vhost-user-scsi: offloading virtio-scsi to userspace

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State of the Art: Qemu handles VQs
Motivation

• Current design imposes certain limitations
  - A 1:1 mapping on VM to host process for handling VQs
  - Impossible to have a single process handling multiple VMs
  - Impossible to efficiently poll on multiple VMs
  - Non-trivial to virtualise a single NVMe to multiple VMs from userspace

• Solution
  - Create a mechanism to offload the datapath to a separate process
  - Precedence: vhost-user-net
State of the Art: Qemu handles VQs

Diagram showing the interaction between VMs, vHW, Linux (host), and HW. The diagram highlights the storage workload and the flow of requests through the vCPU main loop (device emulation) and back to the guest's memory.
State of the Art: Qemu handles VQs
State of the Art: Qemu handles VQs
Trade-offs

• Main benefit: better performance
  - Easier to implement MQ support (with multiple IO threads)
  - Easier to optimise for better batching
    - First pick up everything from all VQs (multiple VMs)
    - Then submit it altogether to your backend
  - Simple to implement VQ polling for multiple VMs

• Drawbacks
  - When using a single backend process, security and stability
    - With separate processes, these are no different than today
  - LUN management is independent (Qemu is not aware of LUNs anymore)
  - Features generally available from Qemu block layer are lost
Side-by-side: vhost-user and vhost
Design/Implementation Highlights

• Small refactoring of vhost-scsi (in Qemu)
  - Original vhost-scsi split into: vhost-scsi-common and vhost-scsi
  - New vhost-user-scsi introduced under vhost-scsi-common

• Live Migration
  - Very straightforward, but ended up dropped from merge
    - Trick: flush the device on GET_VRING_BASE
  - Future work: throttling vhost(-user) devices for convergence

• Key difference with vhost: unix msgs are async
  - ioctl() blocks until the kernel module finished processing the command
  - On vhost-user, use F_REPLY_ACK to wait for completion
Storage Performance Development Kit (SPDK)

What is SPDK?

- Userspace polled-mode drivers, libraries and applications for storage, storage networking and storage virtualization
- Leverages DPDK for hugepage memory management and PCI device enumeration
- Started in 2013, open sourced in 2015
- BSD licensed
- http://SPDK.io
## Storage Performance Development Kit (SPDK)

### Storage Protocols
- NVMe-oF* Target
- iSCSI Target
- vhost-user-scsi Target
- vhost-user-blk Target
- NVMe
- SCSI

### Storage Services
- **Block Device Layer (bdev)**
  - Logical Volumes
  - GPT
  - BlobFS
  - Blobstore
- NVMe PMD
- Linux AIO
- Ceph RBD
- virtio-scsi PMD
- libpmemblk

### Polled Mode Drivers
- NVMe
  - NVMe-oF* Initiator
  - NVMe* PCIe
- virtio-scsi
- Intel® QuickData Technology

**Released**
- Q4’17
Basic Architecture

Configure vhost-scsi controller

- JSON RPC
- creates SPDK constructs for vhost device and backing storage
- creates controller-specific vhost domain socket

Diagram:

- /spdk/vhost.0
- vhost-scsi ctrlr
- scsi dev
- scsi lun
- bdev
- nvme
- NVMe SSD

Logical Core 0

Logical Core 1
Basic Architecture

Launch VM
- QEMU connects to domain socket

SPDK
- Assigns logical core
- Starts vhost-scsi poller
- Allocates NVMe queue pair
- Starts bdev-nvme poller
Basic Architecture

Repeat for additional VMs

- pollers spread across available cores
Asynchronous Polling

Poller execution

- Reactor on each core
- Iterates through pollers round-robin
- vhost-scsi poller
  - poll for new I/O requests
  - submit to NVMe SSD
- bdev-nvme poller
  - poll for I/O completions
  - complete to guest VM
Sharing SSDs in userspace

Typically not 1:1 VM to local attached NVMe SSD
- otherwise just use PCI direct assignment

What about SR-IOV?
- SR-IOV SSDs not prevalent yet
- precludes features such as snapshots

What about LVM?
- LVM depends on Linux kernel block layer and storage drivers (i.e. nvme)
- SPDK wants to use userspace polled mode drivers

SPDK Blobstore and Logical Volumes!
Blobstore Design – Design Goals

- Minimalistic for targeted storage use cases like Logical Volumes and RocksDB
- Deliver only the basics to enable another class of application
- Design for fast storage media
Blobstore Design – High Level

Application interacts with chunks of data called blobs
- Mutable array of pages of data, accessible via ID

Asynchronous
- No blocking, queuing or waiting

Fully parallel
- No locks in IO path

Atomic metadata operations
- Depends on SSD atomicity (i.e. NVMe)
- 1+ 4KB metadata pages per blob
Logical Volumes

Blobstore plus:

- UUID xattr for lvolsstore, lvols
- Friendly names
  - lvol name unique within lvolsstore
  - lvolsstore name unique within application
- Future
  - snapshots (requires blobstore support)
SPDK vhost Performance - Configuration

2x Intel Xeon Platinum 8180 (28 cores each)
• VMs: 46 cores
• vhost: 10 cores

23x Intel P4800x Optane SSD
• SPDK lvvolstore/LVM lvgroup per SSD

46 VMs – 1 vCPU, 2GB DRAM, 100GB logical volume
• 2 VMs per lvvolstore/lvgroup
SPDK vhost Performance

IO/s (in millions)

<table>
<thead>
<tr>
<th></th>
<th>Linux</th>
<th>SPDK</th>
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<tbody>
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<td>IO/s (in millions)</td>
<td>2</td>
<td>8</td>
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QD=1 Latency (in us)

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<tr>
<th></th>
<th>Linux</th>
<th>QEMU</th>
<th>SPDK</th>
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<tbody>
<tr>
<td>QD=1 Latency (in us)</td>
<td>13</td>
<td>38</td>
<td>50</td>
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System Configuration: 2S Intel® Xeon® Platinum 8180: 28C, E5-2699v3: 18C, 2.5GHz (HT off), Intel® Turbo Boost Technology enabled, 12x16GB DDR4 2133 MT/s, 1 DDim per channel, Ubuntu Server 16.04.2 LTS, 4.11 kernel, 23x Intel® P4800x Optane SSD – 375GB, 1 SPDK lvologstore or LVM lvgroup per SSD, SPDK commit ID c5d8b108f22ab, 46 VMs (CentOS 3.10, 1vCPU, 2GB DRAM, 100GB logical volume), vhost dedicated to 10 cores

As measured by: fio 2.10.1 – Direct=Yes, 4KB random read I/O, Ramp Time=30s, Run Time=180s, Norandommap=1, I/O Engine = libaio, Numjobs=1

Legend: Linux Kernel vhost-scsi QEMU: virtio-blk dataplane SPDK: Userspace vhost-scsi
Future

vhost-user-blk

Live Migration

Logical Volume snapshots
SPDK Community


**Github**: [https://github.com/spdk/spdk](https://github.com/spdk/spdk)

**Trello**: [https://trello.com/spdk](https://trello.com/spdk)

**GerritHub**: [https://review.gerrithub.io/#/q/project:spdk/spdk+status:open](https://review.gerrithub.io/#/q/project:spdk/spdk+status:open)

**IRC**: [https://freenode.net/](https://freenode.net/) we’re on #spdk
Thank you!

Questions?

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