrated into one, and unified services are provided for users. These operations are transparent to upper-level users. The biggest feature of cloud computing is dynamic. Without dynamic virtualization technology, there would be no cloud, and there would be no series of development of cloud computing. In cloud computing platforms, virtualization is an important part of the IaaS layer. The idle rate of resources makes the system have higher resource utilization and more flexible interoperability. In addition, the use of server integration technology in virtualization technology can effectively reduce the number of running servers in the system, thereby reducing the operating cost of the system. And it can reduce the number of server downtimes without disrupting the continuity of services. Virtualization technology can become the basic technology of cloud computing mainly because it has the following characteristics: improve the deployment efficiency through the virtual machine rapid deployment technology based on the fork idea, and realize the effective reduction of virtual machine deployment time; Improve system reliability under the condition of affecting service quality [7, 8].

2.2.2. Energy Consumption Management Technology

Energy management technology refers to the use of various software and hardware related technologies to reduce the total energy consumption of cloud computing systems. For the energy consumption optimization problem of IT equipment system, the corresponding energy consumption optimization technology can be researched from the processor equipment, etc. For the energy consumption optimization problem of the cooling system, it is necessary to comprehensively consider the data center space size, rack placement, air Factors such as the direction of circulation, the direction of cooling air transmission of fans and air conditioners, etc., have been studied to optimize the energy consumption of cooling equipment in the data center; for the power distribution system, green energy such as wind energy and solar energy can be used as the power supply source to significantly reduce the carbon emissions of the data center.

2.2.3. Mass Data Processing Technology

It is mainly divided into computing and storage. The massive data computing technology mainly uses the parallel programming model MapReduce, which encapsulates the details, provides a programming interface, and writes functions through the programming interface. Conducive to load balancing, the caching mechanism can improve performance and improve system operation efficiency. In addition, GFS reduces the difficulty of implementation and improves efficiency.

2.2.4. Resource Management and Task Scheduling Technology

The resources of the cloud data center are large in scale and various in variety. The essence of resource management is to accept the requests of cloud users reaching the cloud computing system, and allocate specific resources of the cloud data center according to the user's request, so that the corresponding user tasks can be run. The dynamic changes of tasks and resources make the mapping between tasks and resources present a many-to-many relationship, which brings certain challenges to the resource management technology of cloud computing. Task scheduling can actually be abstracted into three main bodies, namely task request, data center resources and task scheduling target. Task scheduling technology is based on the corresponding resource management technology, and the final task scheduling is determined by the corresponding scheduling target algorithm.

2.3. Task Scheduling Strategy

Depending on the rules used to map tasks to resources, different task scheduling algorithms are formed.

2.3.1. Characteristics and Goals of Task Scheduling

Task scheduling in the cloud computing environment mainly has the following characteristics:

(1) The resources of cloud data centers are heterogeneous and diverse, and the scale is huge, that is, the configuration of data center resources by cloud service providers varies greatly, which may be server nodes with high performance, or computer nodes with average performance. Different service performances of resources are quite different;

(2) The number of cloud users is huge, and the types of cloud users are different, resulting in a wide variety of tasks in the cloud computing environment, with obvious differences. Traditional desktop computers, laptops, tablet computers, smartphones and other new networking devices can request the cloud. Computing resources, in other words, any device on the Internet can access the resources of the cloud data center. Different types of tasks lead to various cloud users' demands for resources, and the urgency of resource demands is also different;

(3) The number of cloud data center resources is constantly changing. For example, when the cloud computing system develops from the initial stage of operation to the stable stage of operation,

it is necessary to increase resource nodes. In the process of the development of the cloud computing system from the stable stage of operation to the later stage of operation, due to The number of resource nodes decreases due to node failure, and the internal structure of resource nodes is constantly changing during the entire operation of the cloud computing system [9, 10].

Cloud computing task scheduling has different goals from different aspects:

(1) Service quality objectives, cloud computing task scheduling needs to provide a relatively high-quality user experience, including providing deadline guarantees, response time guarantees, system reliability guarantees, and service security guarantees. The operating rule of "customer first", so this goal is one of the most important goals for the success of cloud computing system application;

(2) Load balancing target, cloud computing task scheduling should achieve a more balanced load distribution, without causing some resource overload or some resource underload situation, this target can optimize the resource allocation of cloud data centers, to a certain extent Extend the use time of resource equipment, so this goal is the key goal of making the resource equipment of the cloud computing system run stably for a long time;

(3) Service revenue target. When scheduling cloud computing tasks, it is necessary to improve the utilization rate of cloud computing systems as much as possible, so that cloud service providers and users can improve their own benefits and achieve mutually beneficial results. Cloud computing can exist stably. Part of the reason is that it can promote the common development of both sides of the service, so this goal is the main goal of the stable development of cloud computing systems;

(4) To reduce the cost target, the cloud computing data center needs to invest a huge operating cost in the early stage of operation, and also needs to invest a large maintenance cost during the operation process. Therefore, it is necessary to optimize the investment and improve the flexibility of cost input such as operating equipment and maintenance equipment. This goal is the premise goal of the stable development of the cloud computing system;

(5) Energy consumption optimization goal, when scheduling cloud computing tasks, it should be committed to reducing the energy consumption of cloud data centers, reducing the emission of carbon dioxide and other pollutants, and promoting the long-term harmonious and stable development of cloud computing systems. This goal is to promote the stable development of cloud computing systems. Optimize the target.

2.3.2. Classification of Task Scheduling Strategies

The traditional task scheduling strategy is also the classic task scheduling strategy. The Min-Min algorithm requires the task to be completed in the least time, that is, the task is mapped to the resource node that takes the shortest time to complete the task. This is a typical greedy algorithm, which can easily lead to serious load imbalance, that is, the task is always mapped to partial processing. On resource nodes with strong capabilities, such resource nodes run at high load, which violates the load balancing goal. The Max-Min algorithm is also a typical greedy algorithm, which pursues "difficulty first and then easy", which is the opposite of the former. The latter can be scheduled faster in long-running tasks. The scheduling performance of these two algorithms has its own advantages depending on the specific application [11, 12].

2.3.3. Task Scheduling Strategy

According to the different requirements of the tasks in the system for the deadline, the task scheduling strategy can be divided into hard real-time task scheduling strategy, soft real-time task scheduling strategy and non-real-time task scheduling strategy. Generally, soft real-time task scheduling strategy The scheduling strategy and the non-real-time task scheduling strategy are collectively referred to as the general real-time task scheduling strategy.

2.4. Research on Cloud Computing Energy Consumption Algorithm

2.4.1. Cloud Computing Energy Consumption Calculation

In order to reduce the idle probability of computing nodes, the concept of cloud system utilization threshold is proposed. At this time, the total energy consumption E is as follows:

$$E = P_2 yMfT_1 + (N - M)P_3T_3 + (N - M)P_4T_4 + (N - M - 1 + X)P_5 \frac{L_{ij}}{b_{ij}} \tag{1}$$

Among them, (NM) P_3T_3 is the energy consumption generated by the node state switching, (NM) P_4T_4 is the energy consumption required after the node state transition, (NM-1+X)P_5 Lij/bij is the virtual value of the task being executed on the node energy consumption for machine migration. The conversion power when the cloud node transitions from the normal working state to the sleep state is denoted as P_3, the sleep power is P_4, and the transmission power of the virtual machine migration of the low-power cloud node is defined as P_5.

2.4.2. Optimization Algorithm

When the execution power of the cloud system is lower than the specified threshold, iterative calculation of the algorithm is performed to make the system idle nodes and some low-power nodes enter the sleep state to save low-utilization energy consumption, and at the same time migrate the virtual machine running on the node. Task, the optimization model can be formally described as:

$$\min Z = E_{sum}$$
$$s.t. \begin{cases} T_n = \lambda(T_{n-1})_{emp} + (1-\lambda)(T_{n-1})_{for} \\ T > \dfrac{E_1 + E_2 + E_3}{P} \\ \dfrac{\sum_{x=1}^{n} f_x}{n} \geq y \\ E_{sum} = E_1 + E_2 + E_3 \end{cases} \tag{2}$$

Among them, E_1, E_2, and E_3 respectively represent the task switching energy consumption, virtual machine migration energy consumption and sleep energy consumption during the shutdown process of the cloud node, and the total energy consumption is defined as Esum. In the above formula, Constraint 1 represents the relationship between the low utilization time of the nth prediction and the last low utilization time and the sleep time of the previous prediction; Constraint 2 represents that the state transition must meet the transition time threshold, and the algorithm is executed. Constraint 3 indicates that the cloud system utilization is higher than the utilization conversion threshold y, and constraint 4 indicates the calculation formula of the total energy consumption of the cloud system after optimization.

3. Experimental Research on Energy Consumption Measurement and Management Method Based on Cloud Computing Environment

3.1. Energy Consumption Management Methods

It is mainly divided into hardware component level, node level and system level.

3.1.1. Hardware Component-level Energy Consumption Optimization

The method is mainly used for a single energy-consuming component of the system, including a processor, a storage device, and a network device. In a specific cloud computing system, the energy consumption optimization module observes the energy consumption components in the system, and transmits the observation information to the control module. The control module sets the corresponding energy consumption optimization strategy to control and adjust the system parameters, and finally optimizes Energy consumption of hardware components.

(1) Optimization of processor energy consumption: The most influential factors of processor energy consumption are the voltage and clock frequency of the processor, so the processor energy consumption optimization strategy mainly adjusts the voltage and clock of the processor in real time by detecting the load of the processor through the operating system frequency, in addition to the ability to put the processor into a low-power operating mode through dynamic power management.

(2) Optimization of memory energy consumption: The energy consumption of memory is related to the memory, speed, and read/write throughput of the memory chip module. The larger the chip memory, the slower the storage; the greater the memory read/write throughput, the smaller the power consumption, which is related to the memory bus, processor speed, and the number of memory page misses. Therefore, it is necessary to detect the number of missing memory pages, adjust the memory page replacement strategy in real time, and also adjust the memory to a low-power operating mode through dynamic power management.

(3) Optimization of hard disk energy consumption: The energy consumption of the hard disk is related to the speed of the spindle of the hard disk. The faster the spindle rotates, the greater the energy consumption of the hard disk. Therefore, if the task does not specify that a faster hard disk is required, generally choose a medium-speed hard disk. In addition, the hard disk can also be adjusted to a low-power operating mode through dynamic power management. Unlike the power conversion of the processor, the low-power mode of the memory and hard disk is a complete hibernation.

(4) Energy consumption optimization of network equipment: The energy consumption of network equipment is mainly related to the working time of the equipment (switches, routers), so the sleep-wake mechanism can be used in the network communication process to dynamically adjust the network equipment according to the characteristics of the arrival of data packets. condition.

3.1.2. Node-level Energy Consumption Optimization

The cloud task scheduling algorithm is studied from the server node or virtual machine node, so that the resources of the execution process are fully utilized, the resource utilization rate is improved, and the execution energy consumption of the middle node is reduced, so as to realize the energy consumption optimization at the node level.

3.1.3. System-level Energy Consumption Optimization

Starting from the global level of the system, combine software and hardware to optimize energy consumption, balance system performance and energy consumption, meet user needs, and reduce center energy consumption. The methods mainly include resource allocation, resource deployment and integration optimization.

(1) Resource allocation: At present, there are two extreme resource allocation strategies. One is that all server nodes in the system are turned on and waiting for the arrival of computing tasks. This strategy wastes a lot of energy. The server node is turned on and waits for the arrival of computing tasks, which will affect the service performance. The resource allocation strategy based on operations research can achieve a relative balance between system energy consumption and service performance.

(2) Resource deployment: Map virtual machine nodes to server nodes, and use heuristic algorithms to achieve different packing according to different goals, which are divided into dynamic and static.

(3) Integration optimization: Combining resource allocation and resource deployment, deploying virtual machine nodes to a small number of server nodes, shutting down redundant server nodes or switching to a dormant state to integrate and optimize system energy consumption.

4. Experimental Analysis of Energy Consumption Measurement and Management Method Based on Cloud Computing Environment

4.1. Cost-constrained Energy Consumption

In order to compare the performance of energy consumption optimization algorithms based on cost constraints, hereafter we refer to the designed algorithm as the ECOC2 algorithm, which is compared with the HAE algorithm, which uses the requirements of game theory to manage a cloud computing architecture smart energy hub. Cloud service provider prices simulate different time zones, etc. The electricity price and the simulation of the service capacity of the data center are shown in Table 1:

Table 1: Data center electricity price list

Place	A ($)	uj	wj/kw
Asia Pacific	10.57	11	0.14
Europe	8.61	9	0.12
Latin America	7.56	10	0.10
Oceania	9.84	9	0.11
New Zealand	10.26	10	0.13
Africa	13.68	8	0.12

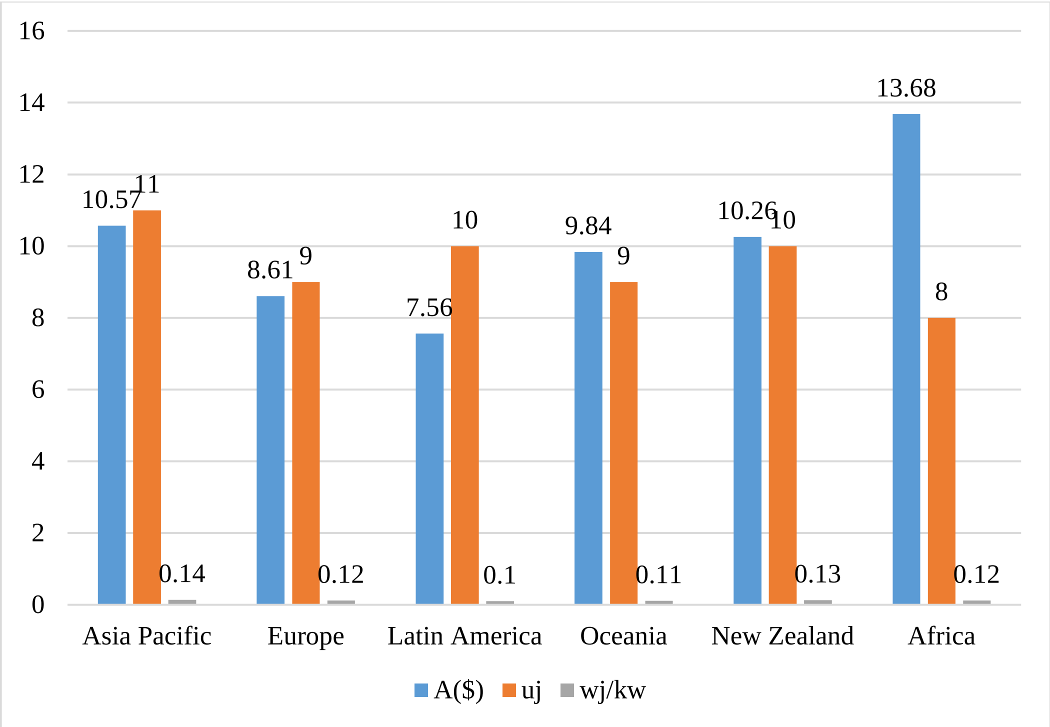

Figure 1: Data center electricity price list

As can be seen from Figure 1, Latin America is the lowest, only 7.56; Africa is the highest, with a full $13.68. At the same time, the service capacity is not proportional. It can be seen that the economic impact is still great.

4.2. Relationship between Constraint Cost and System Energy Consumption and Data Movement

In order to verify the advantages of the simulation algorithm, the experiment is divided into two parts for simulation verification. First, the model is verified, and the algorithm uses Lingo11 to solve the model. For the designed cost-constrained energy consumption optimization algorithm model, observe the relationship between the constraint cost, system energy consumption, and data movement, as shown in Table 2:

Table 2: The relationship between constraint cost and execution energy consumption and data movement

Constraint cost (yuan)	System execution energy consumption (KJ)	Data Movement (GB)
750	24	77
800	22.5	74.5
850	21	70
900	21	67
950	19.5	63.5
1000	19	62.5

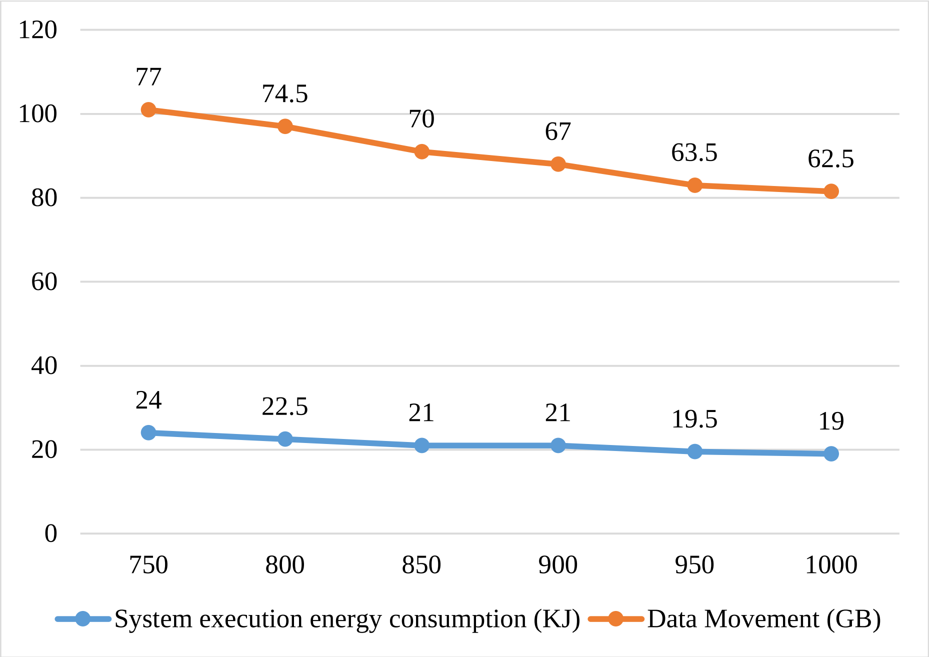

Figure 2: The relationship between constraint cost and execution energy consumption and data movement

Figure 2 specifically shows the relationship between constraint cost and total system energy consumption and system data movement in the process of random task scheduling. The scale of the selected data center is 128, the number of tasks is 100, and the average of the results is obtained by conducting experiments multiple times. It can be seen from the figure that with the gradual increase of the constraint cost in the scheduling process of random tasks, the average total execution energy consumption of the cloud system and the amount of mobile data in the system are both declining, indicating that the scheduling process of tasks is gradually decreasing.

5. Conclusions

As an emerging computing model, cloud computing is being used by more and more users and enterprises. This paper analyzes the architecture of cloud computing, conducts research on cloud resource scheduling from the application attribute layer, scheduling layer, etc., and analyzes the characteristics of resource scheduling. With the continuous popularization of cloud computing technology, it has encountered many challenges in the development process. Among them, the utilization of energy by cloud data centers gradually shows high energy consumption and low utilization rate, which is becoming a bottleneck restricting the development of cloud computing. The problem of high energy consumption in data centers has to be paid attention to, and with the increasing number of real-time tasks in recent years, how to reduce energy consumption as much as possible on the premise of meeting deadlines has become a new topic in the research on energy consumption optimization management in cloud computing platforms. challenge. Resource allocation technology and task scheduling technology are the key technologies of energy consumption optimization management of cloud computing platform, and also the research focus and difficulty of energy consumption optimization management of cloud computing system.

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