Towards an efficient snapshot approach for virtual machines in clouds

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Abstract

High-availability of virtual machines is of significant importance for a cloud computing environment, because cloud services may be compromised due to system maintenance, malicious attacks, and hardware and software failures. The virtual machine (VM) snapshot can effectively back up the state, disk data, and configuration of a machine at a specific time point. However, the existing VM snapshot methods suffer from performance issues such as long downtime and I/O performance degradation during a live snapshot. To address such issues, we proposed an efficient VM snapshot system, iROW (improved Redirect-on-Write), based on the qemu-kvm virtual block device driver. iROW employs the following techniques. (1) A bitmap-based light-weight index method is designed to reduce the query cost of the existing two-level index table structure compared with qcow2. (2) An index-free approach is used for VM state data to improve the performance of data saving and loading operations of VM state. (3) VM state data is separated from disk image data in a snapshot. (4) The free page detection (FPD) is designed using virtual machine introspection to identify and skip saving free pages in the guest OS during snapshotting, thus reducing the VM state snapshot creation time and the snapshot disk space usage. Our experimental results demonstrate that iROW is evidently advantageous over qcow2 in performance, in terms of the disk snapshot, the state snapshot and the disk I/O.

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1. Introduction

In the recent years, the cloud computing has emerged as an efficient paradigm enabling a ubiquitous and on-demand service access to a reliable and shared computing and storage resources [5,16]. In a cloud, the virtualization technology is popularly employed to run multiple virtual machines (VMs) with strong isolation on a single physical machine. A VM encompasses resources to facilitate the execution of a complete operating system (OS), and both user data and application data can be stored in the VM [13,19]. Unfortunately, the data reliability and service availability of the VM might be compromised by system maintenance, malicious attacks, and hardware and software failures [1,10].

The virtual machine snapshot is a file-based approach greatly enhancing the availability of the data and services in the VM. It can back up a VM at a specific time point by the disk snapshot saving the disk of the VM, and the state snapshot which saves the running state of the VM including the states of the virtual CPUs and of all connected virtual devices of the VM [2,6,10,26]. Moreover, the VM can be easily reverted to any previously saved state, and then can be allowed to run continuously [7,8].

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Supported by the QEMU processor emulator used by several hypervisors including KVM, qcow2 (QEMU copy-on-write version 2) is a widely adopted VM image format allowing the disk snapshot and the VM state snapshot. This format adopts copy-on-write (COW) for the disk snapshot, and a simple stop-and-copy method for the state snapshot, as well as a two-level tree index tree to store its metadata. However, this structure brings extra overheads to the snapshot performance and the I/O performance whilst data clusters of the VM are accessed. (1) The disk snapshot creation time grows dramatically with the increase of the VM disk size (Fig. 1). (2) The write performance loss is about 15 ~ 45% of the raw format (another plain format of VM disk) in different cluster sizes. As a result of this inherent drawback of the COW-based snapshot, the 1st-write performance loss of qcow2 after the snapshot creation reaches up to 60% ~ 90% (Fig. 2). (3) The VM suffers from a long downtime during the live snapshot (Fig. 3) because of the stop-and-copy state snapshot of qcow2. (4) The sophisticated metadata structure of qcow2 designed to allocate the disk space on demand overlaps with sparse file, the similar function provided by host file systems, such as ext2/ext3/ext4, NTFS, reiserFS, etc. Therefore, the performance of VM snapshot creation and management is significantly affected, as well as the normal I/O performance of the VM disk.

In this paper, we design a bitmap-based light-weight index method to boost the operation performance of both the VM disk snapshot and VM disk I/O.

To boost the state snapshot creation, many techniques have been proposed, such as memory image compression [21], duplicated data elimination and unused memory elimination. Nevertheless, memory image compression has been found ineffective for checkpoint images [25]. Moreover, duplicated data elimination [18], tracks all disk I/O operations to maintain a map between memory pages and the identical blocks on the external storage. When a snapshot is captured, such duplicated pages are excluded. However, the I/O tracking burdens the VM I/O operations, and the time required to restore a VM from an optimized checkpoint image may increase remarkably, because it has to read the disk image discontinuously to restore those memory pages excluded before. Furthermore, unused memory elimination is not easily applicable to fully-virtualized guests.
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