Resource Scheduling Optimization Research for Energy Consumption in Cloud Computing

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Abstract. The latest researches results of the energy optimization in cloud computing platform are introduced from the energy resource modeling of cloud computing, the implementation mechanism of energy resource management, and energy resource scheduling optimization algorithm in this paper. The faced serious problem of energy management and optimization in cloud computing platform is analyzed, and the difficulty of energy consumption monitoring and optimization in cloud computing platform is pointed, then the specific aspects of the energy optimization are analyzed in detail, furthermore the whole energy consumption optimization model of cloud computing platform is proposed, and the progress of energy optimization mechanism in the current is summarized from the resource scheduling in the software and voltage control in the hardware, simultaneously the energy optimization algorithms are classified and compared. Finally, a summary and the further research direction are proposed.

Keywords: Cloud computing, energy optimization, resource scheduling, voltage control.

1. Introduction

Cloud computing has become an emerging computing model for consumers and suppliers in the scientific research, industrial and commercial and other fields. Although the concept of cloud has appeared in many forms within a period of time, its roots can be traced back to the mainframe era. However, with the development of virtualization technology, the business trends of reducing total cost of ownership has made it had a greater appeal compared to the first proposed. The cloud's goal is deliver a more economical solution to the entity. On the economic level, its meaning is consumer pay for demand of the resources used, but maximizing the benefits is its ultimate goal forms the provider's point of view. In this sense, the energy optimization problem becomes critical.

Cloud computing becomes quickly a hot topic in academia and industry with its advantages of high scalability and high availability as a new way. With the rapid development of cloud computing, the number and size of the data centers is also rapid growth, and the energy optimization problem becomes more important. On the other hand, the power system of large data centers is very high; electricity cost is also greatly increasing. A recent Internet Data Center reported that the spends on business services and the heat consumption all the world is more than 30 billion U.S. dollars [1], which is more than the spent on the purchase of new hardware devices. In the past few decades, the computing and cooling energy consumption of data centers has increased by 400%, and this figure will continue to increase. The energy optimization of data centers is becoming a hot research.

2. Energy Optimization Techniques Classification in Cloud Computing Environment

Since more and more the cloud data centers are established, cloud provider's operating costs also will increase. The energy optimization of cloud computing will be rapid growth in the future. On the one hand, The reducing hardware prices allow people to buy a more powerful server at a lower cost; on the other hand, the rapid growth in demand for cloud computing will bring more investment in hardware. On the surface, this is a positive development. But the underlying question is that with energy prices rising year by year, the inexpensive infrastructure will bring more energy optimization. If the hardware energy costs exceed the cost of hardware, it will greatly hinder the development of the

IT industry. We can say that Moore's Law led indirectly the computer to high computing speed and high-energy-oriented development, but not necessarily in line with the environmental costs, the hardware costs dropping is not necessarily linked to energy efficiency improving. It is foreseeable that green cloud computing will become the next one of the most challenging research topics.

The focus of the computer system design has been improving system performance, increasing efficient system designs are driveling a steady improvement in performance. This result also coincides with Moore's law for the performance description of computer components. Although performance-per-watt within the rise, the total power consumption of computing systems has never declined. On the contrary, the annual power consumption exponentially increases. If this trend continues, the costs of server will exceed hardware costs within its life cycle, especially for such large-scale computing infrastructure in cloud computing environment, the problem will worsen.

Energy optimization technology of cloud computing is a resource scheduling technology of energy consumption in task communication. Due to the size of the cloud data center continues to expand, the energy consumption of communication of each cloud task is also increasing. Therefore, it is needed to reduce energy consumption of the communication of cloud tasks. By using low-power cloud task scheduling technology, giving full consideration to the energy consumption of cloud communication between tasks, the energy consumption of cloud data centers are reduced effectively.

2.1. Dynamic Voltage Scaling Technology.

The dynamic voltage scaling techniques is mainly used in the adjustable system components of processors and other voltage frequency. According to the increasing convex function of power and frequency, the energy consumption is the lowest when the processor stables at the lowest possible frequency in the same amount of work completed. On the other hand, the application does not always need to be the fastest execution. If we can reduce the processor frequency to meet the performance requirements of the task, you can reduce energy consumption or to achieve the desired battery life. The key issue is to correctly predict the processor workload demands, a reasonable allocation of processor quotas. Through heuristic scheduling, a cluster of parallel tasks binding, the dynamic voltage frequency scaling technology is used to reduce energy consumption clusters. For a time it is no later than the deadline task parallel tasks, and analysis of mission-critical and non-critical tasks, without affecting the entire premise of parallel task completion time. In order to extend the execution time of non-critical tasks to non-critical tasks to perform dynamic voltage scaling, adjust its voltage to reduce total energy consumption of the parallel task. The literature [2] breaks the traditional dynamic voltage scaling is used only on a single physical machine limits, and proposes combining service level agreement in multi-tier web services environment demands dynamically to adjust CPU voltage solution scheme. Its deployment distributes energy management services in three-tier web services environment, and proposes optimization algorithm to optimize the coordination of each settings to maximize the reduction of the overall data center power consumption. The literature [3] proposes energy optimization algorithm based on dynamic voltage adjustment. The algorithm for the prediction task execution time is not accurate, and the predicted execution time is longer than the actual results the computer idle time period is assigned to a new task or adjusted processor voltage to reduce energy consumption.

The first category is the handmade regulation of the dynamic voltage scaling, which is divided into coarse-grained manual adjustment and fine-grained manual adjustment according to the different program analysis of granularity. The coarse adjustment method records the entire program of the execution time of the voltage frequency selected to meet the performance constraints of the lowest voltage, which is attributable to such literature work. Fine-grained structural adjustment program code is studied to determine their execution according to the execution time of each subprogram and execution times frequency. The literature [4] chooses the perform frequency for each loop with the method.

The second category is the dynamic voltage scaling based on compiler analysis. it applies in the systems with increasing the number of frequency and the large-scale structure complex program.

Compiler techniques is used in the voltage and frequency, ,the cost of reducing the time and the frequency setting relies on the method of the program input greatly.

The third category is the adaptive real-time systems, which achieves a completely transparent to users, and ensures the consistency of program analysis. The literature [5] proposes a adaptive algorithm determines the voltage and frequency of execution automatically, which achieves cut the real-time scheduler of MPI (Multi Point Interface) to determine the communication. The literature [6] uses compiler to monitor dynamic access delay in serial code real-time. The Linux provides a time-based interval of the dynamic voltage scaling scheduler to adjust the power based on CPU utilization.

2.2. Dynamic Power Management Technology.

the Many components of cloud computing system owns multiple power modes, such as disk drives, communications card, memory, etc., such member may be called a power management unit. The power management unit can remain in the high-power state in the idle, and respond to a request once the service request arrives immediately. It also can be switched to a low-power sleep mode, activated when a request arrives, and then to provide services. The experimental observation discovers that many of the components of a computer system are idle most of the time. Because power consumption in sleep mode is generally much lower than the operating mode, the system can be a low-power sleep mode by setting the idle power management unit selectively to reduce the power consumption of idle time.

The dynamic power management technology is a widely used low-power design techniques. This technology enables the dynamic configuration system to meet the required performance in the least load. The Power management of the system can run in real-time monitoring power management unit component of the load conditions, which can adjust dynamically the degree of power consumption of the power management unit of the system to meet the requirements under the premise. And the control system is switched into a different operating mode to reduce the idle time of the system so as to achieve the purpose of energy saving.

2.3. Virtualization Technology.

The virtualization technology has been widely used in cloud data centers. It not only becomes more convenient that the virtualization technology is used to manage cloud data centers, but also improves the reliability of data center services and resource utilization. We can put these attributed to the inherent characteristics of virtualization technology. The virtualization technology can improve the resource by achieving multiple virtual machines to share a single physical machine's resources. The physical resources can be a more effective use of the various virtual machines simultaneously in this way and each other with the main reason can rate independently. The virtual migration is another important technique used to improve resource utilization, because migration of virtual machines can integrate load. By integrating the virtual machine load more rationally to minimize the physical machine to a physical machine off or idle adjustment to a low power state. Thereby the energy consumption of the entire data center is reduced. The Real-time virtual machine migration technology provides a more advanced way, under the premise produce little effect on the quality of service for load consolidation, which makes the integration of technology advantage loads more obvious. On the other hand, most of the current virtualization management software, allows the system administrator to set minimum and maximum virtual machine resource allocation, making more rationalization and intelligent resource allocation for different priority applications. The literature [7] proposes the energy management technology and virtualization technology, which has developed a management method virtual power for large-scale data center energy optimization. This method supports virtual machines run independently of their energy consumption control method, and can be reasonably coordination between the different virtualization platforms, power control requests between different virtual machines on the same virtualization platform to achieve overall optimization of energy management. The literature [8] develops a distributed multi-tier energy control systems. The system consists of two subsystems is a host-level and user-level subsystems. The host-level subsystem controls the energy consumption of the entire system from the macro, according to all user requests a reasonable allocation of hardware resources, making the energy consumption of each virtual machine does not exceed the upper limit of its provisions. The user-level subsystem in the virtual machine layer re-allocates the virtual hardware resources so that energy generated by each task does not exceed the upper limit of its provisions.

2.4. Energy optimization in cloud storage.

The data storage is an important component of cloud computing, which is the basis for a variety of cloud computing services, and accounts for a large proportion of the total energy consumption of the cloud. The energy consumption of a number of large-scale data center storage systems accounts for 27%~40% of the energy consumption in the entire data center. The factors on system performance storage devices include disk type, the proportion of disk access request frequency, cache size, and storage of data. The information may also be stored as reduced energy consumption considerations. A typical network application requests usually has a strong locality, we can use and distribute requests the same lines, the concept of popular reference data so that you can gather this part of the data stored in the part of the low-power high-performance disk array, while other storage devices can be in low power state to conserve energy. In storage systems, the literature [9] proposes a skills program for data center storage services. The program will migrate the data of a higher frequency into a group of hard among so hard to adjust to other low-power state, so as to achieve the purpose of reducing the energy consumption of the storage system.

2.5. Resource Scheduling Technology.

The system can calculate the luxury energy consumption to optimize control of the cloud by the way of resource scheduling, thus the total energy consumption is reduced. The cloud virtualization technology is mainly used, cloud computing will be a variety of the integration of the data center computing resources, storage resources, and network resources together to form a pool of resources. Because of the kind of resources, large-scale, between tasks and resources tend to be much relationship, computing tasks that correspond to multiple requests for more available resources, and at the same time their status is in a dynamic process of change, which gives a distributed parallel computing to bring the technical difficulties, and many of the problems in this area a is NP-complete problem, so far no satisfactory solution. The described in detail is in the next chapter.

3. Energy Resource Scheduling Research

Energy consumption is the electrical power consumed during the execution of the application by the number of units of Joule or KWH. With the saving problems causing worldwide concern, the software power optimization technology has become an important means to control the energy consumption of a computer system, and the researchers begin to introduce energy consumption measure from the performance of the scheduling algorithm indicators. Not only can greatly reduce energy consumption values, costs and carbon emissions of a computer system, but also improve the reliability of system operation.

Task scheduling problem that how to set procedures in terms of time and space optimally assigned to a group of processing units in parallel to achieve some optimal results. Computing environment is distributed by task scheduling has been extensive and in-depth study of domestic and foreign scholars. As a system-centric scheduling, time constraints energy optimal scheduling and performance optimization of energy efficient scheduling is a representative study of energy-aware scheduling.

3.1. Time Constraint Scheduling.

The energy-aware scheduling in time constraints is studied in the earliest in the literature [10]. It proposes independent tasks on a single processor technology-based energy optimization dynamic voltage scaling online scheduling algorithm Average Rate heuristic, Optimal Available, Some authors extends to support applications of discrete voltage and gas literature tree algorithm to support the expansion AVR hibernation earlier dynamic voltage scaling and dynamic power management integrated use of technology. The literature [11] considers that the system is overloaded and maximum voltage limits algorithm Optimal Available Task based on Optimal Available algorithm.

The literature [12] proposes scheduling Optimal Available algorithm which also takes into account dormant in Optimal Available Task basis.

The task scheduling time algorithms dependence on energy-aware are focusing on three representative algorithms. As a lay of basic research, the literature [13] proposed algorithm according to the author of this article surname called ZHC algorithm based dynamic voltage scaling technique, which to meet the energy value of its target applications under the premise of minimizing time constraints. First of all, based on the parameters of the earliest start time and latest finish time prioritize tasks, and then ready to time to achieve the task assigned according to the time available for each processor with the tasks, and finally the voltage expanded form ILP into integer linear programming problems.

To make ZHC algorithm meet for data-dependent tasks, the literature [14] introduces ZHC ignored on the basis of communication parameters (0.1, 10), herein referred to as VM algorithm, the algorithm is more sensitive to the cost of communication. But K value is great and the algorithm does not consider the communication energy consumption. To set the value of K, the current task is mapped to a processing unit. If the increase in traffic volume on the side of the average amount of traffic and the K value of the plot, the mapping is changed. The most excellent K value associated with the specific task graph can be determined by experiment many times. To supplement existing task scheduling algorithms rely defects, the literature [15] suggests that the optimal number of processing units for solving algorithms, called LJ algorithm. LJ algorithm and coarse-grained dynamic voltage scaling combined with dynamic power management technology to achieve an effective balance the number of processors and clock frequency, which uses a binary search and linear search method to determine the number of processors. It considers the energy consumption of a typical static work, but its processor range over the number of upper and reduced bounds wide, increasing the time and complexity of the algorithm.

The literature [16] proposes an energy-aware task fusion of cloud data to optimize the energy consumption of the virtual cluster center. The mission integration is a way to maximize the use of cloud resources, which can make better use resources and the rational use of IT services. However, maximizing resource utilization does not mean that energy is used more efficiently. Many studies indicate that the cloud is the energy consumption and resource utilization loose pot together, and even some studies pointed out the need to reduce the utilization of energy consumption. The literature [17] presents a novel and user-application-centric energy-aware virtual machine allocation strategy to minimize energy consumption and meet quality of service assurance. An empirical model is proposed based on minimum average energy consumption and the average execution time. The empirical model is based on high-performance computing performance standards to achieve the target of optimizing distribution of virtual machine, such as minimizing energy consumption and execution time.

3.2. Performance Constraints Optimization.

The energy-aware scheduling of large-scale calculates the value of the general requirements to reduce energy consumption without reducing performance in the case, called energy efficient scheduling isomorphic system. Energy research under Lee heterogeneous systems parallel applications aware scheduling ECS algorithm, which abandoned the dynamic voltage scaling technology innovation lies on Slack management. First of all, according to the parameters b-level descending on the task order, then that order is determined for each task processing unit and perform voltage to determine the relative priority of the principle of RS (relative superiority) value maximum, and finally followed by one for each task execution voltage adjustment processing unit and adjust the principles MCER(make span-conservative energy reduction) technology, namely make span and reduce energy consumption without increasing the principles. RS is calculated taking into account the time and energy consumption parameters, and the precluding is calculated using the energy consumption, the energy consumption of the communication ignores the change, which is not suitable for data-intensive applications.

The literature [18] proposes an energy-aware mechanism that can meet the application requests of cloud data center. It can perceive the energy consumed by data centers effectively. Energy-aware mechanism to self-management operations achieves efficient communication between data centers and users. The literature [19] puts forward a deadline based on reliability, which is resource-aware distributed scheduling system. The scheduling system considers the real network topology and communication model. The distributed scheduling system allows large-scale scientific calculations at low cost as possible. The comparison of energy-saving strategies in cloud computing is as table1.

Table 1 Comparison of energy-saving strategies

Algorithms	Target System	Resources	Optimized target	Saving Strategies
EPMS	Real-Time Systems	CPU	Executed energy	DVFS
EEVGAS	Multiprocessor systems	CPU	Executed energy	DPM
EPAF	Cloud Platform	Equipment	Equipment energy	Open
Passive components	Cloud Platform	Equipment	Equipment energy	Close
Green scheduling	Server system	CPU	Idle energy	SPM
Energy efficient	Cluster system	CPU	Idle energy	DCD

3.3. Resource Scheduling Algorithm.

Nowadays, the resource scheduling base on cloud environment is focused on heuristic scheduling algorithms, which compares a wide range of research and application of algorithms including genetic algorithm, Min-Min algorithm, particle swarm optimization, simulated annealing algorithm and ant colony algorithm.

(1) Min-Min algorithm

The target of Min-Min scheduling algorithm is minimum execution time of task executed [20]. It calculates the estimated completion time of all available resources for each task. And it will be assigned the task of ECT smallest to the corresponding node. Min-Min is the tasks with the earliest meaning will be completed in the fastest speed. The features of Min-Min scheduling algorithm are simple, efficient. Its disadvantage is that the load balancing of system, poor quality of service can not be guaranteed.

(2) Genetic Algorithms

Genetic Algorithm is a simulation mechanism of natural selection and computational models of biological evolution process. It is a way to search for the optimal solution process by simulating the natural evolution, which is originally from Michigan University, USA J Professor Holland first proposed in 1975 [21]. Genetic algorithms mimic natural selection and genetic mechanisms through finding the optimal solution. Genetic algorithms are three basic operators: selection, crossover and mutation. Principles of genetic algorithms are randomly generated by the apprenticeship solution consisting of a population, then by selection, crossover and mutation operations, generate new populations. Each of the groups calculates their individual fitness, chooses according to the size of individual fitness. And according to crossover and mutation probability of crossover and mutation, it generates the next generation of the population. So iterations until you find the optimal solution or reached the maximum number of iterations. Genetic algorithms overcome the general iterative algorithm and a “death cycle” phenomenon is easy to fall into the trap of local minima, so that the problem can not be iterative, and are a global optimization algorithm.

The main advantage of genetic algorithm is: fast random search capabilities; search starting from the population, has the potential parallelism, can be compared to multiple individuals at the same time, there is robust; search using the heuristic evaluation function, the process is simple; scalable, easy to combine with other algorithms. But genetic programming algorithm is more complex, you first need to encode the problem, and then find the optimal solution of the problem to decode the other three operators. There are many parameters, such as the probability of selection, crossover and mutation probability, and these solutions of the merits of the value parameter will have an important impact. The current selection of these parameters are mostly rely on the experience, and not be able to use the network timely feedback, and thus slow search algorithm.

Searching the optimal solution in the global space by Genetic Algorithm is widely used in resource scheduling algorithm. The genetic algorithm has been used in multi-processor systems, homogeneous cluster environments and cloud computing environments.

(3) Simulated annealing algorithm

Simulated annealing algorithm is used in the field of combinatorial optimization, which is based on Monte-Carlo iterative strategy for solving stochastic optimization algorithm. Its starting point is the optimization of the physical annealing process in solids based on a combination of general similarity [22]. Simulated annealing algorithm starting from a higher initial temperature, and it is accompanied by declining temperature parameters, combined with the characteristics of the probability of the sudden jump in the solution space randomly find the global optimal solution of the objective function. Its advantages are: high quality; initial value robustness; simple, universal, easy to implement. But the problem is: As the higher initial temperature, the slower the cooling rate, the lower end temperature, as well as the sample temperature enough times, so the optimization process is longer. The algorithm is used in resource scheduling and task scheduling cluster and cloud computing.

(4) Particle Swarm Optimization

Particle swarm optimization is an evolutionary computation technique. It was first proposed in 1995 by Dr. Eberhart and Dr. kennedy [23]. Particle swarm optimization stems from the behavior of birds of prey. It is a flock of birds foraging behavior through simulation-based group collaboration. The stochastic search algorithm is an iterative optimization algorithm. One of the biggest features of Particle swarm optimization is the memory, and it is simple and easy to achieve without many parameters need to be adjusted compared it with the genetic algorithm. All the particles may be faster convergence to the optimal solution. The problem is the existence of particle swarm optimization for discrete handling is poor, and easy to fall into local optimum.

4. Conclusion and Prospect

In this paper, the technology of resource scheduling optimization of energy consumption in cloud computing are studied deeply and systematically, and the classification of energy optimization technology is summarized. The types of energy consumption resource scheduling in cloud computing are studied deeply. The algorithms of energy consumption optimization are classified and summarized in detail.

But the technology of energy optimization in cloud computing platform is still in the nascent stage, there are still many issues that need further be studied. In the future, the energy consumption and the performance should be optimized simultaneously. An effective energy-saving method not only can reduce energy consumption, but also ensure without sacrificing performance. Because sometimes the performance and the energy can not be optimized simultaneously, such as the server consolidation can reduce the number of physical hosts to save energy, but at the same time affect the performance due to the competition, therefore a dual objective optimization method is needed.

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