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Research on the Virtualization Technology in Cloud Computing Environment

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Abstract. Virtualization and Cloud computing are two popular research directions in recent times. Today, Virtualization is being used by a growing number of organizations to reduce power consumption, Server Consolidation, Testing and Development, Dynamic Load Balancing and Disaster Recovery, Virtual Desktops and Improved System Reliability and Security. Virtualization also provides high availability for critical applications, and streamlines application deployment and migrations. Through cloud computing, Information Technology resources can be delivered as services over the Internet to the end user. *Virtualization* is one of such important core technologies of cloud computing. In this paper, we present a detailed review on virtualization. Furthermore, three technologies for x86 CPU virtualization and the architecture of Xen are introduced. Specifically, we propose an architecture of the cloud computing platform based on virtualization. Finally, we discuss the performance evaluation of server virtualization in saving cost, time and energy consumption.

1 Introduction

According to Wikipedia, *Virtualization* refers to the act of creating a virtual version of something, including but not limited to a virtual computer hardware platform, operating system, storage device, or computer network resources[1].Virtualization includes server virtualization, network virtualization, storage virtualization, application virtualization and desktop virtualization. In recent times, *Virtualization* techniques has recorded many advantages such as reducing costs and power, simplified administration and deployment, improving mobile applications, enabling cross platform support, etc [2]. Cloud computing is a style of computing in which dynamically scalable and virtualized resources are provided as a service over the Internet. It is the integration of multiple technologies which includes distributed computing, utility computing, parallel computing, virtualization, etc. It can be classified as public, private or hybrid. Typical cloud computing environments have a three-tier service, including SAAS, PAAS and IAAS. At present, virtualization is one of the most important core technologies of cloud computing. If the virtualization technology is applied to cloud computing, more and more enterprises can gain the benefits in saving management costs, hardware costs and power consumption costs. Recently, cloud computing services based on virtualization have been widely used in many fields, such as data centres', education, finance and government.

A key question about virtualization and cloud computing is: How to build the architecture of cloud computing platform based on virtualization, and how to give the evaluation of the impact of server virtualization on the performance of a cloud network. One possible way to solve this problem is to build a cloud computing platform with the existing virtualization products on the market. Furthermore, the evaluation results are given on the performance of server virtualization by comparison to several application examples.

In this paper, we focus on building the cloud computing platform based on the virtualization products. We will present the architecture of the cloud computing platform and later discuss the evaluation of the impact of server virtualization on the performance of a cloud network. The remainder of this paper is organized as follows: in Section 2, we introduce a thorough review on the virtualization technology, especially the architecture of Xen. Section 3, discusses how to apply virtualization to cloud computing. In Section 4, the performance evaluation of cloud network platform based on server virtualization is presented. Finally, the conclusion is given in section 5.

2 Review on Virtualization

Virtualization originated in the IBM project in 1964, but it development was very slow. After commercial virtualization software on the X86 platform was introduced by VMware Inc in 1999, it came into the rapid development period. At present, with AMD, Intel and Microsoft joining, the development has entered a stage of outbreak.

The architecture of x86 virtualization

With the architecture of x86 virtualization, a layer called Hypervisoror Virtual Machine Monitor (VMM) is added between the hardware and operating system. There are two architecture type of VMM as shown in figure 1. Type I is a hypervisor architecture which installs the virtualization layer directly on a clean x86-based system. Type II is the hosted architecture which installs and runs the virtualization layer as an application on top of an operating system. At present, Type I is used in the mainstream enterprise-class virtualization products, including Oracle VM, VMware ESX Server, Microsoft Hyper-V and Citrix XenServer.

Three techniques for x86 virtualization with type I VMM

With x86 architecture, each VMM needs to implement virtualization with CPU virtualization, memory virtualization and device and I/O Virtualization. The x86 architecture offers four levels of privilege known as Ring 0, 1, 2 and 3 to operating systems and applications to manage access to the computer hardware. The x86 architecture requires virtualized instructions set so that the guest OS on top of the VMM can have access to the computer hardware resources, but there are some sensitive instructions which can't effectively be virtualized because they have difficulty in trapping. In order to resolve this problem, three techniques exist now in implementing virtualization in the CPU on the x86 architecture [3, 4, 5].

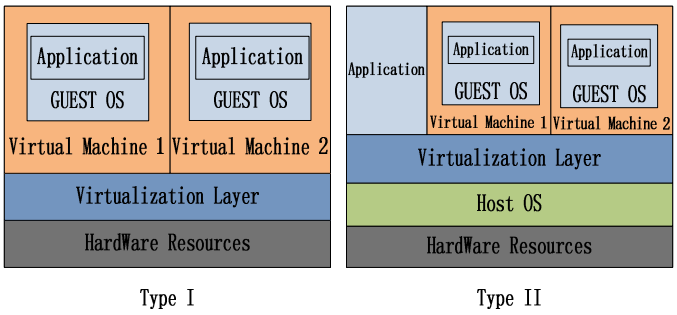

Fig. 1 Two types architectures of VMM

Full virtualization using binary translation

In a fully virtualized environment, hypervisor runs on the bare hardware, acting as the host operating system, but the virtual machines managed by hypervisor runs the guest OS. The hypervisor provides full virtualization through a combination of binary translation and direct execution. Binary translation makes sensitive instructions virtualized through translating a small set of the processor instructions. Other instructions can be directly executed on the virtual machines. The guest OS can't distinguish itself from being installed on the physical machine or on the hypervisor.

The full virtualization offers the advantages of simplified migration and portability. It provides the best isolation and security for virtual machines. The unmodified guest OS instance can run on virtualized or native hardware. Its main drawback is low performance by using binary translation work. There are many full virtualization products, such as Microsoft Virtual Server.

OS assisted virtualization or paravirtualization

This approach requires that the hypervisor manage each virtual machine and let them be independent of each other. This approach adds a specific virtual instruction which is named Hyper calls in the guest operating system and adds the corresponding call interface in the hypervisor, through which instructions can be directly invoked by the hypervisor layer. The paravirtualization offers the advantages of high performance and lower virtualization overhead. Its drawback is poor compatibility and portability because of the need to modify the paravirtualized virtual machine and operating systems. There are many examples of paravirtualization, such as Xenserver.

Hardware assisted virtualization

By extending and upgrading the CPU instruction set and the processor operating mode, complete virtual operating system can directly call to the hardware resources. Typical technologies are Intel VT and AMD-V.

The architecture of Xen

Xen is an open-source type-I hypervisor, supporting paravirtualization and full virtualization. It consists of three most basic components as shown in figure 2, including Xen Hypervisor, Domain 0 and DomainU[6]. Xen Hypervisor runs directly on top of the hardware, but also controls the execution of virtual machines as they share the common processing environment. The domain 0, a modified Linux kernel, contains drivers for the hardware, as well as the tools tack to control VMs. It has rights to access physical I/O resources and can interact with the other virtual machines. The Domain 0 must run before any other virtual machines can be started. The DomainU is a client operating system running on Xen hypervisor. It can't directly access the hardware resources. However, a plurality of DomainU can run independently.

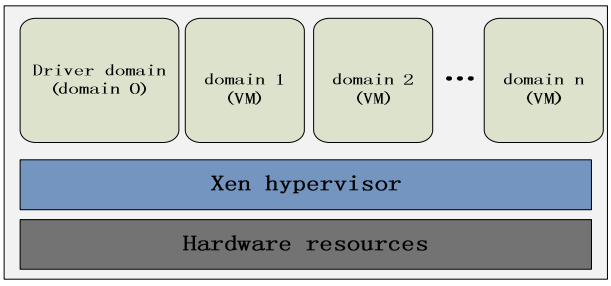

Fig. 2 The architecture of Xen

In summary, there is no open standard to define and manage virtualization. At present, each company develops their own virtualization solutions. However, many people think new hardware assisted virtualization is very promising in the future because it will diminish the need of paravirtualization and full virtualization.

3. Applying Virtualization to Cloud Computing

Cloud computing is the delivery of computing as a service rather than as a product, whereby shared resources, software, and information are provided to computers and other devices as a utility over a network[7]. A well-designed cloud computing platform should have the characteristics of dynamic scalability, on-demand division of resources, high availability, high performance and load

balancing. Cloud computing involves a lot of research themes including power management, stability, virtualization and scalability, etc. The virtualization technology is just one of several important technologies in cloud computing. Through virtualization, Cloud computing manages the hardware in a distributed shared resource pool. All IT resources through virtualization can improve resource utilization and allocated dynamically.

At present, the products of VMware, vCloud and Xen Cloud Platform is generally used to build the cloud platform. The Xen Cloud Platform is an enterprise-ready sever virtualization and cloud computing platform based on the powerful Xen hypervisor. Though Xen Cloud Platform, users can access VM consoles, view VM properties, perform power operations, manage VM snapshots, and migrate VMs between server hosts in a pool. The VMware vCloud is a virtual VMware's cloud infrastructure tools. Here we demonstrate how to build a cloud computing infrastructure using the VMware vCloud tools.

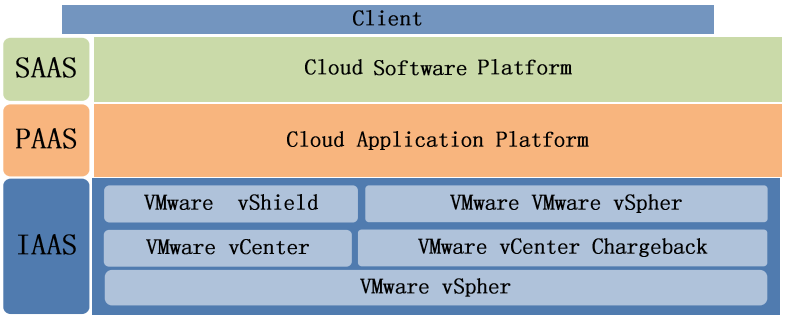

Fig. 3 The three-tier cloud computing platform based on the VMware vCloud tools.

As shown in figure 3, the cloud computing platform solution also has three-tier structure. The SAAS layer is mainly for terminal applications virtualization. The PAAS layer provides cloud application platform-it allows developers to create portable cloud applications. The IAAS layer is a cloud-based infrastructure and is built by the VMware vCloud[8, 9]. The VMware vCloud has five main components, which are VMware vCloud Director, VMware vSphere, VMware vShield, VMware vCenter Chargeback and VMware vCenter. They are the core of computing services infrastructure. The VMware vCloud Director component can allow customers integrate infrastructure resources into virtual data centre resource pool, and allow them to on-demand consumption of these resources. It can also use technologies such as linked clones and snapshots to dramatically speed up access to the infrastructure. The VMware vShield component provides network security services including Layer 2 isolation, NAT, firewall, DHCP, and VPN. It supports virtualization protection for virtual data centres and cloud computing environments, and it also allows the user to increase application and data security. The VMware vCenter component provides a central control point to monitor every aspect of virtual infrastructure and achieve daily automate tasks. It also manages large data centre with scalability. The VMware vCenter Chargeback component provides resource metering and cost models. It is mainly to help users get accurate cost estimates and analysis of cloud computing services. It also can help users better understand what the cost of resources is, and how to optimize resource utilization and reduce the overall infrastructure costs of cloud computing services. The VMware vCloud tools constructed based on vSphere-the vSphere component has many features such as server virtualization, storage virtualization and network virtualization. It can perform automatic load balancing across hosts and real-time virtual machine migration. It also performs non-disruptive storage migration, eliminates virtual machine storage and I/O bottlenecks and frees up valuable storage capacity.

In short, the IAAS layer is the core layer in the cloud computing services platform, and we can build the IAAS layer using the VMware vCloud tools. Through this framework shown in figure 3, a public or private cloud platform can be built for enterprises.

4. Performance Evaluation

Server virtualization (SV) is a proven technology that enables multiple virtual machines to run on a single physical server [2]. At present, server virtualization has been widely used in the architecture of the data centres and cloud computing platforms. It has a myriad of advantages such as scalability, cost savings and energy efficiency among others. With these advantages, this technology could be easily inculcated in cloud computing. Below is the performance evaluation through several application examples.

A. The evaluation of the total cost benefit

At present, there have been many new problems in the data centres, such as difficulty in management and excessive costs of hardware and maintenance. Jing Nie [10] concludes that, there are five types of costs which are hardware cost, energy cost, software cost, maintenance cost, downtime and recovery cost in data centre. They analysed the total cost benefit using server virtualization. Their experiments was carried out to contrast the total costs between using 20 physical host severs and 20 virtual host severs. The result indicates that the cost reduced significantly by using the server virtualization technology in the long run.

B. The evaluation of energy efficiency

In recent times, it is regarded as *out of place* to excessively purchase physical servers for enterprises. The SV technology can enable server consolidation and reduce the number of physical servers. It can also achieve the goal of reduction of power usage and carbon footprint. Lu Liu [11] gave detailed analysis about how server virtualization offers an energy efficiency solution. The experiments was carried under three conditions including VMware workstation, VMware ESX/ESXi and physical servers. The data collected in the experiments shows a similarity in consumption between VMware Workstation and VMware ESX/ESXi under the four different type's workloads. The collected data also shows that virtualized severs can significantly reduce energy consumption compared with the physical servers under the same workloads.

C. The evaluation of time efficiency

CIVIC is a hypervisor-based computing platform proposed by Jinpeng Huai[12].The CIVIC platform consists of five layers from bottom to top, including Resource layer, Container layer, Coordination layer, Instance layer and Interaction layer. The resource layer is formed by physical machines distributed over the Internet. The container layer can deploy the hypervisor on the top of physical machines and provide some interfaces for remote management and interaction. The virtual machine instance can be hosted in the container layer. The coordination layer has many different kinds of coordination functions. The instance layer provides virtual machine instance, virtual machine network instance, and virtual application instance for users. The interaction layer contains two types of interaction modules for users and managers respectively. In CIVIC architecture, the SV technology is applied in the container layer composed of many container nodes. Each node can install hypervisor. The experiments based on CIVIC platform shows that the installation time of virtual machine templates is far less than the installation time of physical machines. It also shows that the time to deploy a virtual network is far less than to configure a physical network. For this reason, we can conclude that time efficiency can be obtained using SV technology.

5. Conclusion

In this paper, we have introduced the development of virtualization and analysed the architecture of a virtualization business product. We further applied the virtualization technology to cloud computing, and built the cloud platform using the VMware vCloud tools. Finally, the performance evaluation of server virtualization in the cloud platform is summarized through some implementation examples. Through the research and analysis related to the technologies on virtualization and cloud computing, we presented some performance advantages, including gaining

the total cost benefits, reducing power consumption and time. Future studies could be directed to the use of Virtualization and cloud computing in Distributed Information Retrieval[13,14] to determine its effectiveness in such an environment.

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