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Research on energy consumption model and measuring method under cloud computing environment

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ABSTRACT

With rapid development and gradual maturity of cloud computing technology, cloud computing service on the Internet is also widely applied. However, the issue of high energy efficiency becomes a main issue facing the opening of cloud computing new era. With social development in recent years, virtualization technology and could computing mode also get rapid development due to such features as flexible management, high resource utilization rate and good expandability. Moreover, they can be used to predict wide prospects in future data centers. For a solution to high energy consumption of cloud computing data center, we combine traditional energy consumption management techniques with virtualization technologies, and propose an effective model and measuring method under cloud computing environment. This is an important research orientation.

KEYWORDS

Cloud computing environment; Energy consumption model; Measuring method.

INTRODUCTION

High energy consumption of computer data center is an issue demanding prompt solution. From various data calculated results, it is observed that computer is swallowing considerable energy resources. As predicted, computer energy consumption will keep continuously increasing at a rapid speed in the future decade. Main reasons are described as follows: i) our demands for such large-scale computing mode as could computing will continuously increase, resulting in increased demands for hardware input; and ii) with the development of science and technology, the price of hardware will gradually decrease. Thus, people only need to spend less money while buying strong servers. Superficially, this development is benignant. Through an in-depth analysis, however, we can find that the energy price will keep increasing with continuous development of the society. Thus, costs for energy will remarkably increase. Once hardware energy consumption costs exceed the price of hardware itself, it will block the development of IT industry. Actually, no relatively mature solution is provided through cloud computing to evaluation and reduction of energy consumption. For green computing, we must find an effective model for measurement.

ESTABLISHMENT OF FOUR-LAYER SYSTEM STRUCTURE

Home gateway is the unique interface in embedded intelligent housing system. This system is mainly used to process, save and forward all equipment information about a family. Therefore, there is a home gateway in each family. At the same time, overall functions are all concentrated on home gateway. If new system functions need to be added, all families should be changed accordingly, which will result in certain influence on expansion of the system. Centering on embedded intelligent housing system, therefore, the author organically combines wireless sensor network, Internet of Things, middleware technology, WIFI and 3G network through scientific and reasonable methods, so as to guarantee relatively high control function of the intelligent housing system, optimize and integrate information, promote effective expansion of the system, prevent the phenomenon of information isolated island, comprehensively integrate information of various functions, and realize an intelligent community. From the perspective of system function basis, intelligent housing system totally includes four layers of system structure, as shown in Figure 1 (System Structure of Smart Home).

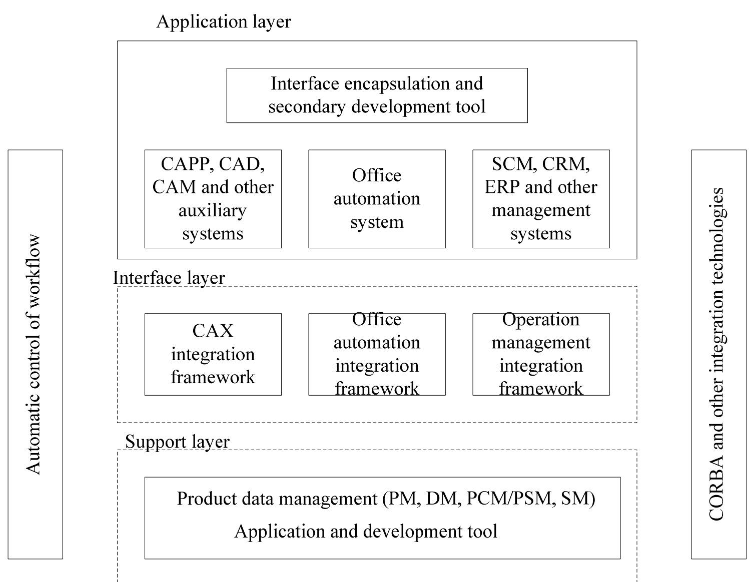

Figure 1 : System Structure of Smart Home

ISSUES FACING ENERGY CONSUMPTION MANAGEMENT AND MEASUREMENT UNDER VIRTUALIZATION CLOUD COMPUTING ENVIRONMENT

Issues Facing Energy Consumption Management

On the one hand, virtualization technology greatly reduces the total possession costs for cloud computing infrastructures, and improves the flexibility of management and operation. This is mainly realized by the flexible pattern of dynamic resources, for instance, removal of virtual machine. However, this will also result in certain expenditures, increasing network communication load and bandwidth requirement for the data centre. Thus, network equipment must have high performance, so as to meet its demand for rapid transfer of load. Additionally, for the optimal load performance, it is necessary for virtualization technology to add some latest processors with hardware virtualization supports. Thus, some decisions that may change the data center are introduced. At the same time, virtual machines with hundreds of key tasks may be operated on one physical host, which proposes higher requirements for the reliability of its hardware and performance.

Thus, costs and performance of the system must be balanced in the design process of virtualized data center. On the other hand, virtualization technology also brings about new challenges for energy consumption management operations. Relevant reasons are described as follows: i) in the virtualization platform, physical resources and virtual resources are not integrated, especially in the case of migration. Thus, it brings about difficulties for clients to realize program level energy consumption management of virtual machine; and ii) inconsistency of the data center will become more serious with frequent renewal of the platform and failure processing and other operations, thus leading to increased isomerism of the platform. Considering isolation and independence demands of virtual machine, however, the countermeasure of meeting changes with constancy is usually adopted. There are two solutions: the one is to use the users' energy consumption management strategies for virtual machine to realize energy consumption management operations of the virtual machine. The disadvantage of this method is that the hardware energy consumption management function of virtual machine can not be used directly. Moreover, direct visit to hardware resources will also influence performance isolation. The other one is to use the hardware energy consumption management mechanism to realize energy consumption management operations of virtual machine. The disadvantage of this method is that energy consumption management strategies at the hardware level will be shared by several client virtual machines. Thus, it is difficult to realize energy consumption management of specific virtual machine[1]. Thus, it can be seen that energy consumption management under cloud computing environment cannot be realized unless combine "hardware" and "software" energy consumption regulation technologies are used in combination.

Issues Facing Energy Consumption Measurement

Issues facing virtual machine energy consumption measurement are mainly represented in two aspects: the first one is that energy consumption of virtual machine can not be directly measured. In real cloud computing system, management and measurement of energy consumption are important issues. Due to internal demands of modern data center for energy consumption management, many new servers begin to provide built-in energy consumption measurement functions for the hardware layer from power consumption distribution units and other aspects. Under the cloud environment, however, energy consumption of virtual machine can not be directly measured from hardware. The second one is the challenge facing the accuracy of energy consumption model. Energy consumption of virtual machine is determined by the evaluation on CPU utilization of the current virtual machine. This is a pattern frequently used in the virtualization cloud computing data center. Its utilization can not make real and accurate response to the use conditions of CPU. Therefore, power consumption of CPU can not be really reflected. Thus, it can be seen that simple virtual machine energy consumption model has limitations.

RESEARCH PROGRESS OF CLOUD COMPUTING MEASUREMENT

Up to now, considerable researches are made on the measurement of cloud computing platforms at home and abroad, for instance, CloudSta-tus authorized to the third party Hyperic, CloudWatch of the cloud computing platform supplier Amazon, NetWiser project of Microsoft Research Institute, the project of "measurement science of cloud computing" funded by NIST, and measurement of Amazon EC2 and Google GAE by the academic circle[2]. Through these researches, it can be observed that cloud computing measurement technology and cloud computing monitoring system structure are two main research orientations of cloud computing measurement. The research on cloud computing measurement technology mainly centers on specific feature measurement and analysis method of cloud computing platform, mainly including the performance, flow, topology and reliability of the platform (TABLE 1 shows a comparison of various cloud computing platform detection systems). As a basis design of cloud computing platform, the cloud computing monitoring system structure can effectively realize large-scale data collection, storage, processing, display and other requirements. These researches provide references for us to solve the issue of high energy consumption of cloud computing.

TABLE 1 : Comparison of Various Cloud Computing Platform Detection Systems

Name of System	System Structure	Date Collection	Data Analysis	Applicable Platform Type
Monlytics	Mixed structure	Agency	Local analysis and concentrated analysis	IaaS
CloudBeacon	Centralized	No agency	Concentrated analysis	IaaS
Dapper	BigTable	Agency	Local sub-sampling and MapReduce	PaaS
CloudBeacon	Centralized	No agency	Concentrated analysis	IaaS

ESTABLISHMENT OF ENERGY CONSUMPTION MODEL UNDER CLOUD COMPUTING ENVIRONMENT

There are two types of energy consumption model: energy consumption prediction model based on hardware performance counter and energy consumption evaluation model based on system function unit. Most energy consumption models belong to the first type, as the accuracy of model is mainly considered. It can predict energy consumption of the system according to key system events collected by the hardware performance counter, so as to realize the optimization of energy consumption. Under cloud computing environment, energy consumption model can be established from two perspectives: dynamic energy consumption modeling and static energy consumption modeling. Dynamic energy consumption modeling mainly refers to energy consumption modeling of virtualized dynamic application scenarios (such as online migration and server integration). In static energy consumption modeling, energy consumption of functional units (such as CPU, internal memory, disc and other subcomponents of the system) of single virtual machine system is mainly measured[3]. The establishment model is shown in Figure 2.

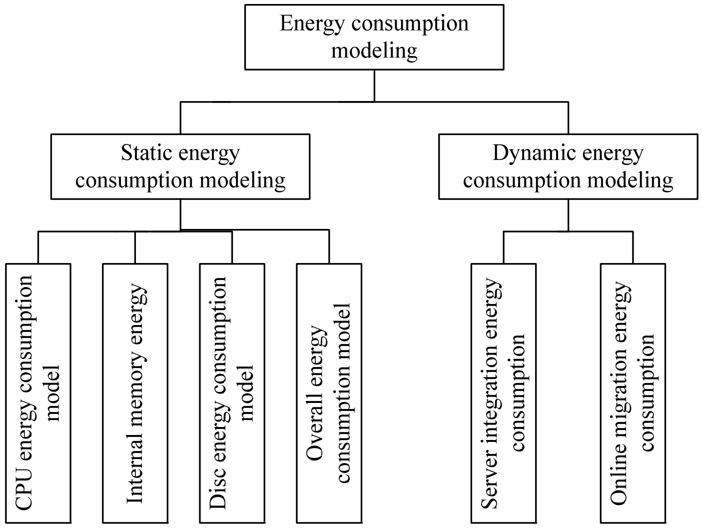

Figure 2 : Classification of Energy Consumption Modeling Approaches of Virtualization Cloud Computing Platform

In the establishment of this model, we mainly consider energy and efficiency, so as to optimize the cloud system. The computer efficiency is measured by FLOPS (floating point operation per second) or MIPS (million instructions per second). Watt is mainly used to measure electric energy absorbed or generated by the equipment in unit time. Thus, FLOPS/Watt represents the ratio between calculation times and energy consumption of computer within certain time. It can be used to measure the energy efficiency of computer and represent the times of floating-point calculation under unit energy consumption[4]. FLOPS/Watt computing method can be deduced as follows:

$$FLOPS / Watt = (Operations / \sec ond) \ per \ Watt = Operations / Joule$$

Each computer in the cloud system has rated power and CPU frequency. In operating environment, the utilization of CPU is closely correlated with the algorithm of operations. With changes in the size of task load, its frequency will also have dynamic regulation. At the same time, its power will change as well. Thus, it can be observed that calculation of energy consumption should be based on measured values.

ENERGY CONSUMPTION MEASURING METHOD UNDER CLOUD COMPUTING ENVIRONMENT

The measurement of energy efficiency can be divided into L(T) measurement and E(T) measurement. With respect to the former, its result is obtained by accumulation of fc(t) and wc(t) on time T (Formula 1). Frequency scaling algorithm and size of task load of the system has a decisive effect on f(t). $w_c(t)$ depends on the algorithm itself. While executing I/O intensive algorithm, CPU needs to wait for I/O. therefore, its utilization is not high at normal cases[5]. In general, we can obtain L(T) by means of measurement although function expressions of $f_c(t)$ and $w_c(t)$ can not be accurately found. In the measurement process of E(T), actual power lies in dynamic changes. Therefore, we still calculate the value of E(T)[6] by collecting once real-time power of each node with an interval of △t (as shown in Formula 2).

$$L(T) = \sum_{i=1}^{N} \int^{T} f_i(t)\omega_i(t)dt \approx \sum_{i=1}^{N} \sum_{j=1}^{M} f_i(\Delta t \cdot j)\omega_i(\Delta t \cdot j)\Delta t \qquad \textbf{(1)}$$

$$E(T) = \sum_{i=1}^{N} \int^{T} p_i(t)dt \approx \sum_{i=1}^{N} \sum_{j=1}^{M} p_i(\Delta t \cdot j)\Delta t \qquad \textbf{(2)}$$

However, there are also some deficiencies for the two measurement methods, mainly representing in three aspects: i) the power measurement range of electricity meter is limited; ii) it is impossible for electricity meter to distinguish energy consumption of each computer; and iii) it is difficult for electricity meter to realize synchronization, control and summarization of data[7]. Thus, it can be seen that the measurement of energy consumption under cloud computing environment still needs extra equipment. We can remarkably simplify the measurement of energy efficiency[8] if we can calculate real-time power according to frequency and utilization of CPU and calculate energy consumption on this basis.

ELASTIC CALCULATION MODEL

For terminal users, how service is provided is not important. Mobile users need a mobile cloud application store. Different from other applications directly downloaded into mobile devices, however, these applications can be operated on mobile terminals or cloud platforms. According to dynamic changes of computing environment, the application can be migrated between mobile devices and cloud. Users can use browsers to perform (visit) these applications. Such application is called elastic application. The elastic framework structure is shown in Figure 3.

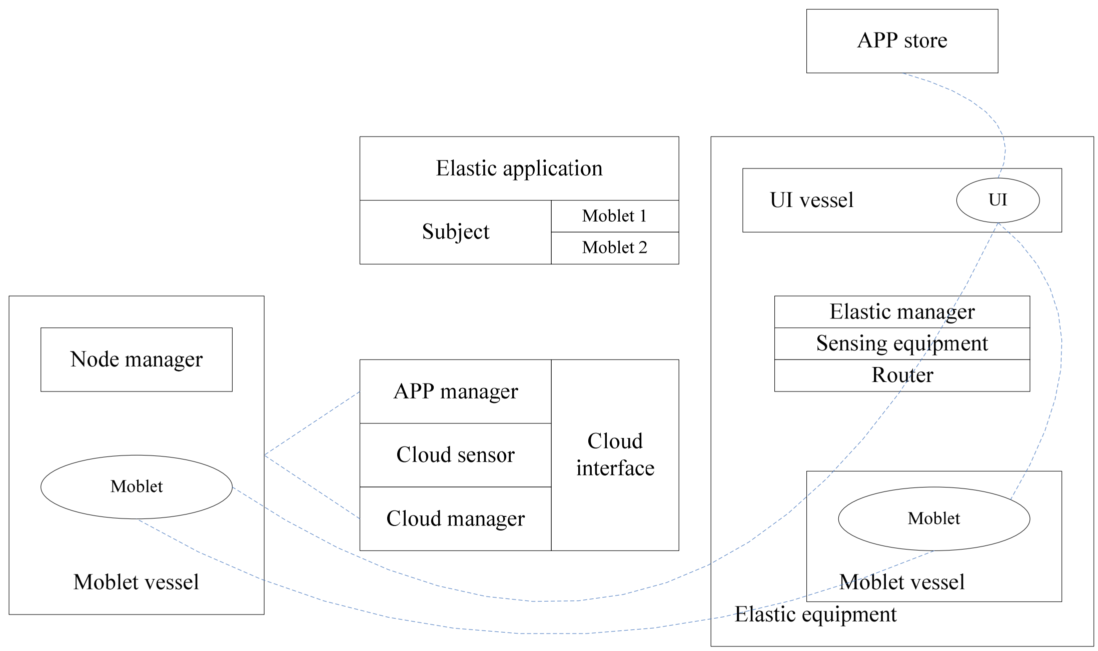

Figure 3 : Elastic Framework Structure

CONCLUSION

The research on energy consumption model and measuring method under cloud computing environment is still in the preliminary stage. The objective of the establishment of energy consumption model is to realize better optimization of energy consumption. Through the research and analysis in this paper, we draw a conclusion as follows: energy consumption of the cloud calculating system should not be separately surveyed. Arithmetic speed is the most effective constraint. Therefore, low power will lead to a reduced arithmetic speed. In the cloud computing measurement system, it is impossible for us to measure real-time power of each node. Therefore, the computational formula is proposed for relations between CPU operating state and computer power. Thus, the power of CPU can be calculated through frequency and utilization of CPU. This method is simple and easy to be operated. Moreover, it has relatively high accuracy. Generally speaking, there is great space for improvement of energy consumption model and measurement under cloud computing environment, and we need to make more researches on the two items.

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