Chapter 17

Virtual Machine Migration in Cloud Computing Environments: Benefits, Challenges, and Approaches

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ABSTRACT

Recent developments in virtualization and communication technologies have transformed the way data centers are designed and operated by providing new tools for better sharing and control of data center resources. In particular, Virtual Machine (VM) migration is a powerful management technique that gives data center operators the ability to adapt the placement of VMs in order to better satisfy performance objectives, improve resource utilization and communication locality, mitigate performance hotspots, achieve fault tolerance, reduce energy consumption, and facilitate system maintenance activities. Despite these potential benefits, VM migration also poses new requirements on the design of the underlying communication infrastructure, such as addressing and bandwidth requirements to support VM mobility. Furthermore, devising efficient VM migration schemes is also a challenging problem, as it not only requires weighing the benefits of VM migration, but also considering migration costs, including communication cost, service disruption, and management overhead. This chapter provides an overview of VM migration benefits and techniques and discusses its related research challenges in data center environments.

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Specifically, the authors first provide an overview of VM migration technologies used in production environments as well as the necessary virtualization and communication technologies designed to support VM migration. Second, they describe usage scenarios of VM migration, highlighting its benefits as well as incurred costs. Next, the authors provide a literature survey of representative migration-based resource management schemes. Finally, they outline some of the key research directions pertaining to VM migration and draw conclusions.

INTRODUCTION

With rapid expansion of Information Technology (IT) infrastructures in recent years, managing computing resources in enterprise environments has become increasingly complex. In this context, virtualization technologies have been widely adopted by the industry as a means to enable efficient resource allocation and management, in order to reduce operational costs while improving application performance and reliability. Generally speaking, virtualization aims at partitioning physical resources into logical resources that can be allocated to applications in a flexible manner. For instance, server virtualization is a technology that partitions the physical machine into multiple Virtual Machines (VMs), each capable of running applications just like a physical machine. By separating logical resources from the underlying physical resources, server virtualization enables flexible assignment of workloads to physical machines. This not only allows workload running on multiple virtual machines to be consolidated on a single physical machine, but also enables a technique called VM migration, which is the process of dynamically moving a virtual machine from one physical machine to another.

VM migration shares many similarities with its precursor called process migration, which aims at migrating a running process from one machine to another. Similar to VM migration, process migration moves the state of a running application process from one physical machine to another. However, its objective is to migrate running processes rather than VMs. Process migration has been extensively studied during the 1980s; however, it has been rarely used in practice due to the difficulty in handling the dependencies between various operating system modules. VM migration, on the other hand, does not suffer from these limitations. As VM migration moves the entire operating system along with the running processes, the migration problem is simplified and can be handled efficiently. Over the past decade, VM migration has proven to be a powerful technique for achieving a number of objectives, including workload consolidation, load balancing, reducing energy consumption, facilitating maintenance activities as well as supporting mobile applications. Consequently, it has received wide adoption in the industry in recent years. However, VM migration also has inherent challenges related to service disruption, bandwidth consumption, management overhead, and increased security risks. As such, devising applications that make effective use of VM migration has become a research question that gained considerable interest in the research community.

This chapter provides a comprehensive study of VM migration, highlighting its benefits, costs and underlying research challenges. First, it provides an overview of VM migration technologies found in the literature, and discusses the benefits and costs pertaining to VM migration. Then, it surveys various schemes that leverage VM migration for resource management in virtualized environments, and discusses key research directions related to VM migration. The ultimate goal is to provide an in-depth understanding of the state-of-the-art developments in the area of VM migration and to foster further research on this topic.
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