International Journal of Engineering Education Vol. 30, No. 3, pp. 596–602, 2014
Printed in Great Britain

0949-149X/91 $3.00+0.00

Applying Cloud Computing Technologies to Upgrade the Resource Configuration of Laboratory Course: The Case of Quality Engineering Education Platform*

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The cloud computing (CC) is an important emerging information technology for the information resource optimizing. In this case study, we applied CC technology in the quality engineering education platform design process, and investigated the effects of CC on saving resources, optimizing process, and education innovations. First, we described the designing and applying process of CC education platform. Then, we designed a measuring software aided method on evaluating quality of CC application. Finally, a standard was applied to evaluate university laboratory's management ability on CC platform. By applying cloud computing technology in quality engineering courses, and providing evaluating method, this research has both teaching and research implications for engineering education, like teaching students how to management cloud computing platform with "learn by doing" model.

Keywords: cloud computing technology; laboratory; resource configuration; management evaluation

1. Introduction

Cloud computing is an important emerging IT service model for information resource optimizing, which can be defined as "an information technology service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location" [1]. Compared with other IT service model, CC has several key characteristics, such as: 1) providing immediate access to hardware resources, 2) lowering the cost of entry for smaller organizations trying to benefit from compute-intensive analytics, and 3) making it easier for organizations to scale their service, like managing computing resources through software, and deploying them very fast as new requirement arises. Considering the key advantages of cloud computing, in the world wide, more and more organizations and researchers have tried to apply this service to upgrade their resource configuration and get business value, from the aspects of resource utilization, virtualized physical resources, and dynamic scalability of resources [2, 3].

Although the numerous business applications in enterprises, rare studies had focused on the applications of cloud computing in the education (e.g. laboratory management, teaching method of engineering courses), and investigate how this emerging technology/service benefit the engineering education. For a long time, universities' laboratory faced a huge problem of wasting resources, such as servers, printers, terminals, fax machines. In the past, it is hardly to be solved, as these resources belong to different units, have different management principles, and there are different technology standard [4–9]. With the emergence of cloud computing, we may have the possible solutions on the above problems, by setting cloud computing hardware in the university's lab, designing effective management principles, and improving the using effectiveness.

From the perspective of engineering education, the application of cloud computing in university laboratory includes both IT development and management issue, as it is a typically systematic process which involves upgrading resource configuration of hardware, and managing computing resource through software [10]. Thus, applying cloud computing in engineering education has several key

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* Accepted 20 July 2013.

advantages for universities: 1) optimizing the resource configuration of laboratory equipment, 2) improving management skills and laboratory running cost, and 3) ''learn-by-doing'': enhancing the engineering students' knowledge on developing and managing emerging technologies by encouraging them to join in the university clouding computing application project.

In this study, we conducted a case study on the educational application of cloud computing in university laboratory, at Capital University of Economics and Business (CUEB), a university in Beijing area of China. The research questions are: *How to set hardware and software to optimize resource configuration of laboratory courses? How to evaluate the management levels of cloud computing platforms? How to teach students in quality engineering courses with support of innovative emerging technologies?* For answering these questions, we focused on the key process of its application in education, including: 1) hardware setting process of platform, 2) managing and optimizing process of resource configurations through software, 3) evaluating process of management capacity of platform, with the reference of the module of Capability Maturity Model for Software (CMM), and 4) teaching process on improving students' abilities on technology development and management skills.

2. Importance of cloud computing on energy saving: our previous work

Considering the importance of cloud computing, in 2012, Capital University of Economics and Business (CUEB) carried out a research project to investigate the energy saving situations in different industries, and find out if cloud computing can improve the effectiveness. We conducted a survey in joint venture of 500 world strong enterprises in China, Chinese famous research universities and institutions, and some virtual organizations [11, 12]. The results of our previous studies showed that the resource utilization of these institutions was very low. For most respondents, the resource utilization is less than 20%, even 0% for some respondents. Except low utilization, there are some other problems like imbalance of user structure and time distributions. We also conducted the survey and interviews on applications of cloud computing and its effectiveness. In the results, we found the applications of cloud computing are still very rare in these institutions, which stand about 25%. The results are illustrated in Fig. 1.

Based on our previous research, we found there is still a big problem for saving energy for different industries and institutions in China. And there is a huge gap between potential usefulness of cloud

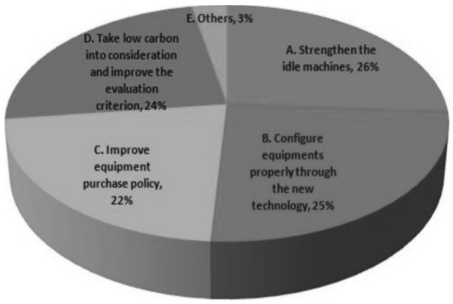

Fig. 1. The Situation of Applying Cloud Computing in Chinese Institutions (25%).

computing and institutional actual adoptions. There are several reasons for low acceptance level of cloud computing service in China, e.g., different hardware and software standards, different management principles. And another very critical reason is that there are rare institutions have successful experience on applying this emerging technology. In China, most of institutions need knowledge of best practice, and engineering students also need to learn how to adopt and apply cloud computing. Thus, we tried to firstly establish a cloud computing platform in Beijing area, and share our experience on applying cloud computing in university and engineering education.

3. Case study: cloud computing platform in university's lab

Capital University of Economics and Business (CUEB) is a key university which belongs to Beijing municipal government. Recent years, CUEB emphasized engineering education, and strengthened the investment on developing the laboratory center of engineering education. In this study, we focused on the case with the laboratory center of information school (IS), which is one of biggest lab in CUEB. Currently, IS lab have installed numerous servers, experiment apparatuses, and several researching and teaching information systems. With the rapid of development of laboratory, there are several problems occurred in running and managing process, such as:

1. Low utilization of hardware: Based on analyzing the data in logs of servers at several months, we found there is a significant imbalance of resource configuration at two levels, i.e., server quantity and using time. On the one hand, within the same timeframe, more and more servers were working at same time, but CPU utilization became lower (i.e., less than 15%), that means most of core resources of servers are in idle situation. On the other hand, the energy waste and electronic power

consumption is higher, as more than half power were wasted by air-condition. Even for power used within IT equipments, CPU just took 30% power, and other 70% was wasted by free waiting sources (e.g., fans, memory, disks).
2. Low effectiveness of management: Based on the observations, there are several wastes are due to conflict between IT platforms and lab or university management principles, e.g., the information security and working time.

Considering most electric power comes from fossil fuel product in China, more power consumption means more carbon emission [4]. For reducing carbon emission in laboratory and improving effectiveness of management, we conducted a case experiment on applying cloud computing in laboratory. We had invited several engineering students to join in each part of project (e.g., platform setting, testing, and evaluation), and they were awarded with teaching points in quality engineering courses.

4. Experiment process in the case

4.1 Experiment environment

In this experiment, we selected 6 servers which had been installed in the information school's lab. The working environment of servers is campus intranet, where adopted Giga-byt Ethernet switch. The descriptions of servers for experiment are illustrated in Table 1.

4.2 Experiment objective and design process

In this experiment, we had set an objective for participants, as "How can we improve the utilization of each server and reduce the actual using numbers of servers, by applying cloud computing platform?" From the universities perspective, we want try to use the least numbers of servers to accomplish same workload of 6 original servers.

We had designed experiment process, which includes 4 steps:

1. Testing original servers' utilization: A monitoring software (i.e., Cacti) was adopted to test the utilization of each original server.
2. Simulating and optimizing the number of servers: Based on the analysis of real running data and simulating the mission requirement (e.g., CPU, efficiency). We tried to calculate what the optimal number of servers with highest effectiveness is. The result shows that only 2 servers working with cloud computing platform could take on the same work by 6 servers without cloud computing platform.
3. Setting cloud computing platform.
4. Analyzing and measuring the service condition of cloud computing.

4.3 Procedure of setting CC

In this experiment 2, we used 2 physical servers (A and B), to set up platform. With virtualization technology, these 2 servers formed a cluster and set up 6 virtual machines within the cluster environment. Then, the 6 previous application programs were installed and run in each virtual machines seperately. The detailed procedure is:

1. Installing VMwarevSphere system components, which includes 3 basic components, i.e., ESXi (virtualization tier), vCenter Server (management tier), and vSphere Client (interface layer).
2. Setting up data center and cluster.
3. Adding mainframe and setting up virtual machines: 2 mainframes were added in the above cluster and they set up 6 virtual machines distributed with proper physical resource of CPU, internal memory and disk.

For the managing cloud computing platform in VMwarevSphere system, there are always three options on setting its location:

1. Option 1: occupying an individual server.
2. Option 2: occupying a whole PC.
3. Option 3: installing the above system in a virtual machine without occupying any special server.

For achieving the experiment objective and managing more easily, we adopted a server to install vCenter Server components as the cloud computing platform (Option 1). The detailed location and setting process are illustrated in Fig. 2.

Table 1. Server for Experiment

No.	Server name	Type	Number of CPU Core	Application
1	OA testing server - 1	HP ML 350 G5	4	School OA system
2	Application testing server - 2	HP DL 380 G5	4	Multimedia application
3	Linux testing server - 3	HP ML 370 G4	2	Teaching system for Linux case
4	FTP testing server - 4	HP DL 580 G5	16	School resource download
5	DB testing server - 5	HP DL380 G6	8	SQL Server database
6	WEB testing server - 6	HP DL 380 G5	4	Innovation platform for students

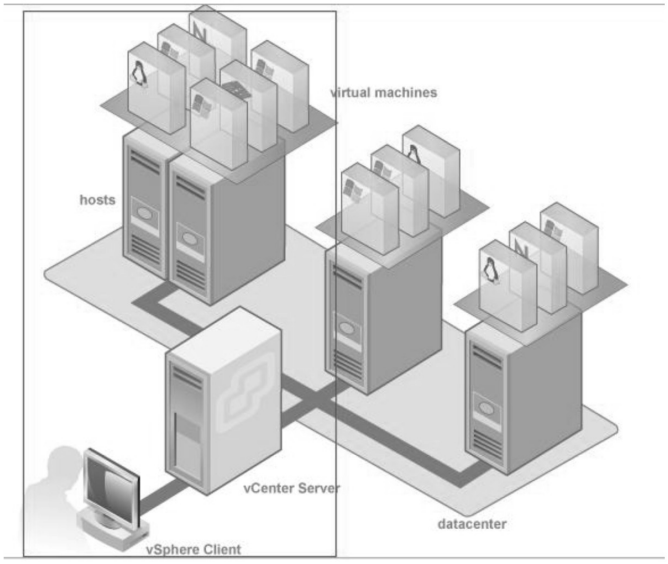

Fig. 2. Cloud Computing Platform.

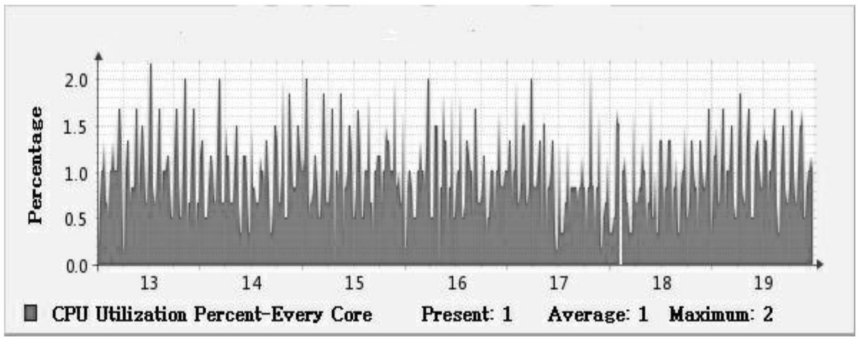

Fig. 3. CPU utilization Rate of Linux Testing Server.

5. Testing effectiveness with Cacti software

In the testing process of experiment, we adopted the software called Cacti. Cacti is a well adopted, graphic analyzing tool for web traffic monitoring. This software was developed with PHP, MySQL, SNMP and RRDtool. For example, Cacti collects data with SNMPGET and makes graphic with RRDtool.

During the testing process, we used Cacti software in 3 places, which are data acquisition, data statistics, and estimating the number of servers should be used.

5.1 Data acquisition and monitoring

Cacti software can monitor the mainframe system working condition and give real-time graphics including the load condition, CPU condition, RAM condition, net traffic, hard disk working condition, system process, the system database serving state and so on. We used Linux testing

Table 2. CPU Utilization Rate before Using Cloud Computing Platform

Server	Type	Average CPU Utilization Rate (%)	Maximum CPU Utilization Rate (%)
OA testing server - 1	HP ML 350 G5	7	17
Application testing server - 2	HP DL 380 G5	17	82
Linux testing server - 3	HP ML 370 G4	1	2
FTP testing server - 4	HP DL 580 G5	8	17
DB testing server - 5	HPDL380 G6	0	0
WET testing server - 6	HP DL 380 G5	1	35

Table 3. CPU Utilization Rate after Using Cloud Computing Platform

Server	IP Address	Average CPU Utilization Rate (%)	Maximum CPU Utilization Rate (%)
Server A	219.224.78.22	36.936	44.89
Server B	219.224.78.3	5.143	14.24

server as the example, the detailed utilization rate are illustrated in Fig. 3.

5.2 Data statistics

Except the function of monitoring, the software can also implement data statistics by given constrains (e.g., special time and condition). The comparison of CPU utilization rate between before and after applying cloud computing platform is illustrated in Table 2 and 3.

5.3 Process of estimating optimal number of servers

The process of estimating optimal number of servers should be used is a complex process where above data should be analyzed and simulated several times. In the decision process, the workloads of original 6 servers were stand by smaller servers. We simulated the servers' amount of cloud computing platforms from 2 to 5 servers repeatedly. In the above process, the monitoring and statistical software have contributed significantly. We spent several weeks in the quality engineering courses on teaching students how to use this software, and they can learn by doing in the actual experiment.

6. Evaluation on the management ability of cloud computing platform in the university lab: the perspective of CMM

In the end of experiment, we also tried to evaluate the management ability of cloud computing platform in CUEB Lab. Considering the cloud computing is an emerging IT service, its application also has several risks, like technology risk and management risk. According to the perspective of IT risks, we could take principles and evaluate the management ability.

Software Capability Maturity Model (SW-CMM) is a well adopted standard which was developed by software engineering institute (SEI) of Carnegie Mellon University [13, 14]. CMM standard emphasizes the enhancement and evaluation of management and engineering capacity of software development within organizations. As shown in Fig. 3, CMM has five different levels for maturity: initial level, repeatable level, defined level, managed level, and optimizing level [15].

In this study, we took the principles and contents of CMM modules, and tried to design a management maturity model for cloud computing applica-

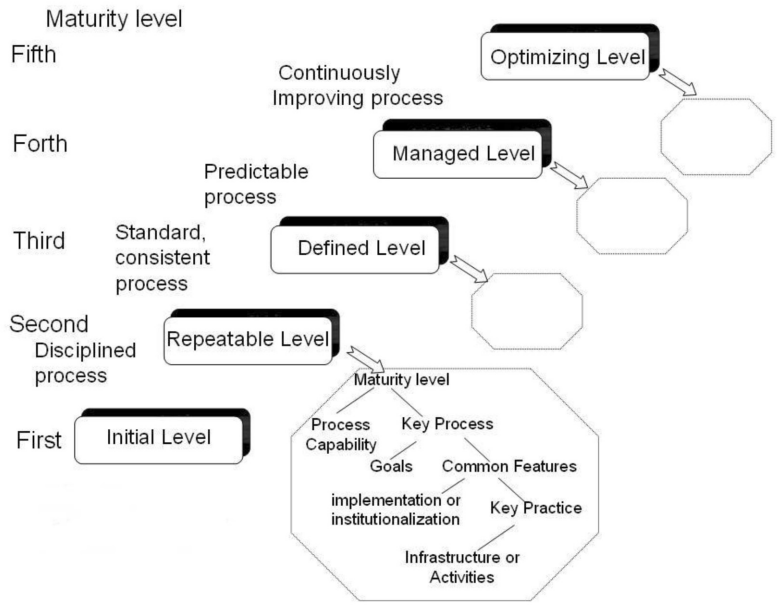

Fig. 4. CMM Modules.

Table 4. Five Levels of Cloud Computing Management Maturity Model (CC-MMM)

Level	Meaning
Initial	No management, extensive random.
Repeatable	Standard management: planning, monitoring, recording, process repeatable.
Defined	Consistency of management templates: consistency in various CC management projects.
Managed	Measuring, testing and quantitative analysis in the management process.
Optimizing	Functions of risk prevention and the optimizing in cloud computing management.

tion. The 5 levels of cloud computing management maturity are illustrated in Table 4.

We asked students to evaluate the cloud computing application and management maturity in university lab with the new standard. Most of the participants responded that after experiment, their capacity of managing cloud computing platform in university lab improved very much (from initial to managed level).

7. Conclusion

Based on the above process on setting hardware platform, testing software, and evaluating management level, we found that application of cloud computing can significantly and effectively upgrade the resource configuration of university lab, i.e., increasing resource utilization rate, cutting down the running cost, saving the energy, and improving risk management as well as ability maturity.

In the research project, we also applied cloud computing experiment in quality engineering courses for long time. Engineering students in information school not only learned the concept of cloud computing, but also ''learn by doing'' by joining the experiment in each processes. This case study may have both contributions on teaching and research in cloud computing application in university's engineering education.

Acknowledgments—This work was supported by the National Natural Science Foundation of China (No. 71201155), Science Foundation of Ministry of Education of China (Grant No. 13YJA630073), and Seed Foundation of Tianjin University; Beijing Philosophical Social Science Project (No. 11JGB077); Beijing Municipal Education Commission Foundation of China (No. KM201110038002); And the Beijing Natural Science Foundation project (No. 9122003).

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