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Application of Virtualization Technology in University Data Centers

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Abstract: *This paper explores the application of virtualization technology in the construction of university data centers. Firstly, the problems of traditional physical server architecture in data centers are analyzed, including low resource utilization, poor fault tolerance, high construction costs, and complex system maintenance. Then, an overview of virtualization technology is provided, including concepts such as compute virtualization, network virtualization, and storage virtualization. Next, using China University of Geosciences (Beijing) as an example, the specific implementation and effects of data center virtualization based on the VMware vSphere platform are introduced. Finally, the significant benefits of virtualization technology in university data center construction are summarized, including cost savings, improved operational and management efficiency, simplified administration, and enhanced resource utilization. This paper comprehensively and systematically elucidates the advantages of virtualization technology in addressing the challenges faced by university data centers, providing valuable insights for the planning and construction of university data centers.*

Keywords: *Virtualization, Data center, Server*

1. Introduction

With the continuous advancement of information technology in universities, the scale and complexity of data centers are rapidly increasing. University data centers play a crucial role in supporting academic research, teaching, and administrative management, making their efficient operation and reliability vital for university development. However, many university data centers still follow traditional models, with each information system individually configured on physical servers and hardware devices isolated from each other. Due to different system requirements for server configurations, a certain amount of redundant resources needs to be reserved on each server to ensure smooth operation. In the current context of university information technology, continuing with the traditional model would require increasing the number of devices to meet the growing hardware demands. This inevitably leads to equipment redundancy, low resource utilization, excessive energy consumption, and significant resource wastage, resulting in a substantial waste of resources and increasing workloads for data center management and system maintenance[1].

As society progresses and develops, universities need to reform their data center construction and deployment models with innovative concepts to explore more efficient solutions. Virtualization technology, particularly virtualized server cluster technology, has become increasingly mature and is now the mainstream approach in various data center constructions[2]. By building virtualized server clusters, virtualization technology divides physical servers into multiple virtual machines, enabling the sharing and flexible utilization of hardware resources. This effectively addresses the current issues in data center construction, laying a solid foundation for the development of university data centers.

2. Analysis of Disadvantages of Traditional Physical Server Architecture in Data Centers

Universities, as important producers and disseminators of knowledge and information, rely heavily on data centers to support academic research, teaching, and administrative management. However, many university data centers still adhere to traditional server room architectures, often adopting a one-server-per-application approach to enhance application system stability and security. With the advancement of society and the widespread adoption of automation concepts, the number of system applications in university data centers has increased significantly. Consequently, the number of servers has also dramatically increased, leading to a series of problems such as insufficient cabinet quantity, inadequate

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UPS power supply, insufficient cooling capacity, and limited floor space[3].

2.1. Low Resource Utilization

University data centers face the issue of low resource utilization. In the traditional data center architecture, each information system is allocated its own physical server, resulting in a large amount of redundant and idle hardware resources that cannot be effectively utilized. Many servers cannot fully utilize hardware resources during operation, leading to wastage. Moreover, to ensure system stability, each server requires a certain amount of redundancy, further reducing resource utilization. Traditional data centers have limited scalability and can only increase the number of servers to meet demand, which not only requires additional investment but also increases redundancy and waste.

2.2. Poor Fault Tolerance

Traditional data centers using independent physical servers suffer from poor fault tolerance. If a server fails, the corresponding application system may experience interruptions, affecting critical work. Additionally, the backup and recovery mechanisms in traditional data centers are relatively weak, requiring individual operations for each server, which increases workload and risk. The limited fault isolation capability means that a failure in one system can potentially impact other systems, resulting in the propagation of failures.

2.3. High Construction Costs

Firstly, selecting and purchasing physical servers based on system requirements involves lengthy steps, including receiving, shelving, and deployment configurations. It requires coordination and communication among different departments, reducing efficiency. Secondly, system upgrades require capacity expansion or migration to higher-configured servers, resulting in significant workload and time costs. During capacity expansion, downtime is required to add hardware and reconfigure, impacting running systems. Migration involves purchasing new servers and repetitive deployment, resulting in redundant work. Therefore, both the initial construction and subsequent expansion and migration processes in the traditional physical server model consume significant manpower and resources.

2.4. Complex and Lengthy System Maintenance

The traditional physical server model leads to complex and lengthy system maintenance in data centers. Each system relies on independent servers, and maintenance requires individual operations for each server, increasing workload and time costs. Hardware repairs and fault troubleshooting for traditional servers also require significant time and resources. Hardware replacement and debugging/testing are necessary in the event of a failure, potentially prolonging downtime. Regular optimization, updates, and backup and recovery tasks also need to be completed within limited time frames, increasing the difficulty of maintenance.

3. Introduction to Virtualization Technology

For university data centers, many still operate in traditional modes, adopting complex system architectures that combine servers, networks, storage, databases, and management software from different vendors to enhance application system stability and security. This architecture meets the early demands of data centers. However, with the development of information technology and the exponential growth of data, this model gradually reveals issues such as system integration challenges, low availability, low physical device utilization, and difficulties in system upgrades. These problems can be addressed through the use of virtualization technology.

Virtualization technology reconstructs the presentation, access, and management of IT infrastructure, network systems, and software computing resources. By reducing application dependence on the physical environment, virtualization enables IT personnel to rapidly deploy applications, improve resource utilization, reduce costs, and enhance the stability and availability of IT infrastructure[4].

There are various types of server virtualization software available, including products from companies such as VMware, Microsoft, and Citrix, allowing universities to choose according to their specific needs. Virtualization software logically divides each physical server into multiple independent

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virtual machines, with the hardware resources of the physical server allocated to the virtual machines. Each virtual machine functions identically to a traditional physical server, having its own operating system and software, and can host different information systems. By planning and deploying systems onto designated virtual machines, rapid deployment can be achieved without the need for additional server purchases.

3.1. Common Virtualization Technologies

3.1.1. Compute Virtualization

Compute virtualization refers to the process of partitioning the computing resources of a physical server into multiple virtual machine instances. Through compute virtualization, a single physical server can be divided into multiple independent virtual machines, each having its own operating system, applications, and computing resources. Such a virtualized environment provides higher resource utilization, flexible deployment and management methods, as well as improved isolation and security.

3.1.2. Network Virtualization

Network virtualization is a technique that partitions physical network resources into multiple logical networks. Through network virtualization, a single physical network can be divided into multiple independent virtual networks, each having its own network topology, IP address space, and network policies. This virtualized network environment provides more flexible, scalable, and secure network services.

3.1.3. Storage Virtualization

Storage virtualization is a technique that abstracts physical storage resources into logical storage pools and makes them available to multiple virtual machines or applications[5]. Through storage virtualization, multiple physical storage devices, such as hard drives and solid-state drives, can be integrated into a unified storage resource pool, making it transparent to the upper-layer applications and simplifying storage management and configuration complexities.

4. Practical Implementation of Data Center Virtualization Based on VMware

China University of Geosciences (Beijing) has adopted the VMware vSphere server virtualization platform to build a virtual data center for a digital campus. By leveraging server virtualization technology, the utilization of hardware resources such as computers and storage has been significantly improved. Server management has become more convenient, and the deployment speed of application systems has also been enhanced, achieving favorable results.

4.1. Introduction to the VMware Virtualization Platform Architecture

VMware is a leading virtualization platform that adopts a layered architecture, including ESXi hosts, vCenter Server, vSphere Client, and other key components. ESXi hosts serve as the virtualization operating system, providing compute, storage, and network resources. vCenter Server acts as the centralized management and control center for configuring, monitoring, and operating the virtualized environment. vSphere Client serves as the user interface for managing and operating virtual machines and resources. vSphere also includes VDS for network management and vSphere Storage supporting various storage options. By providing flexibility, reliability, and advanced management capabilities, vSphere helps enterprises build and manage efficient, scalable virtualized environments and achieve optimized resource management.

4.2. Structural Design of Data Center Virtualization System

The data center adopts the VMware vSphere server virtualization platform, utilizing 10 DELL R930 physical servers, the MacroSAN MS5520 for storage resources, and the DELL Brocade 6505 for data center switches. The system architecture is shown in Figure 1.

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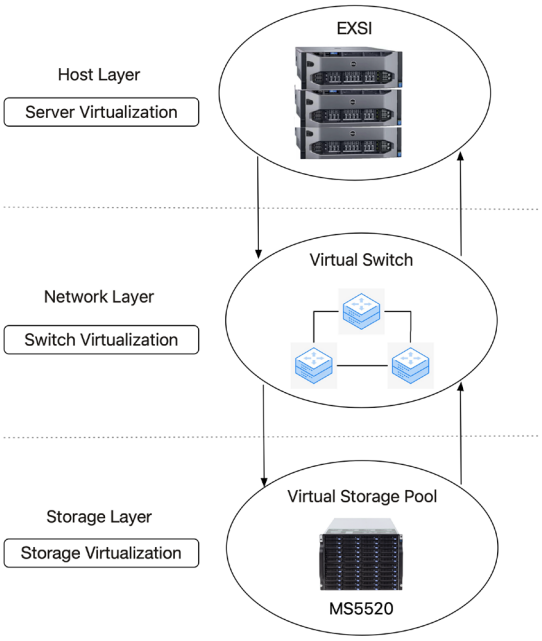

Figure 1: System Architecture.

By implementing server virtualization in the data center, over 100 servers have been successfully migrated onto 10 hosts, ensuring that each virtual machine is allocated at least 1-5 vCPUs and a minimum of 16GB of memory. This implementation has achieved a virtualization ratio of approximately 1:10, putting an end to the previous practice of using dedicated servers for each business system. Within the virtualized environment, business systems can be migrated without service interruptions and quickly recovered in the event of a business failure, greatly improving the reliability, availability, and scalability of the systems. Compared to before the data center virtualization, the utilization of server resources, including CPU, memory, and storage, has significantly increased. After running for some time, the virtualization system has performed well, with no bottlenecks or failures even when certain systems reached peak resource usage. Additionally, older servers with longer lifespans have been decommissioned, leading to a significant reduction in energy consumption and cooling requirements for the entire data center. In summary, the utilization of space, carbon footprint, and resource investment in the data center have all greatly improved compared to the previous IT environment.

5. Application Effects of Virtualization Technology in University Data Center Construction

5.1. Cost Savings

Through resource sharing and hardware consolidation, virtualization technology maximizes the utilization of compute, storage, and network resources on physical servers, reducing the costs associated with hardware acquisition and maintenance. Additionally, virtualization simplifies management tasks through centralized management and monitoring, reducing the need for human resources and associated management costs. Virtualization also offers energy-saving benefits by running multiple virtual machines on a single physical server, reducing data center power consumption and lowering electricity costs. Furthermore, virtualization technology provides the ability for quick deployment and migration. With templates and snapshot features, virtual machines can be rapidly created and replicated, significantly reducing the time and costs associated with deployment and migration. Overall, virtualization technology effectively lowers IT costs through resource sharing, streamlined management, energy efficiency, and rapid deployment, providing a reliable solution for efficient data center operations.

5.2. Enhanced Operational Efficiency

Through centralized management and monitoring of the entire virtualized environment, administrators can perform management operations from a unified interface, avoiding cumbersome dispersed management. The application of automated tasks reduces the risks associated with manual operations and human errors, improving the efficiency and accuracy of operational management. The capabilities for rapid deployment and migration allow administrators to quickly create, copy, and migrate

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virtual machines, significantly shortening the time for application deployment and increasing the efficiency and flexibility of operational management. Fault recovery and high availability features ensure business continuity, as virtualized environments can automatically migrate virtual machines to other available hosts for quick fault recovery. Resource optimization and load balancing functionalities enable the optimal utilization of resources, as administrators can adjust resource allocation and workload distribution based on real-time monitoring and analysis, improving operational management efficiency. Overall, virtualization technology significantly enhances operational efficiency through centralized management, automated tasks, rapid deployment and migration, fault recovery and high availability, resource optimization, and load balancing. It empowers administrators to efficiently carry out management and monitoring operations, reducing the need for human resources and lowering operational costs.

6. Conclusion

Overall, virtualization technology provides a more efficient, flexible, and cost-effective solution for university data center construction. With the advent of cloud computing and the era of big data, virtualization technology will play an even greater role in university data center construction. Universities should fully recognize the advantages of virtualization technology and carefully plan a virtualization roadmap based on their specific circumstances. They should promote the application of virtualization technology in computing, storage, networking, and other aspects to build a new generation of data centers that have high resource utilization, intelligent management, automated operations, and flexible scalability. At the same time, attention should be paid to the potential security risks associated with virtualization and the establishment of a sound security protection system. Only in this way can virtualization technology provide solid technical support for the development of university data centers.

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