io_uring in QEMU: high-performance disk IO for Linux

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What we'll discuss today

io_uring API

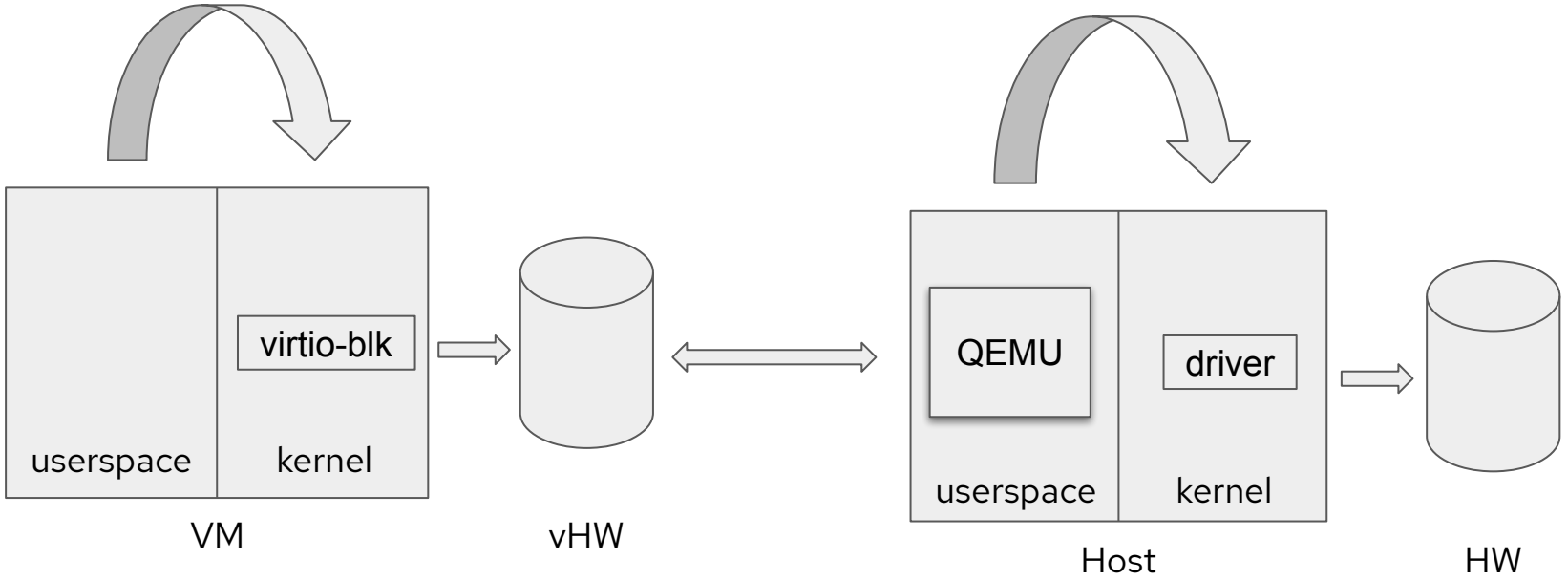
QEMU structure

Features of io_uring and how they helped QEMU

Benchmarks

What left to do

I/O path in VM



Existing solutions

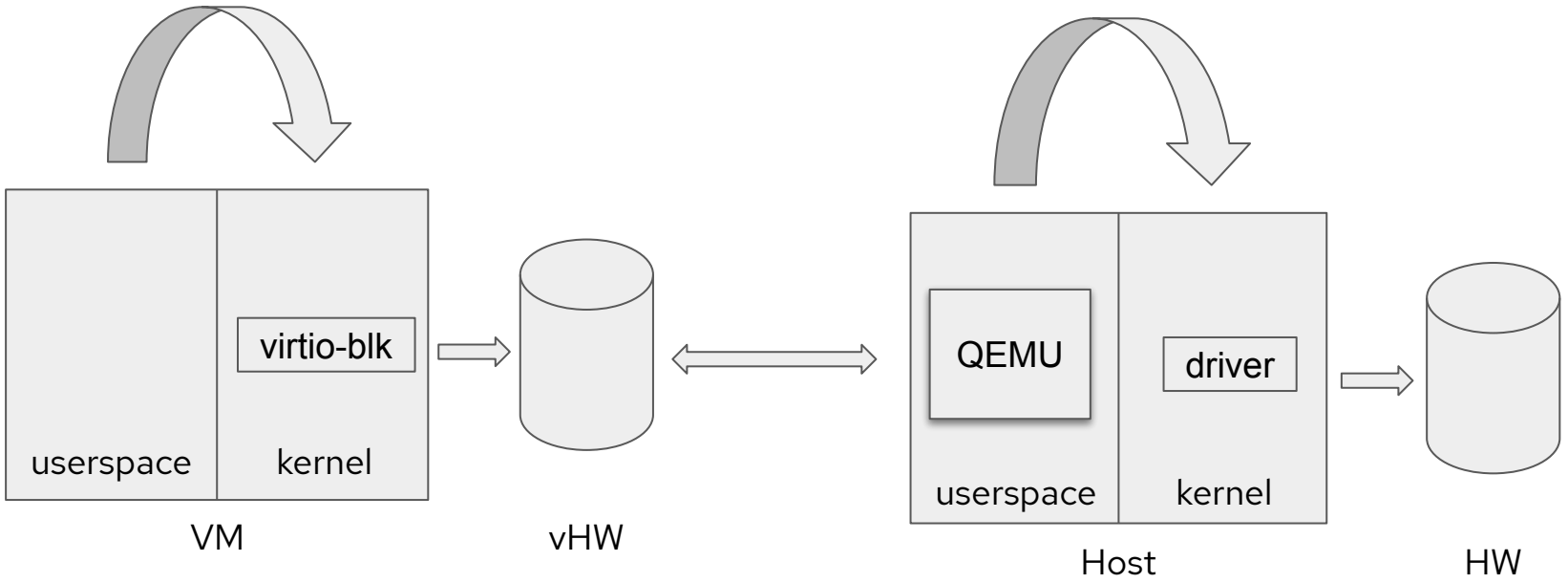
Async I/O

- Linux AIO (aio=native)
- Thread pool (aio=threads)

Other

- NVME passthrough (vfio)
- SPDK

I/O path in VM



----------This part we can improve----------

io_uring

Yet another kernel ring buffer

- New interface for truly asynchronous communication with kernel: latest versions support network and some other syscalls
- Part of linux 5.1

Main features

- Unlike Linux AIO, separate queues for submission and completion (sqes and cqes)
- Sqes and cqes are shared between userspace and kernel
- Async flush

Submission:
QEMU -> kernel -> hw

Completion:
QEMU <- kernel <- hw

Interface

Three new system calls:

io_uring_setup(u32 entries, struct io_uring_params *p)

- Can choose different regimes

io_uring_enter(unsigned int fd,
unsigned int to_submit,
unsigned int min_complete,
unsigned int flags,
sigset_t *sig)

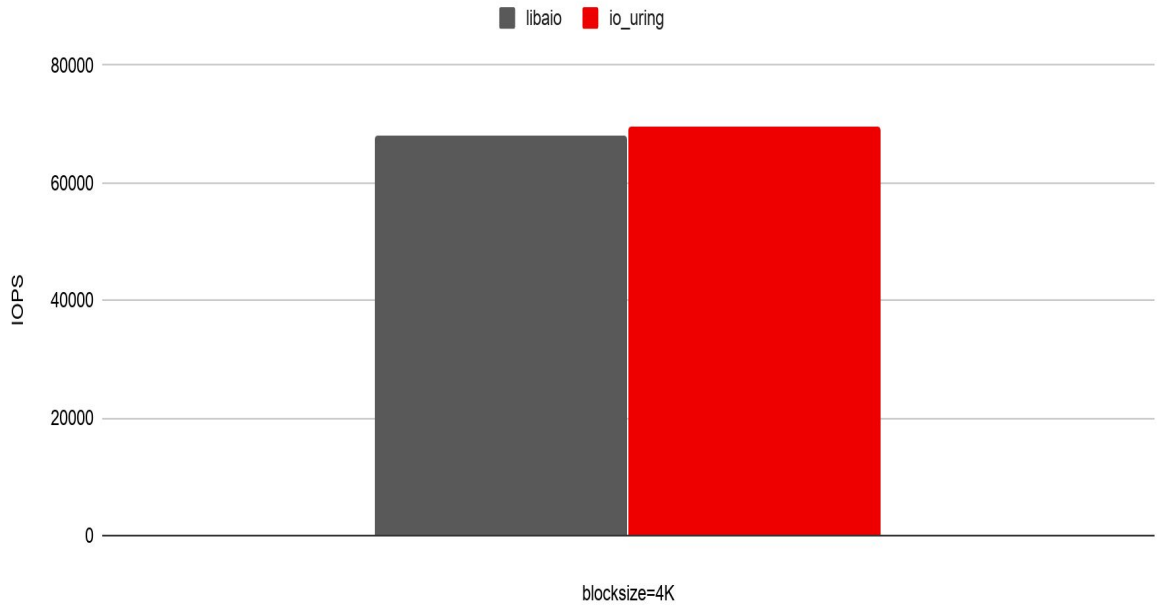
- Submit submissions and fetches completions within one syscall (Not in Linux AIO!)

io_uring_register(unsigned int fd, unsigned int opcode,
void *arg, unsigned int nr_args);

- Register fd ahead. No need to do fget() and fput() on each submission and completion respectively
- Register buffers (struct iovec) ahead. Saves get_user_pages() and put_pages()

How fast is it?

Benchmarks on bare metal



Test with fio 3.14:
aio=libaio
operation=randread

NVMe SSD Intel Optane 320G
CPU Intel Xeon Silver 2.20GHz

Integration into QEMU

What's done:

- Outreachy project idea
- Implemented by Aarushi Mehta
- Basic functionality is merged upstream (will be in QEMU 5.0)

Known issues:

- Problems with file locking in fd registration
- IOPOLL is not implemented

Integration into QEMU

Reuse Linux AIO approach

Qemu event loop is based on AIO context (future improvement: can be switched to io_uring)

Add aio context -> use epoll for completion check

Now we submit requests with io_uring_enter() and check completions on irq

Liburing usage:

Easier to use, less mistakes

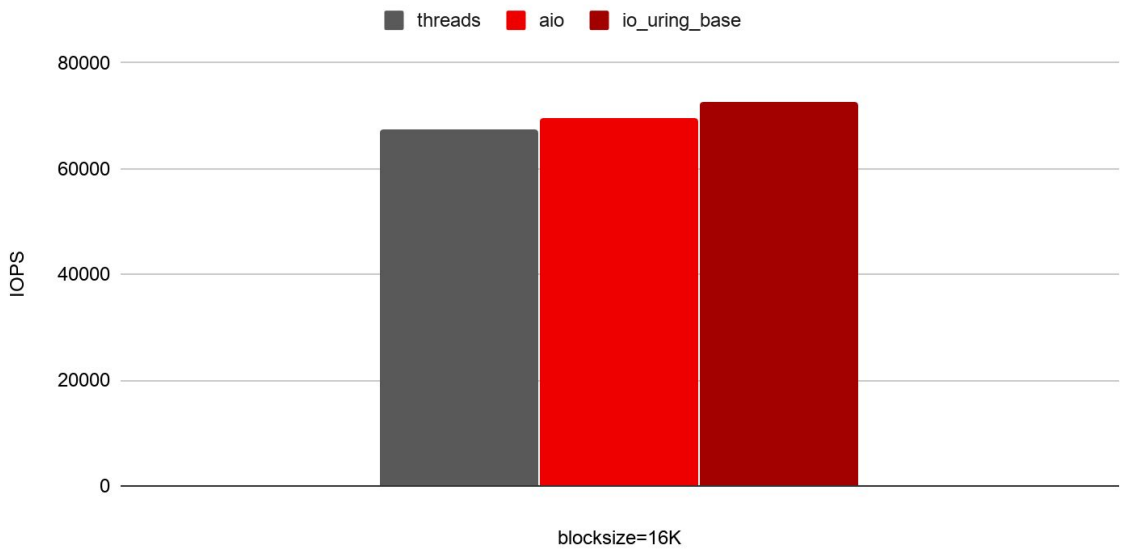
Integration into QEMU

How to launch

-drive file=test.img,format=raw,cache=none,aio=io_uring

Works with both IO_DIRECT and cache workload

How fast has it got without extra features?



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Fd registration

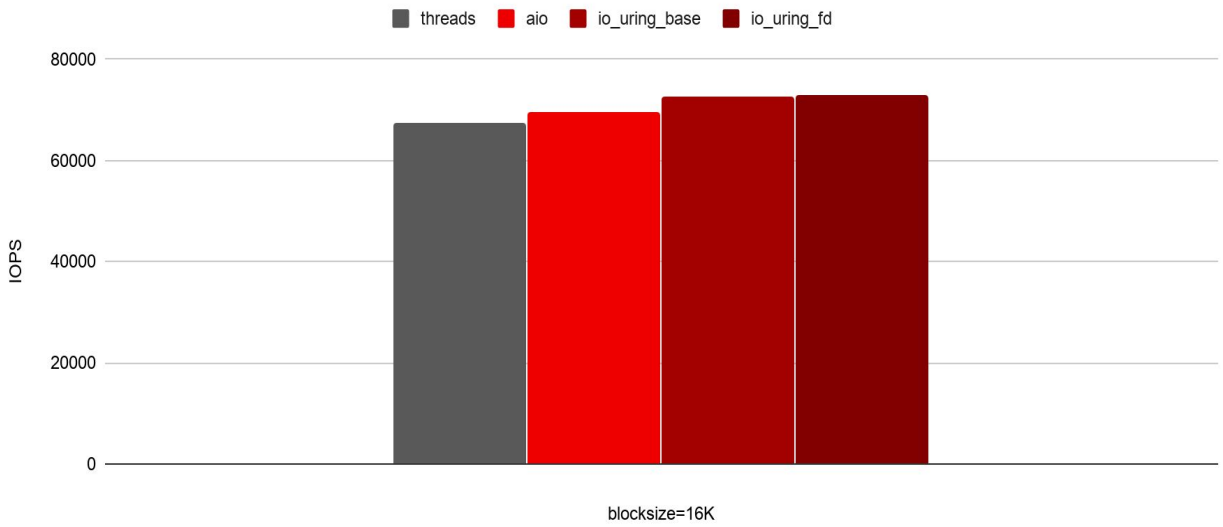
Register set of fd on which I/O is operated with io_uring_register()

Saves atomic fget() on submission path

Saves atomic fput() on completion path

Does this help much?

Not really by itself



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Submission polling

Run a kernel thread to wait for submissions, need to wake up with syscall

io_uring_setup() with flag SQ_POLL

Needs fd registration for effective usage

Now we submit requests without syscall and get completions on irq - path without syscalls

Completion polling

Poll completions with busy waiting on io_uring_enter()

io_uring_setup() with

CPU consuming, but no context switching

In combination with SQ_POLL - the fastest way on heavy workloads

Performance

Not implemented yet

Source:
Insert source data here
Insert source data here
Insert source data here

Future improvements

Merge SQ_POLL and fd registration

File buffers registration and IO_POLL

Switch to io_uring as default aio (if supported)

Ideas:

Switch main loop to io_uring

Thank you

Questions?


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