Introduce a SPDK vhost FUSE target to accelerate File Access in VMs and containers

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Storage Performance Development Kit

Available via spdk.io
@SPDKProject

**Scalable and Efficient Software Ingredients**
- User space, lockless, polled-mode
- Up to millions of IOPS per core
- Minimize average and tail latencies
- Designed for non-volatile media

**Storage Reference Software**
- Optimized for latest generation CPUs and SSDs
- Provides Future Proofing
- Extends to Storage Virtualization and Networking

**Open Source community**
- Open source building blocks (BSD licensed)
- Faster TTM, fewer resources required
Unified SPDK Vhost user target

- SPDK vhost target can provide virtio-blk/virtio-scsi/virtio-fs/NVMe in Guest.
- Build on common vhost-user library to parse vring and NVMe queues.
- Eliminate MMIO access for submission with polling mechanism.
Sharing Host Files with the Guest

- Plan 9 folder sharing over Virtio - I/O virtualization
- QEMU can process the 9p request and send to backend via local existing POSIX APIs.
- Another optimization for Clear Containers which moves the IO process into the Host kernel space, eliminate syscall from userspace to kernel space compared with previous solution.

Container deployments utilize explicit or implicit file sharing between host filesystem and containers.
What’s FUSE

• FUSE (Filesystem in Userspace) is an interface for userspace programs to export a filesystem to the Linux kernel. The FUSE project consists of two components: the fuse kernel module and the libfuse userspace library. libfuse provides the reference implementation for communicating with the FUSE kernel module.

• How can FUSE be used in virtualization environment and accelerate shared file access between different VMs?
Introduction to Virtio-fs

• Virtio-fs is a shared file system that lets virtual machines access a directory tree on the host. Unlike existing approaches, it is designed to offer local file system semantics and performance. This is especially useful for lightweight VMs and container workloads, where shared volumes are a requirement.

• Virtio-fs was started at Red Hat and is being developed in the Linux, QEMU, FUSE, and Kata Containers communities that are affected by code changes.

• Virtio-fs uses FUSE as the foundation. A VIRTIO device carries FUSE messages and provides extensions for advanced features not available in traditional FUSE.

• DAX support via virtio-pci BAR from host huge memory.
SPDK Vhost-fs Target vs. QEMU Virtiofsd

- Eliminate userspace/kernel space context switch by providing a user space file system.
- Zero copied for both READ and WRITE.
- Hugetlbfs is required.
- DAX(Direct Access for files)
Introduction to SPDK Blobfs/Blobstore

- Application interacts with chunks of data called blobs:
- Designed for application that don’t consume block, such as Rocksdb.
- Designed for fast media, such as NVMe SSDs.
- Mutable array of pages of data, accessible via ID.
- Asynchronous, no blocking, queueing or waiting.
- Fully parallel, no locks in IO path.
- Data is direct, Metadata is cached, minimal support for xattrs.
- Logical volumes with snapshot and thin provisioning.
Blobstore Design - Layout

• A blob is an array of pages organized as an ordered list of clusters.
Blobstore Design - Metadata

- Stored in pages in reserved region of disk
- Not shared between blobs
- One blob may have multiple metadata pages
SPDK Blobfs API vs. FUSE

- Open, read, write, close, delete, rename, sync interface to provide POSIX similar APIs.
- Asynchronous APIs are also provided.

<table>
<thead>
<tr>
<th>FUSE Command</th>
<th>Blobfs API</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lookup</td>
<td>spdk_fs_iter_first, spdk_fs_iter_next</td>
</tr>
<tr>
<td>Getattr</td>
<td>spdk_fs_file_stat_stat_async</td>
</tr>
<tr>
<td>Open</td>
<td>spdk_fs_open_file_file_async</td>
</tr>
<tr>
<td>Release</td>
<td>spdk_file_close_async</td>
</tr>
<tr>
<td>Create</td>
<td>spdk_fs_create_file_async</td>
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<tr>
<td>Delete</td>
<td>spdk_fs_delete_file_async</td>
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<tr>
<td>Read</td>
<td>spdk_file_readv_async</td>
</tr>
<tr>
<td>Write</td>
<td>spdk_file_writev_async</td>
</tr>
<tr>
<td>Rename</td>
<td>spdk_fs_rename_file_async</td>
</tr>
<tr>
<td>Flush</td>
<td>spdk_file_sync_async</td>
</tr>
</tbody>
</table>
Operation Mapping of Fuse in Virtqueue

- General FUSE command has 2 parts: request and response.
- General FUSE request is consisted with IN header and operation specific IN parameters.
- General FUSE response is consisted with OUT header and operation specific OUT results.
Open and Close Operations in Fuse and SPDK

Open (File_path) in POSIX

Lookup

Open

Release

Forget

spdk_file_open_async

spdk_file_close_async

Resource preparing

Resource releasing
Implementation Details with Read/Write

- **Posix Read**
- **Fuse Read**
- **Virtio-fs**
  - Submit Fuse CMD

- **Fetch Fuse CMD**
  - **SPDK vhost-fs**
  - **spdk_file_readv**
  - **SPDK SW Stack**

- **Fuse in header**
- **Fuse_read_in**

- **Virtqueue**
  - **Fuse out header**
  - Data
  - Data
  - Data

- **Read(File_id, data) in POSIX**
- **FUSE Read**
- **spdk_file_open_async**
Summary & Future plan

Summary
- SPDK blobfs can support limited file APIs, and only append write is supported for now.
- Friendly for WRITE workload and simple READ cache feature is enabled.
- Optimized for big files, and not friendly for small files.

Future plan
- Continue to improve existing SPDK blobfs, include the thread model as well as asynchronous APIs.
- Benchmarks.

Useful links:
1. https://review.gerrithub.io/#/c/spdk/spdk/+/449162/
2. https://review.gerrithub.io/#/c/spdk/spdk/+/449163/
SPDK Community

Main Web Presence

Email Discussions

Real Time Chat w/ Development Community

Weekly Calls
Multiple Annual Meetups

Backlog and Ideas for Things to Do

Code Reviews & Repo

GerritHub

Jenkins Continuous Integration

https://SPDK.IO

Multiple Annual Meetups