Virtio-blk Performance Improvement

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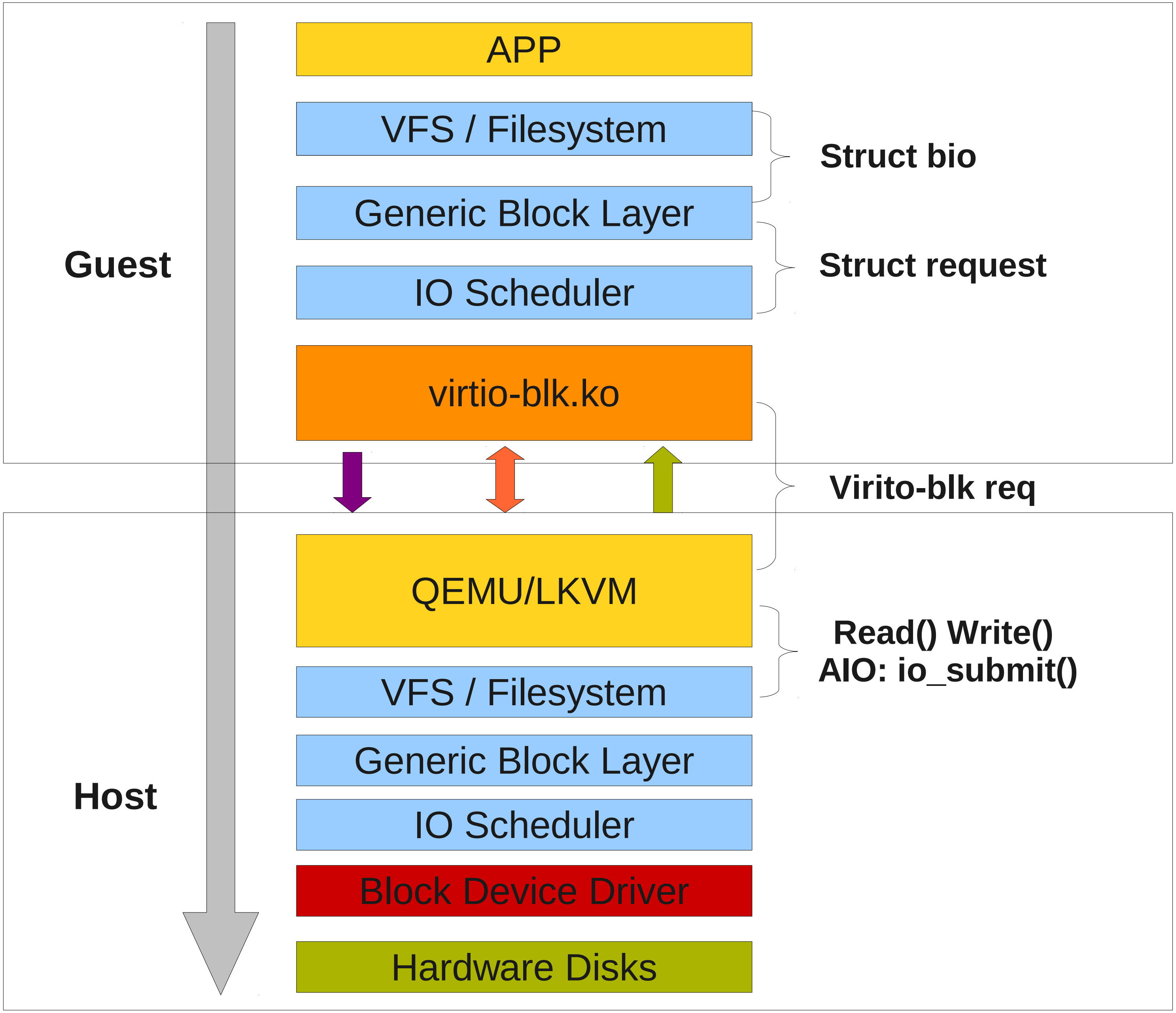
Storage transport choices in KVM

- Full virtualization : IDE, SATA, SCSI
    - Good guest compatibility
    - Lots of trap-and-emulate, bad performance
- Para virtualization: virtio-blk, virtio-scsi
    - Virtio ring buffer provides efficient transport for guest-host communication
    - Provide more virtualization friendly interface, higher performance
- Device assignment
    - Pass hardware to guest, high-end usage, high performance
    - Exclusive access, limited number of slot in a server, hard to do live migration

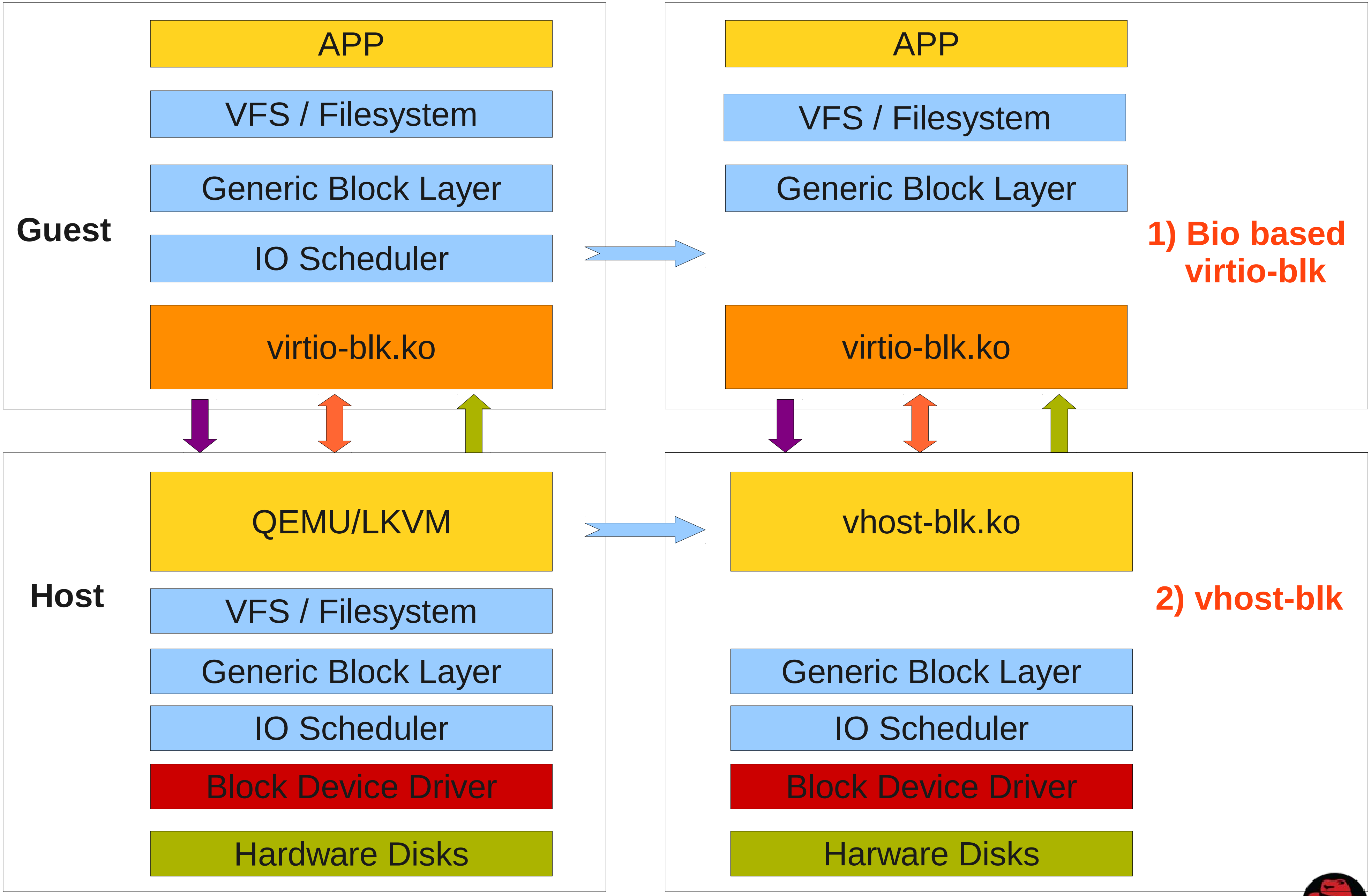
Why improve virtio-blk

- I/O intensive applications
  - Need high storage performance
- Virtio-blk
  - Simple, Just simple read/write/flush command, no scsi overhead, Fast SSD -> PCIE interface instead of SCSI or SATA interface
  - Available for a while, benefits existing users
  - virtio-blk is about ~3 times faster than virtio-scsi in my setup
- virtio-scsi
  - Rich features: True scsi device, Thousands of disks per virtio-scsi device, Effective SCSI passthrough

Lifecycle of a I/O request in virtio-blk



How to improve virtio-blk performance



Bio-based virtio-blk: What is it (1/2)

- Two types of block device dirvers
  - struct request based
    - Takes the advantages of I/O scheduler
    - Most drivers
  - struct bio based
    - Skips the I/O scheduler
    - Few drivers, e.g. Ramdisk driver

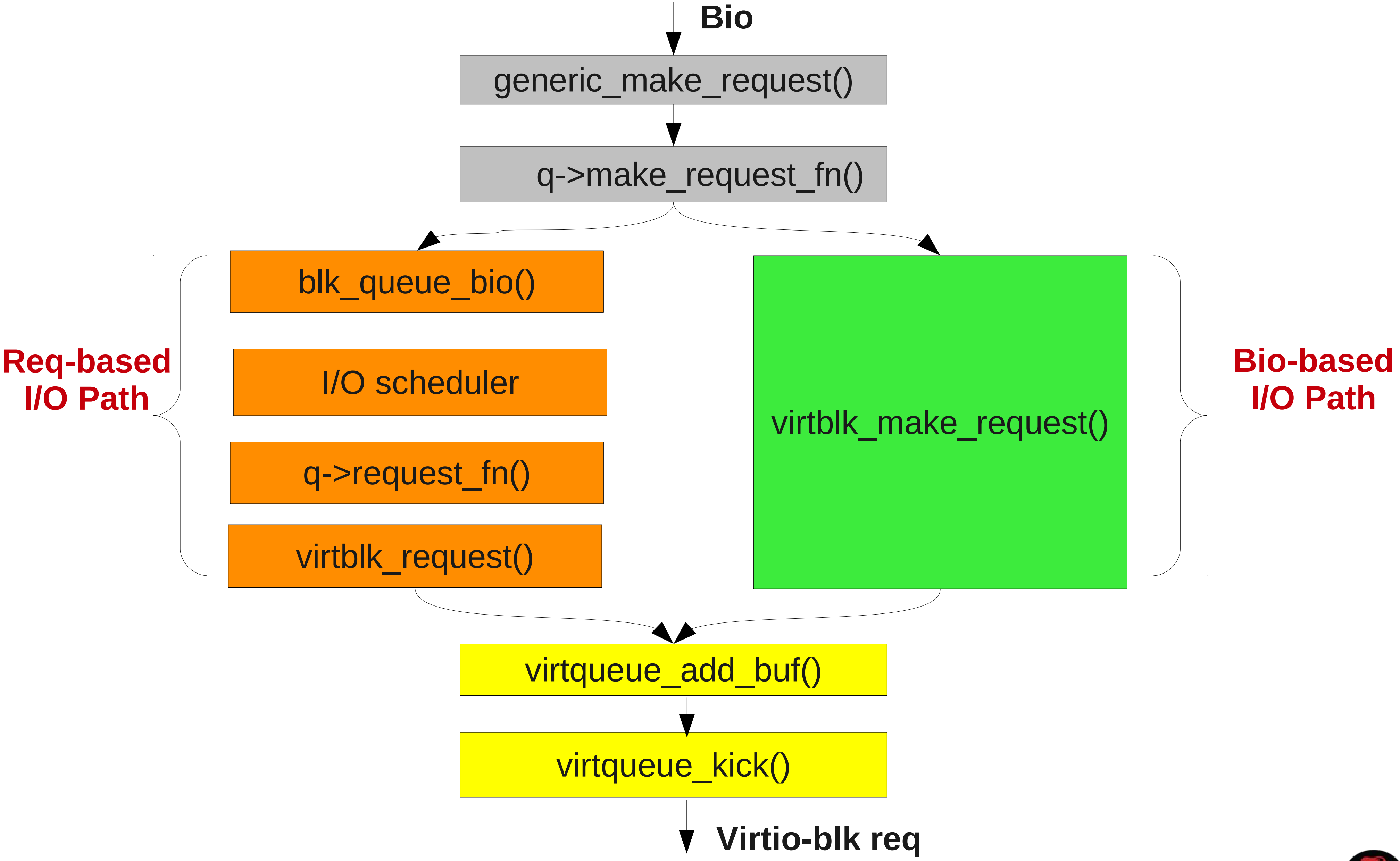
Bio-based virtio-blk: What is it (2/2)

- Vrito-blk block device driver
  - Reqeust-based virtio-blk (original)

Do we really need the I/O scheduling twice in both guest and host? (esp. with high speed SSD device)

  - Bio-based virtio-blk (new)
    - Adds bio based I/O path to virtio-blk
    - Shorten the I/O path in Guest
    - Less lock contention (q->queue_lock), lower cpu utilization
    - Higher IOPS
    - Lower Latency

Bio-based virtio-blk: Architecture

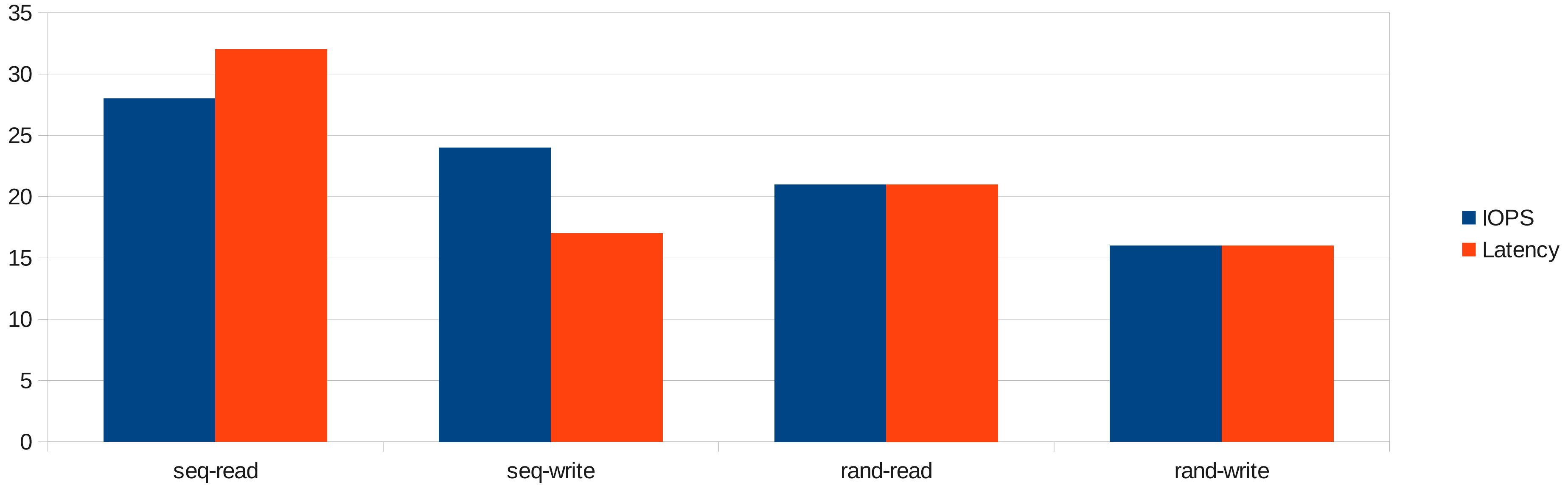


Bio-based virtio-blk: Performance evaluation 1

- 1) On Ramdisk device (fio test 8 vcpu, direct = 1)

  IOPS boost : 28%, 24%, 21%, 16%

  Latency improvement : 32%, 17%, 21%, 16%

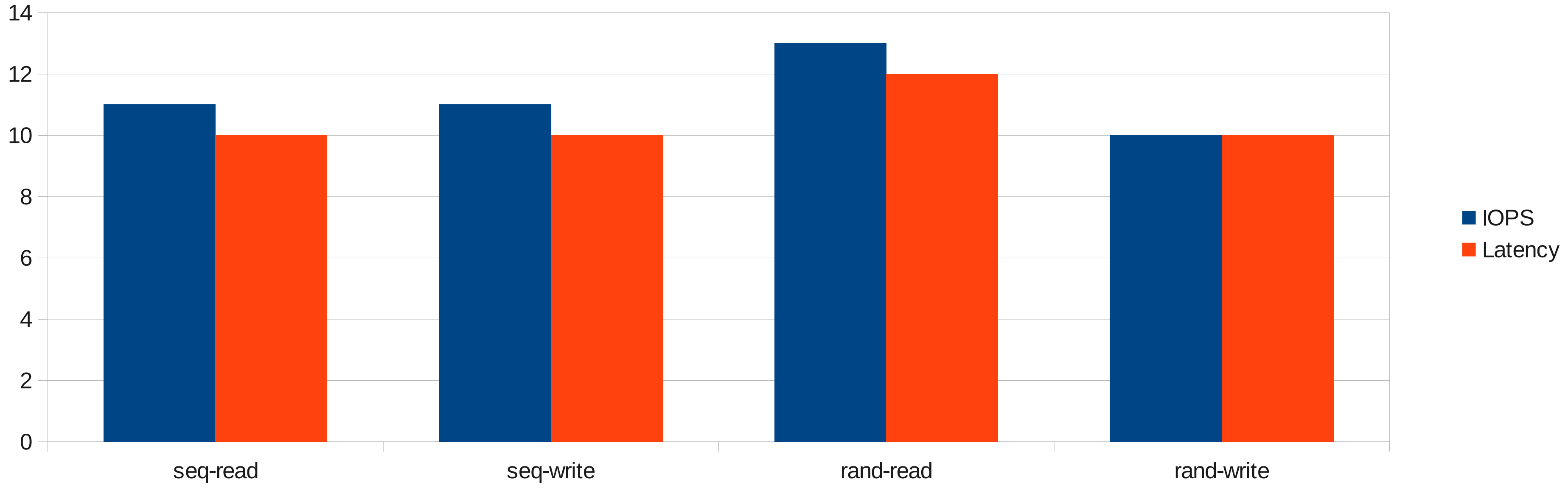


Bio-based virtio-blk: Performance evaluation 2

- 2) On Fusion-io device (fio test 8 vcpu, direct = 1)

  IOPS boost : 11%, 11%, 13%, 10%

  Latency improvement : 10%, 10%, 12%, 10%

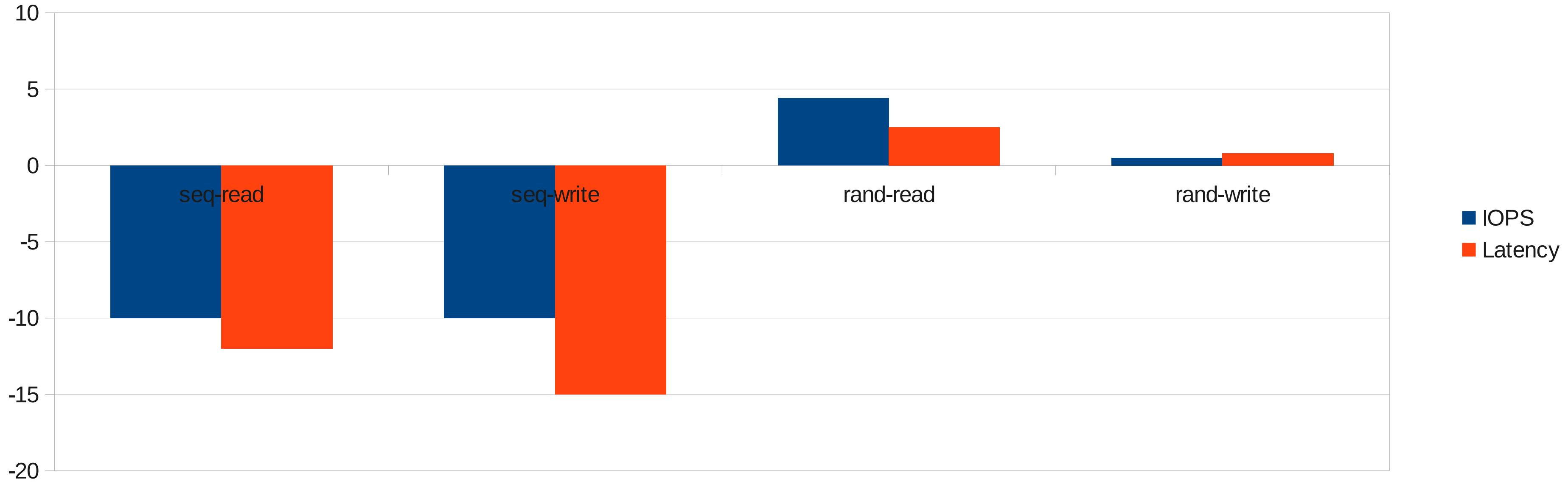


Bio-based virtio-blk: Performance evaluation 3

- 3) On Normal SATA device (fio test 8 vcpu, direct = 1)

  IOPS boost : -10%, -10%, 4.4%, 0.5%

  Latency improvement : -12%, -15%, 2.5%, 0.8%



Bio-based virtio-blk: How to use

- In mainline kernel already
    - Merged in v3.7 merge window
- No changes in host side are needed
- kernel module parameter to turn on/off bio-base path
    - Add 'virtio_blk.use_bio=1' to kernel cmdline
    - modprobe virtio_blk use_bio=1
    - Disabled by default

Bio-based virtio-blk: Limitations

- Doesn't help with slow device on seq read/write
  - Merge is very helpful for spin disks
    - Guest+Host scheduling make the merge more aggressive
  - Merge in guest reduces the total number of request to host and reduces number of VMexit
  - The benefit of scheduling is larger than bio path gives
- Features provided by I/O Schedule is not available
  - e.g. CFQ based blkio (Proportional BW Limit)
  - Block layer based blkio (Max BW Limit) works

Bio-based virtio-blk: Future work

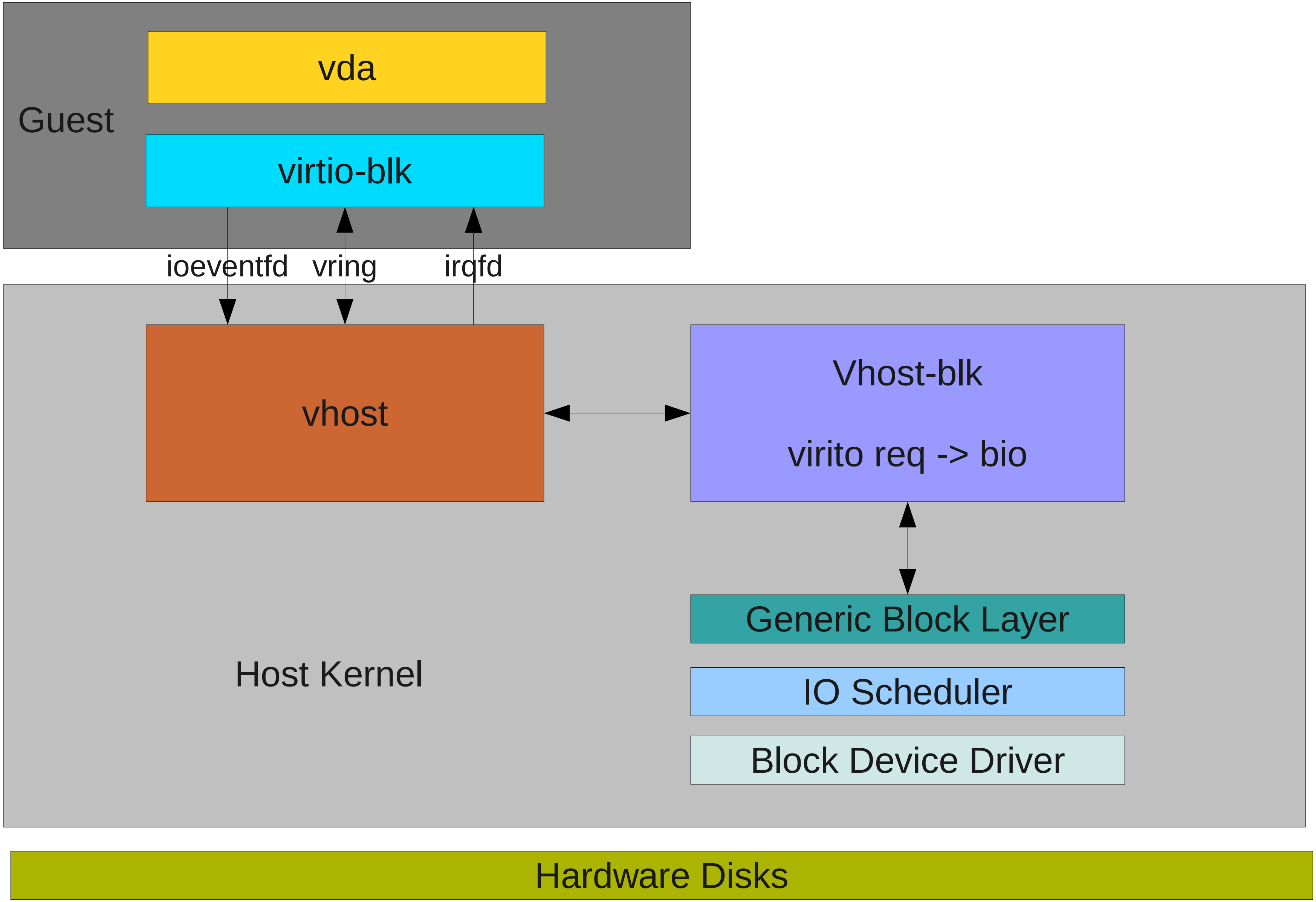
- Make it a feature bit in virtio-blk
  - Host can set the feature on/off
  - No need to configure inside the guest
- Make the decision of using bio-base I/O path or not automatically
  - Detect the underlay device
  - Choose the best I/O path
  - Zero configuration in both side

Vhost-blk: Overview

Host side virtio-blk implementations

- 1) QEMU current
  - QEMU global mutex: only one thread can submit I/O
  - In AIO case, io_submit() is under the global mutex
- 2) QEMU data-plane (prototype)
  - Developed by Stefan Hajnoczi
  - 1) Each virtio-blk device has a thread dedicated to handle request
  - 2) Requests are processed without going through the QEMU block layer using Linux AIO directly.
  - 3) Completion interrupts are injected via ioctl from the dedicated thread.
- 3) LKVM (aka kvm tool)
  - Using data-plane similar architecture from the very beginning
- 4) Vhost-blk (prototype)
  - vhost-blk is an in-kernel virtio-blk device accelerator, similar to vhost-net

Vhost-blk: Architecture



Vhost-blk: Implementation

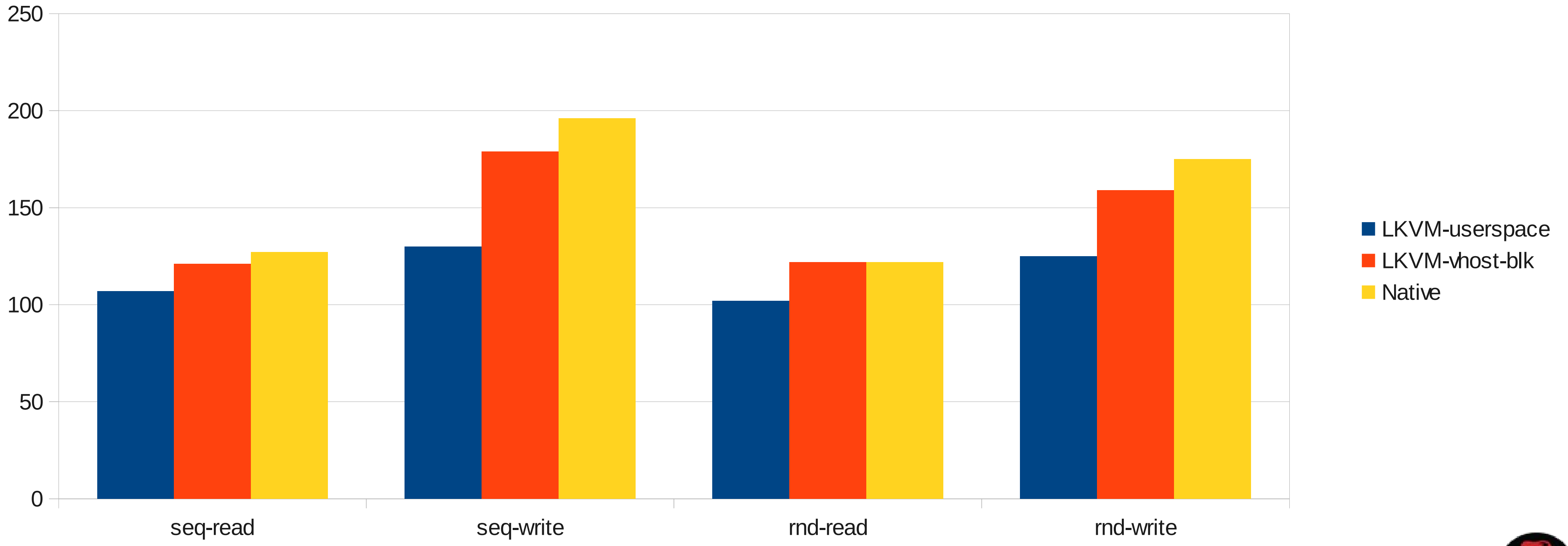
- Using vhost infrastructure
- Send request
    - vhost-<pid> kernel thread to send request
        - created by vhost infrastructure
    - Convert guest's virtio-blk requests to bio
        - get_user_pages_fast() to convert iov based request to page
        - bio_add_page() to prepare the bio
        - set bio->bi_end_io = vhost_blk_req_done as bio completion callback
    - Use submit_bio() to submit the bio to host kernel block layer
- Complete request
    - vhost-blk-<pid> kernel thread to complete request
        - Do request and complete in parallel
    - Uses irqfd to inject interrupt to guest

Vhost-blk: Performance evaluation 1

- **LKVM-userspace v.s LKVM-vhost-blk**

Fio with libaio ioengine on Fusion IO device using LKVM

IOPS(K)	userspace	vhost-blk	Improvement	Native
seq-read	107	121	+13.0%	127
seq-write	130	179	+37.6%	196
rnd-read	102	122	+19.6%	122
rnd-write	125	159	+27.0%	175

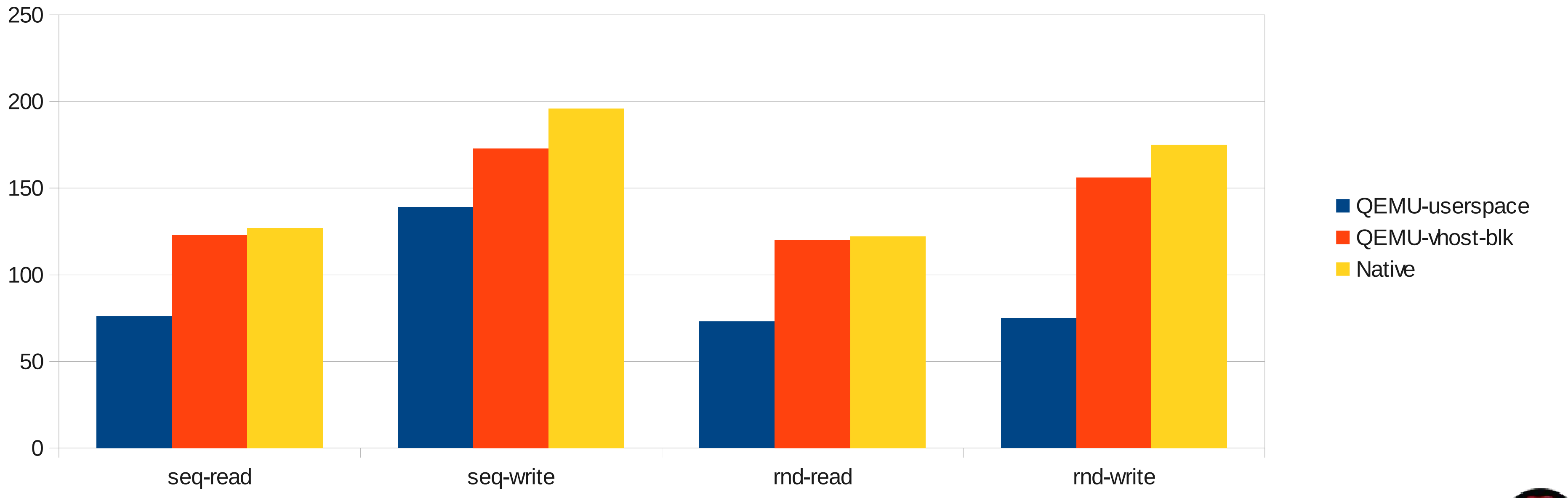


Vhost-blk: Performance evaluation 2

- **QEMU-userspace v.s QEMU-vhost-blk**

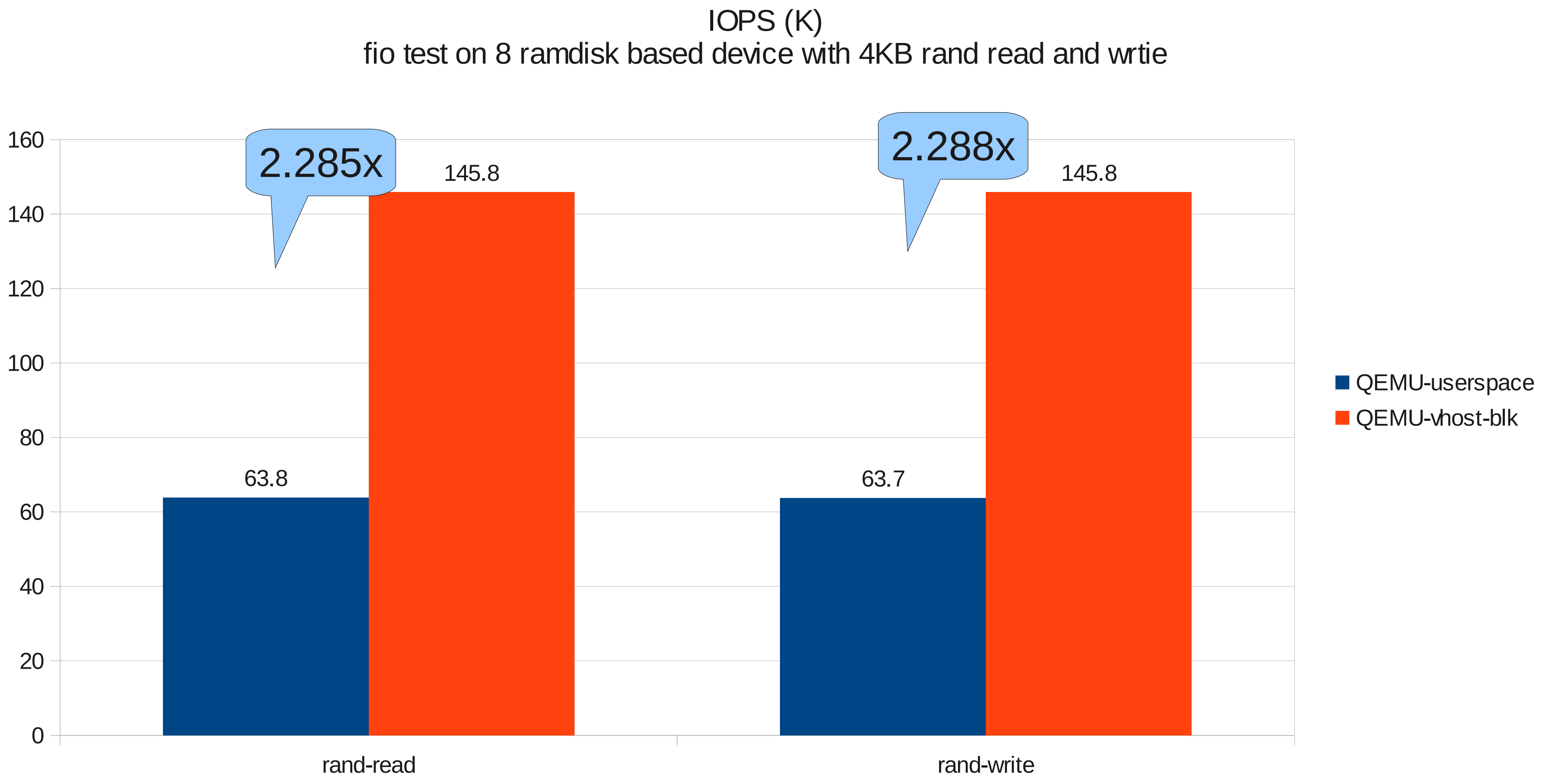
Fio with libaio ioengine on Fusion IO device using QEMU

IOPS(K)	userspace	vhost-blk	Improvement	Native
seq-read	76	123	+61.0%	127
seq-write	139	173	+24.4%	196
rnd-read	73	120	+64.3%	122
rnd-write	75	156	+108.0%	175



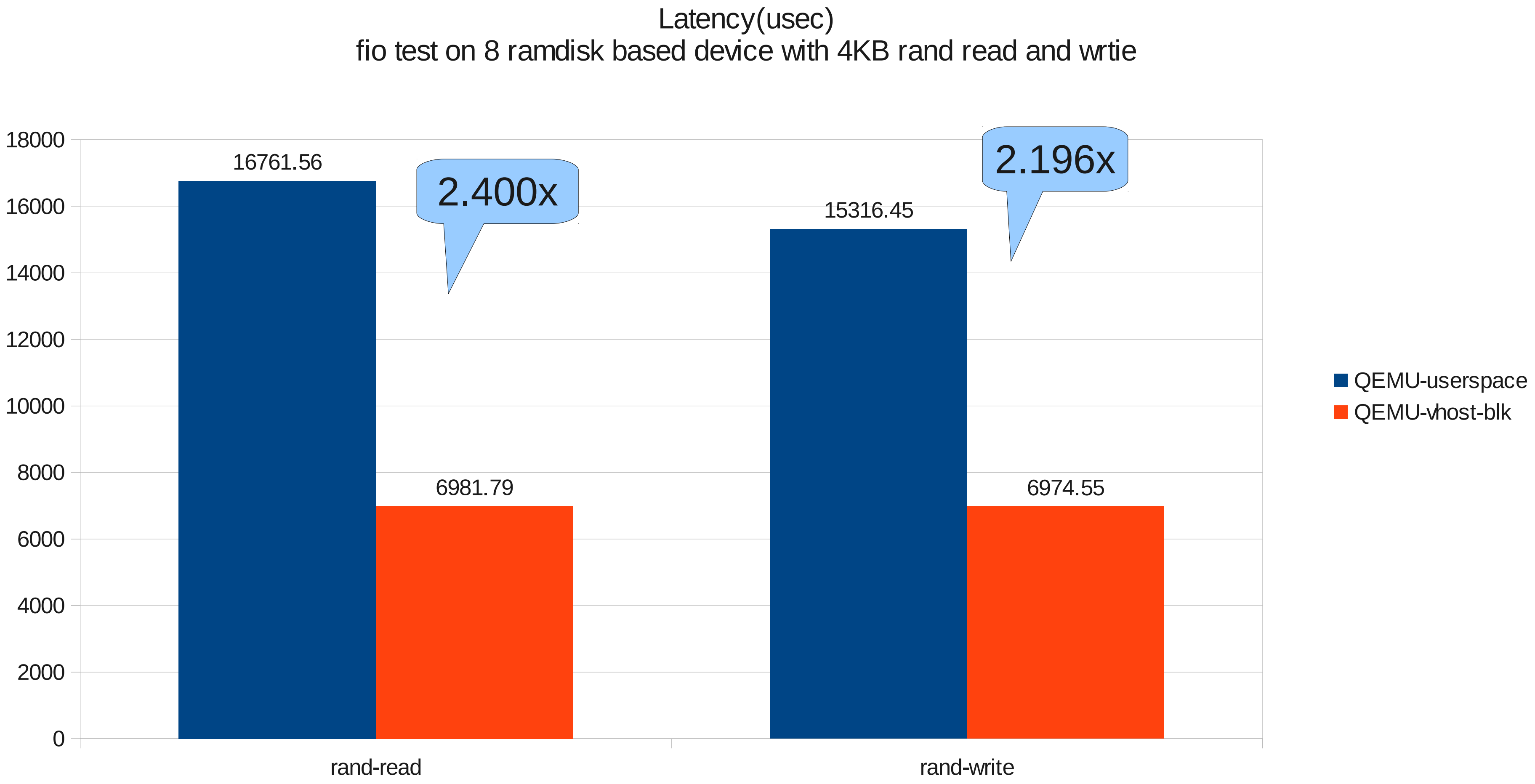
Vhost-blk: Performance evaluation 3

- **QEMU-userspace v.s QEMU-vhost-blk**



Vhost-blk: Performance evaluation 4

- **QEMU-userspace v.s QEMU-vhost-blk**



Vhost-blk: Why

- No QEMU userspace, No QEMU global mutex
- Code path is shorter
  - Guest talks to host kernel directly
  - Host kernel BIO interface
- Save a bunch of system calls
  - epoll_wait() & read(): wait for the eventfd which guest notifies us
  - io_submit(): submit the aio
  - read(): read the aio complete eventfd
  - io_getevents(): reap the aio complete result
  - ioctl(): trigger the interrupt
- Benefits to all KVM implementation
  - e.g. Both QEMU and LKVM

Vhost-blk: How to use

- Source Code
  - KERNEL
    - git@github.com:asias/linux.git blk.vhost-blk
  - LKVM
    - git@github.com:asias/linux-kvm.git blk.vhost-blk
  - QEMU
    - git@github.com:asias/qemu.git blk.vhost-blk
- Cmdline

```
$ sudo modprobe vhost-blk
$ sudo lkvm run -d /dev/sdb,vhost
$ sudo qemu -drive \
  file=/dev/sdb,if=virtio,cache=none,aio=native,vhost=on
```

Vhost-blk: Limitations & Future work

- Only support raw image format
  - No other image format support, e.g. Qcow2
- No file based image support currently
  - Lack of proper in-kernel aio interface
    - bio interface is used in current version
    - Raw block device only
    - /dev/sda, /dev/VolGroup/LogicalVolume
  - Once the work-in-progress in-kernel aio interface goes to mainline (Zach Brown and Dave Kleikamp)
    - it's easy to support raw file based image
- No migration support

Future work

- Multiqueue virtio-blk support
  - Jens' multiqueue linux block layer <-> multiqueue virtio
- More performance test and analysis
  - Different storage configurations / workload

Thanks for listening!

Comments / Questions ?