Improving the QEMU Event Loop

Fam Zheng
Red Hat

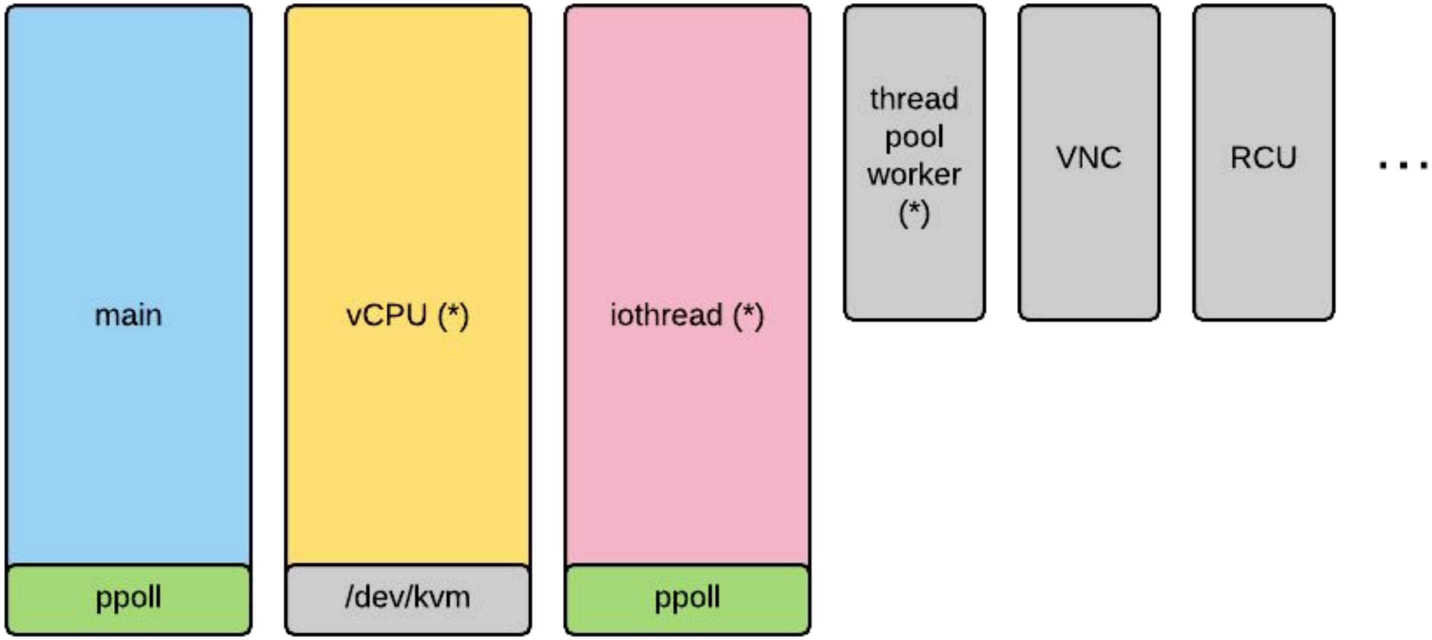
KVM Forum 2015

Agenda

- The event loops in QEMU
- Challenges
  - Consistency
  - Scalability
  - Correctness

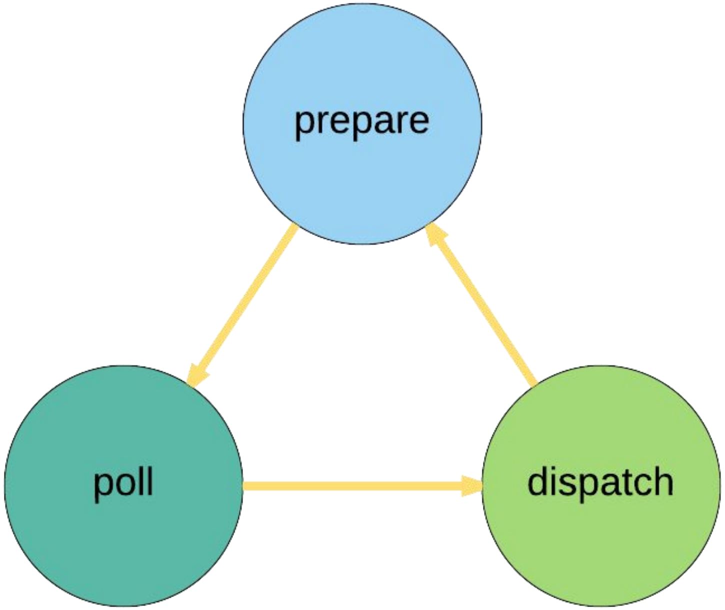
The event loops in QEMU

QEMU from a mile away



Main loop from 10 meters

- The "original" iothread
- Dispatches fd events
  - **aio**: block I/O, ioeventfd
  - **iohandler**: net, nbd, audio, ui, vfio, ...
  - **slirp**: -net user
  - **chardev**: -chardev XXX
- Non-fd services
  - **timers**
  - **bottom halves**



Main loop in front

- **Prepare**

```
slirp_pollfds_fill(gpollfd, &timeout)
qemu_iohandler_fill(gpollfd)
timeout = qemu_soonest_timeout(timeout,
                               timer_deadline)
glib_pollfds_fill(gpollfd, &timeout)
```

- **Poll**

```
qemu_poll_ns(gpollfd, timeout)
```

- **Dispatch**
  - **fd, BH, aio timers**

```
glib_pollfds_poll()
qemu_iohandler_poll()
slirp_pollfds_poll()
```

  - **main loop timers**

```
qemu_clock_run_all_timers()
```

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Main loop under the surface - iohandler

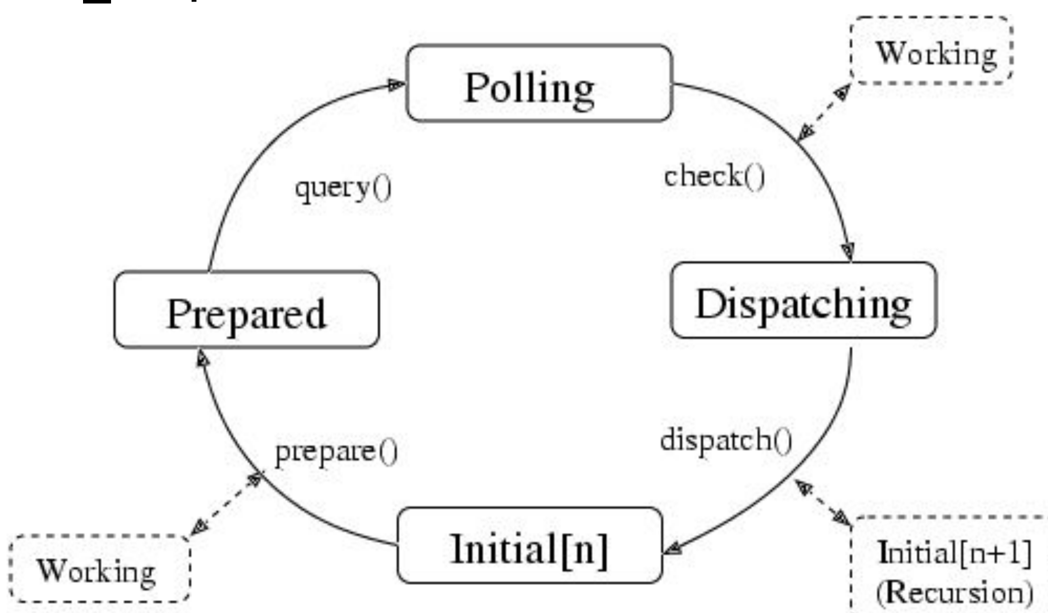
- Fill phase
  - Append *fds* in *io_handlers* to *gpollfd*
    - *those registered with qemu_set_fd_handler()*
- Dispatch phase
  - Call fd_read callback if (revents & G_IO_IN)
  - Call fd_write callback if (revents & G_IO_OUT)

Main loop under the surface - slirp

- Fill phase
  - For each slirp instance ("-netdev user"), append its socket fds if:
    - **TCP** accepting, connecting or connected
    - **UDP** connected
    - **ICMP** connected
  - Calculate timeout for connections
- Dispatch phase
  - Check timeouts of each socket connection
  - Process fd events (incoming packets)
  - Send outbound packets

Main loop under the surface - glib

- Fill phase
  - g_main_context_prepare
  - g_main_context_query
- Dispatch phase
  - g_main_context_check
  - g_main_context_dispatch



GSource - chardev

- IOWatchPoll
  - Prepare
    - g_io_create_watch or g_source_destroy
    - return FALSE
  - Check
    - FALSE
  - Dispatch
    - abort()

- IOWatchPoll.src
  - Dispatch
    - iwp->fd_read()

GSource - aio context

- Prepare
  - compute timeout for aio timers

- Dispatch
  - BH
  - fd events
  - timers

iothread (dataplane)

Equals to aio context in the main loop GSource...

except that "prepare, poll, check, dispatch" are all wrapped in aio_poll().

```
while (!iothread->stopping) {
    aio_poll(iothread->ctx, true);
}
```

Nested event loop

- Block layer synchronous calls are implemented with nested aio_poll(). E.g.:

```
void bdrv_aio_cancel(BlockAIOCB *acb)
{
    qemu_aio_ref(acb);
    bdrv_aio_cancel_async(acb);
    while (acb->refcnt > 1) {
        if (acb->aiocb_info->get_aio_context) {
            aio_poll(acb->aiocb_info->get_aio_context(acb),
                     true);
        } else if (acb->bs) {
            aio_poll(bdrv_get_aio_context(acb->bs), true);
        } else {
            abort();
        }
    }
    qemu_aio_unref(acb);
}
```

A list of block layer sync functions

- bdrv_drain
- bdrv_drain_all
- bdrv_read / bdrv_write
- bdrv_pread / bdrv_pwrite
- bdrv_get_block_status_above
- bdrv_aio_cancel
- bdrv_flush
- bdrv_discard
- bdrv_create
- block_job_cancel_sync
- block_job_complete_sync

Example of nested event loop (drive-backup call stack from gdb):

#0 **aio_poll**
#1 bdrv_create
#2 **bdrv_img_create**
#3 **qmp_drive_backup**
#4 qmp_marshal_input_drive_backup
#5 handle_qmp_command
#6 json_message_process_token
#7 json_lexer_feed_char
#8 json_lexer_feed
#9 json_message_parser_feed
#10 **monitor_qmp_read**
#11 qemu_chr_be_write
#12 **tcp_chr_read**
#13 g_main_context_dispatch
#14 **glib_pollfds_poll**
#15 os_host_main_loop_wait
#16 main_loop_wait
#17 main_loop
#18 main

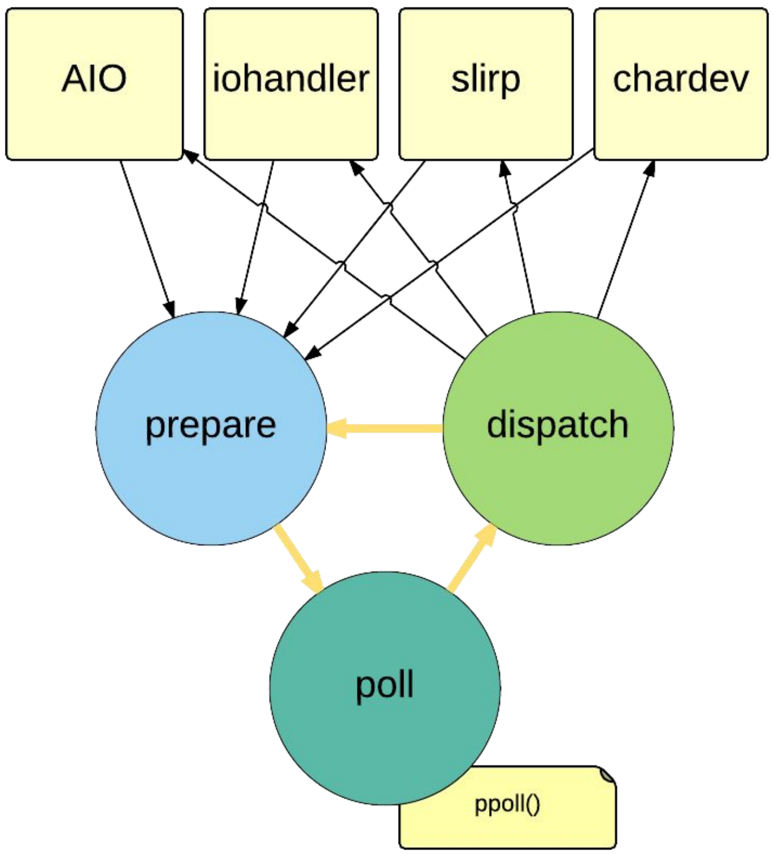
Challenge #1: consistency

	main loop	dataplane iothread
interfaces	iohandler + slirp + chardev + aio	aio
enumerating fds	g_main_context_query() + ppoll()	add_pollfd() + ppoll()
synchronization	BQL + aio_context_acquire(other)	aio_context_acquire(self)
GSource support	Yes	No

Challenges

Challenge #1: consistency

- Why bother?
  - The main loop is a hacky mixture of various stuff.
  - Reduce code duplication. (e.g. iohandler vs aio)
  - Better performance & scalability!

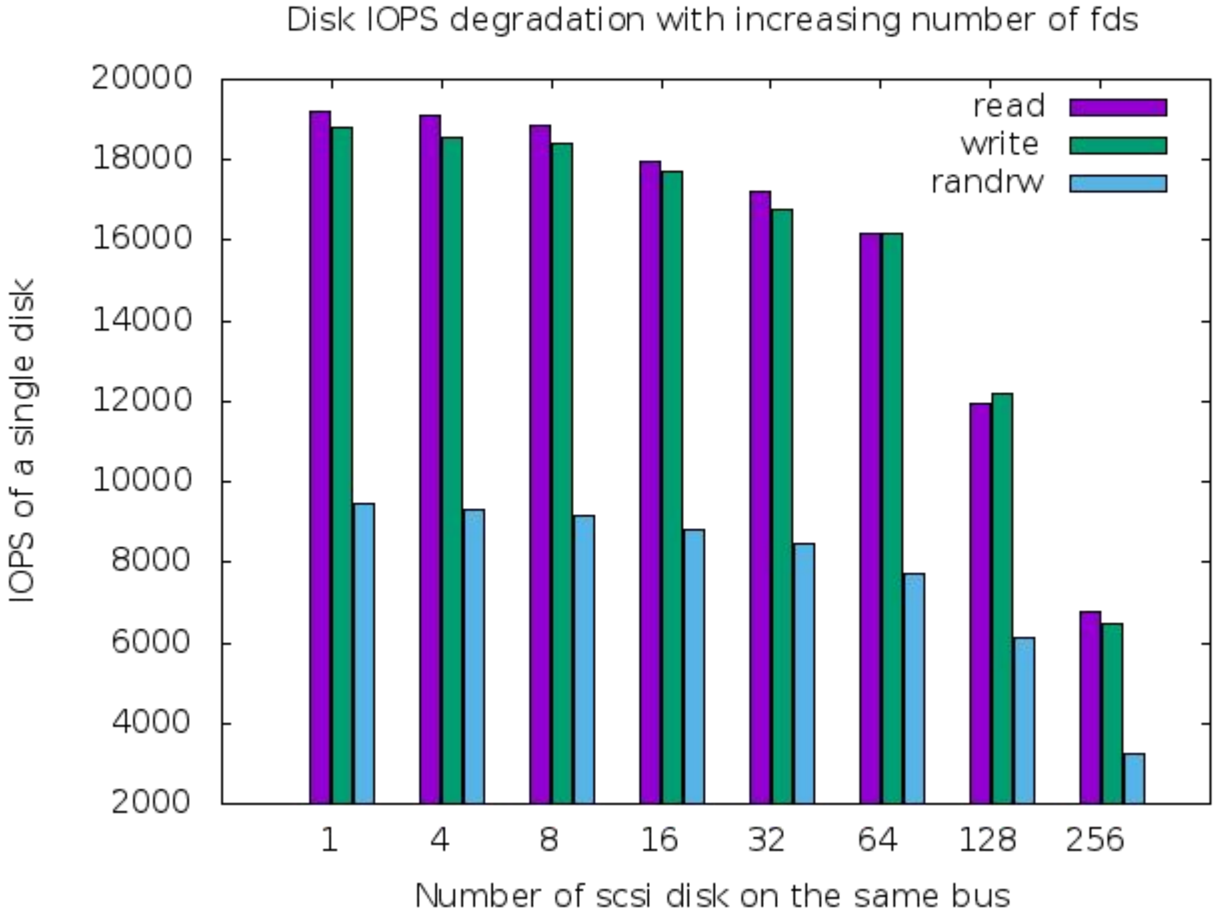


Challenge #2: scalability

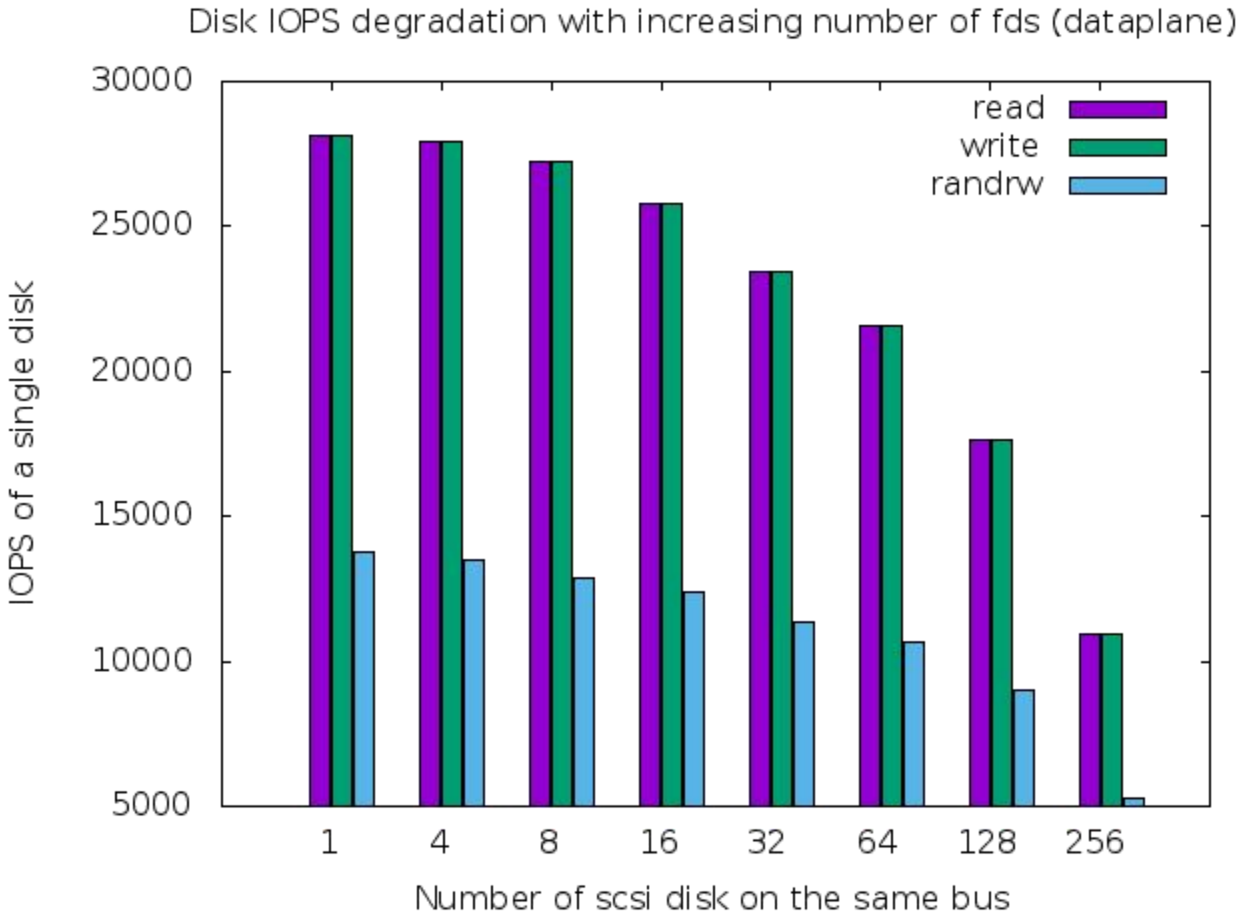
- The loop runs slower as more fds are polled
  - *_pollfds_fill() and add_pollfd() take longer.
  - qemu_poll_ns() (ppoll(2)) takes longer.
  - dispatch walking through more nodes takes longer.

$O(n)$

Benchmarking virtio-scsi on ramdisk



virtio-scsi-dataplane



Solution: epoll

*"epoll is a variant of poll(2) that can be used either as Edge or Level Triggered interface and **scales well to large numbers of watched fds**."*

- epoll_create
- epoll_ctl
  - EPOLL_CTL_ADD
  - EPOLL_CTL_MOD
  - EPOLL_CTL_DEL
- epoll_wait

- *Doesn't fit in current main loop model :(*

Solution: epoll

- Cure: aio interface is similar to epoll!
- Current aio implementation:

  – aio_set_fd_handler(ctx, fd, ...)
    aio_set_event_notifier(ctx, notifier, ...)

  Handlers are tracked by ***ctx->aio_handlers.***

  – aio_poll(ctx)

  Iterate over ***ctx->aio_handlers*** *to build pollfds[].*

Solution: epoll

- New implemenation:

  - aio_set_fd_handler(ctx, fd, ...)
  - aio_set_event_notifier(ctx, notifier, ...)

  Call *epoll_ctl(2)* to update epollfd.

  - aio_poll(ctx)

  Call *epoll_wait(2).*

- *RFC patches posted to qemu-devel list:* *http://lists.nongnu.org/archive/html/qemu-block/2015-06/msg00882.html*

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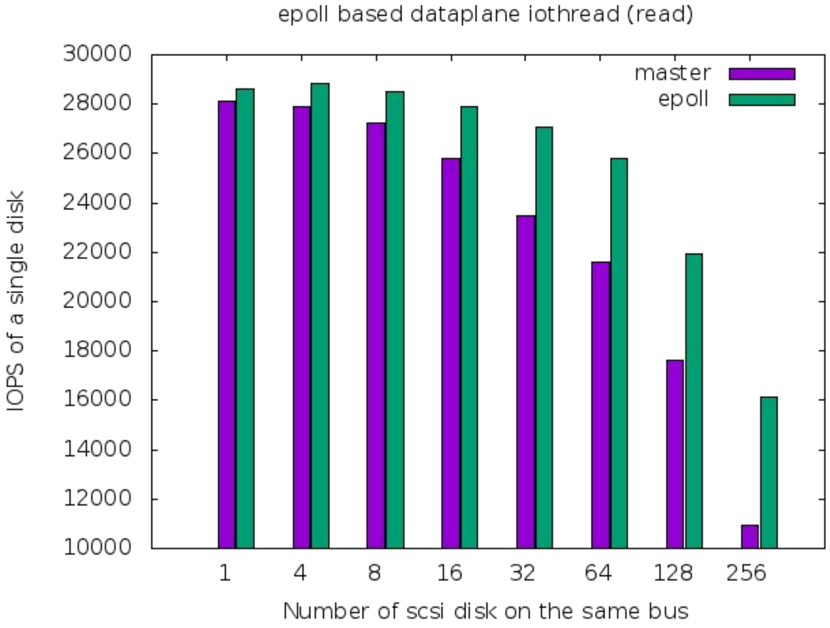
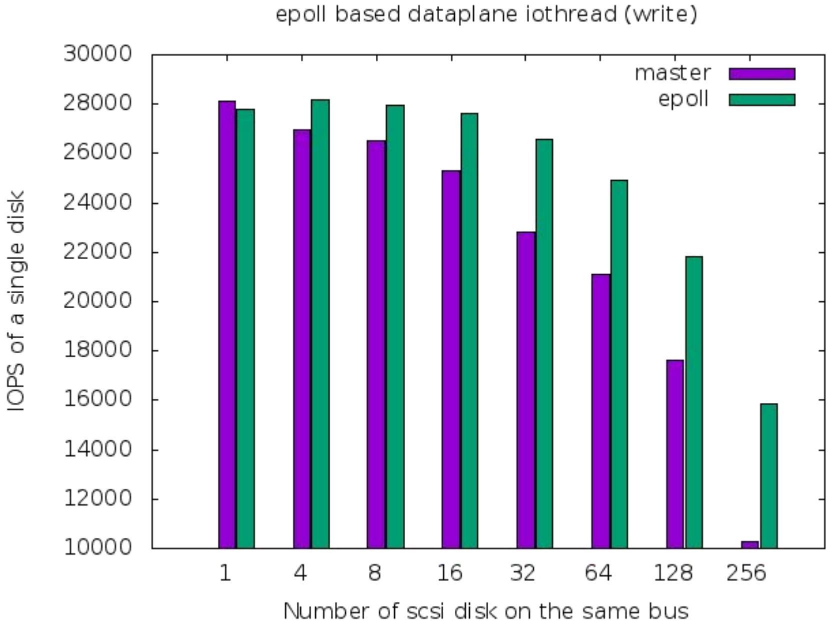
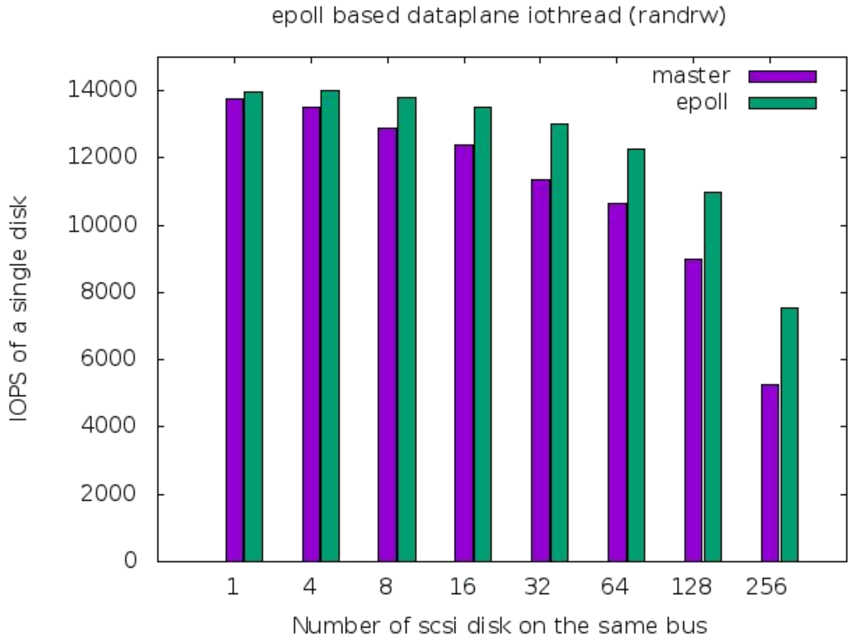


epoll based dataplane iothread (read)
master
epoll
IOPS of a single disk
Number of scsi disk on the same bus



epoll based dataplane iothread (write)
master
epoll
IOPS of a single disk
Number of scsi disk on the same bus



epoll based dataplane iothread (randrw)
master
epoll
IOPS of a single disk
Number of scsi disk on the same bus

Challenge #2½: epoll timeout

- Timeout in epoll is in ms

```
int ppoll(struct pollfd *fds, nfds_t nfds,
          const struct timespec *timeout_ts,
          const sigset_t *sigmask);

int epoll_wait(int epfd,
               struct epoll_event *events,
               int maxevents,
               int timeout);
```

- But nanosecond granularity is required by the timer API!

Solution #2½: epoll timeout

- Timeout precision is kept by combining timerfd:

1. Begin with a timerfd added to epollfd.
2. Update the timerfd before epoll_wait().
3. Do epoll_wait with timeout=-1.

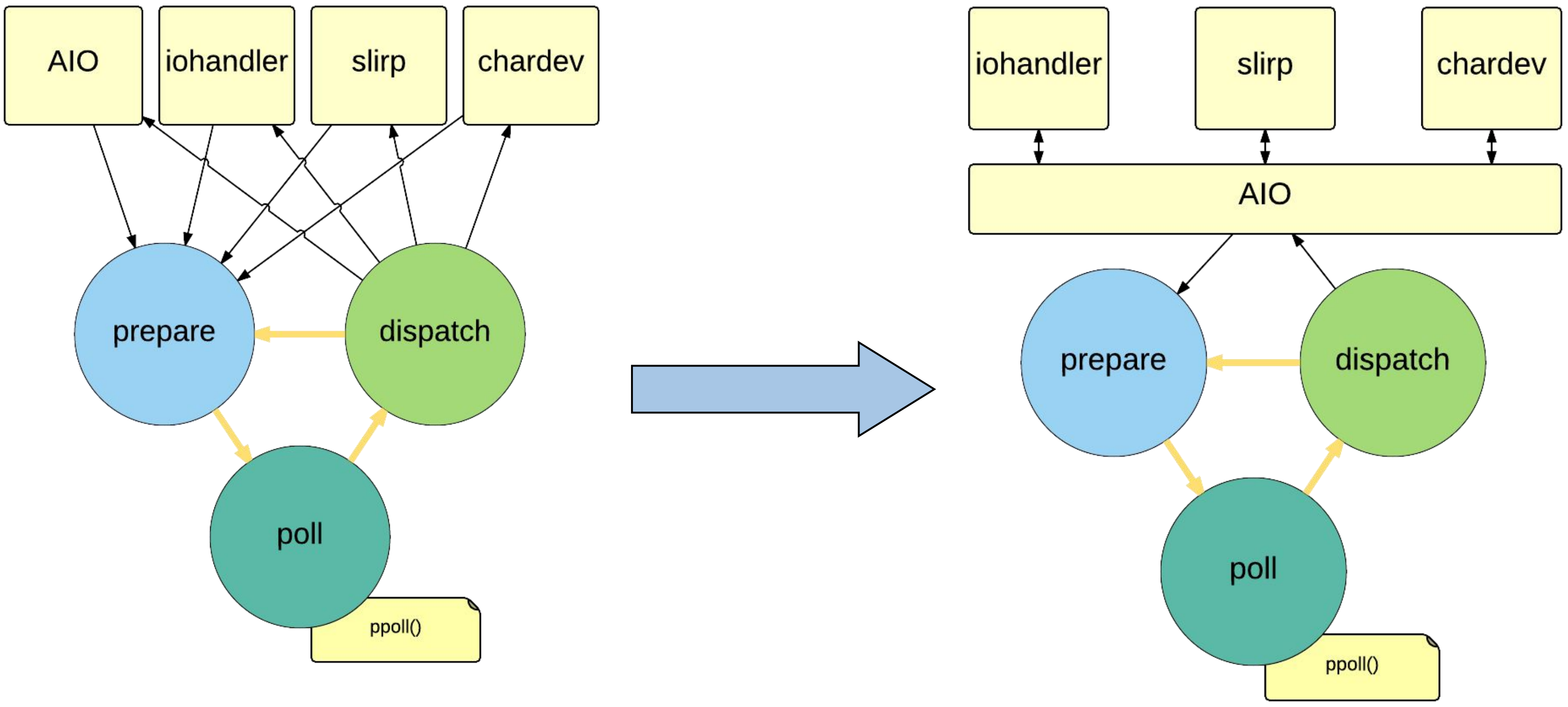
Solution: epoll

- If AIO can use epoll, what about main loop?
- Rebase main loop ingredients on to aio
  - I.e. Resolve challenge #1!

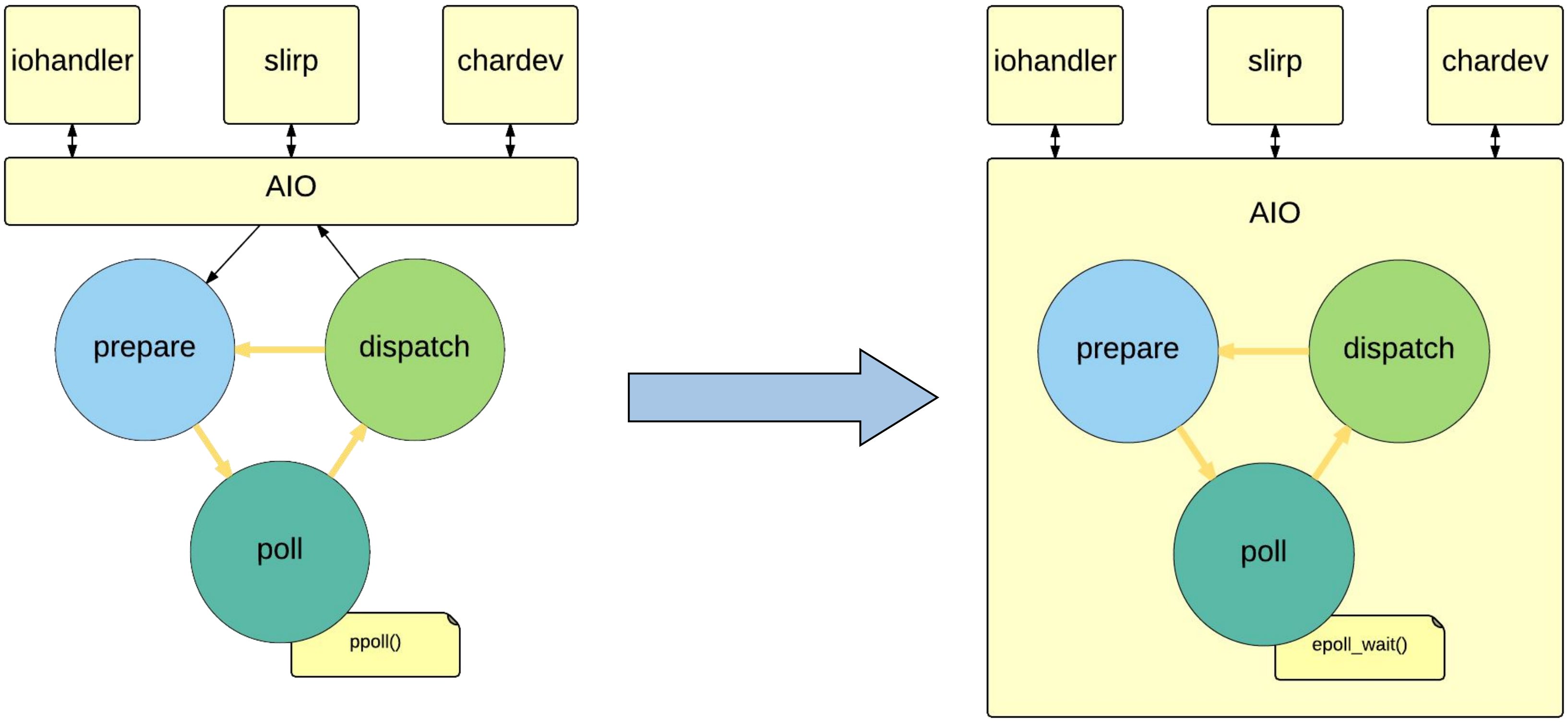
Solution: consistency

- Rebase all other ingredients in main loop onto AIO:
  1. Make iohandler interface consistent with aio interface by dropping fd_read_poll. [done]
  2. Convert slirp to AIO.
  3. Convert iohandler to AIO.
     [PATCH 0/9] slirp: iohandler: Rebase onto aio
  4. Convert chardev GSource to aio or an equivilant interface. [TODO]

Unify with AIO



Next step: Convert main loop to use aio_poll()



Challenge #3: correctness

- Nested aio_poll() may process events when it shouldn't

  E.g. do QMP transaction when guest is busy writing

1. drive-backup device=d0

   bdrv_img_create("img1")

   -> aio_poll()

2. guest write to virtio-blk "d1": ioeventfd is readable

3. drive-backup device=d1

   bdrv_img_create("img2")

   -> aio_poll() /* qmp transaction broken! */

...

Solution: aio_client_disable/enable

- Don't use nested aio_poll(), or...
- Exclude ioeventfds in nested aio_poll():

```
aio_client_disable(ctx, DATAPLANE)
op1->prepare(), op2->prepare(), ...
op1->commit(), op2->commit(), ...
aio_client_enable(ctx, DATAPLANE)
```

Thank you!