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Xen and XenServer Storage Performance

Low Latency Virtualisation Challenges

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Agenda

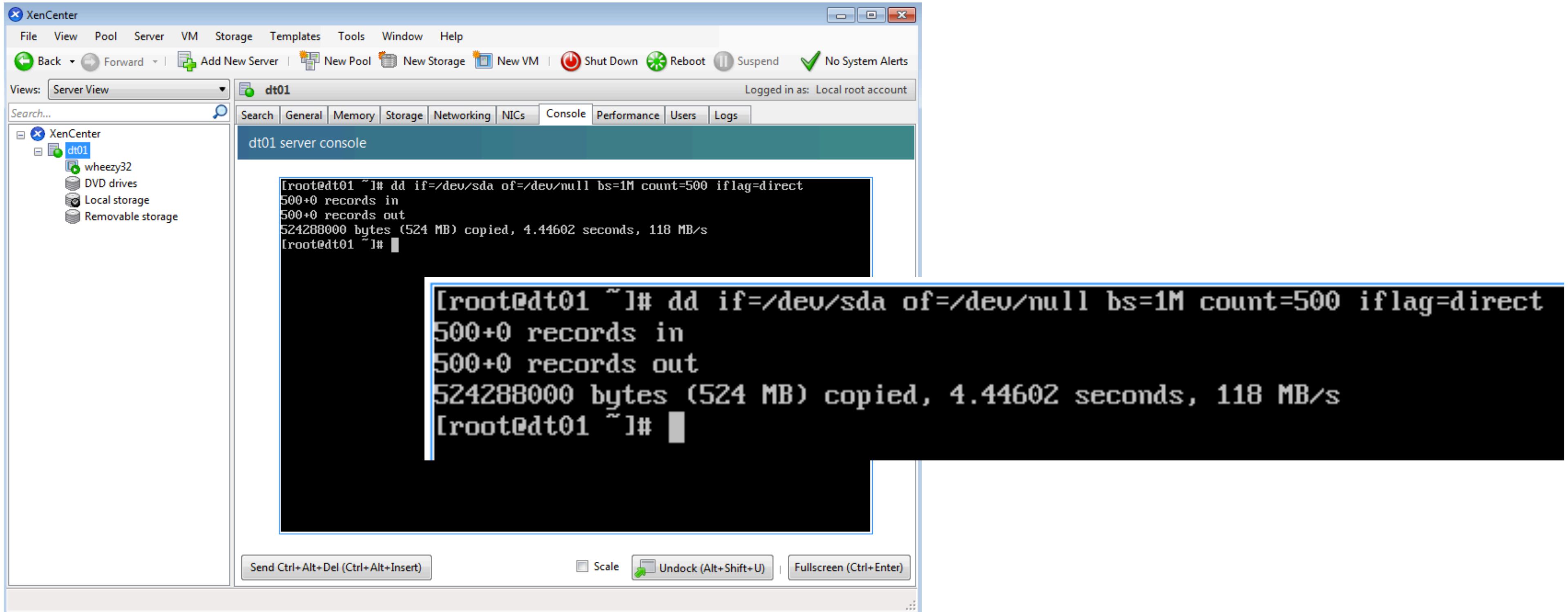
- Where do Xen and XenServer stand?
  - When is the virtualisation overhead most noticeable?
- Current implementation:
  - blkfront, blkback, blktap2+tapdisk, blktap3, qemu-qdisk
- Measurements over different back ends
  - Throughput and latency analysis
  - Latency breakdown: where are we losing time when virtualising?
- Proposals for improving

Where do
Xen and XenServer Stand?

When is the virtualisation overhead noticeable?

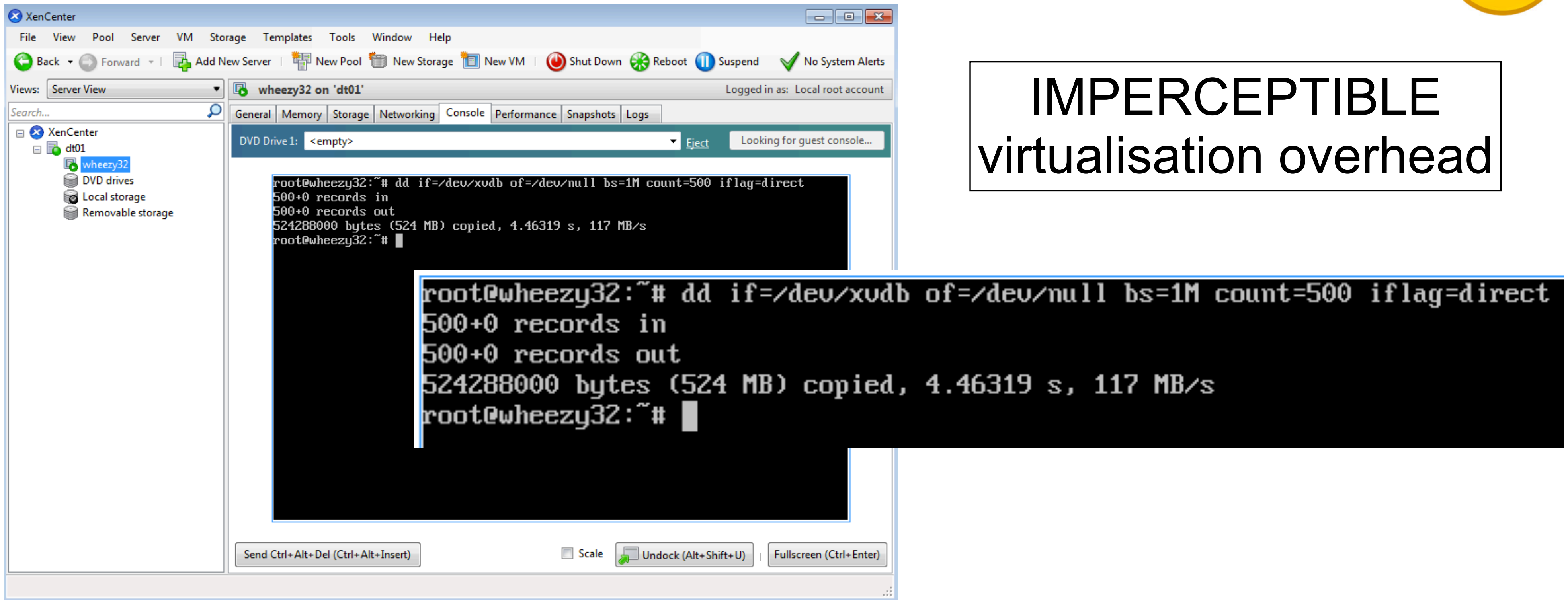
Where do Xen and XenServer stand?

- What kind of throughput can I get from dom0 to my device?
  - Using 1 MiB reads, this host reports 118 MB/s from dom0



Where do Xen and XenServer stand?

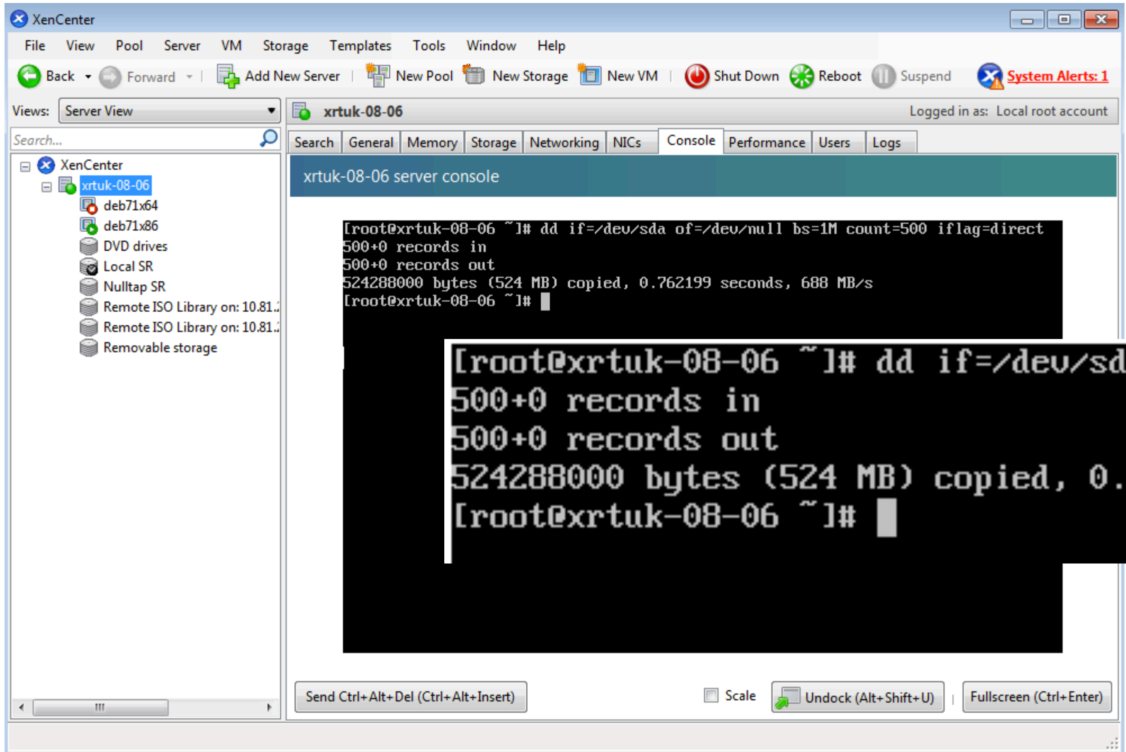
- What kind of throughput can I get from domU to my device?
  - Using 1 MiB reads, this host reports 117 MB/s from a VM

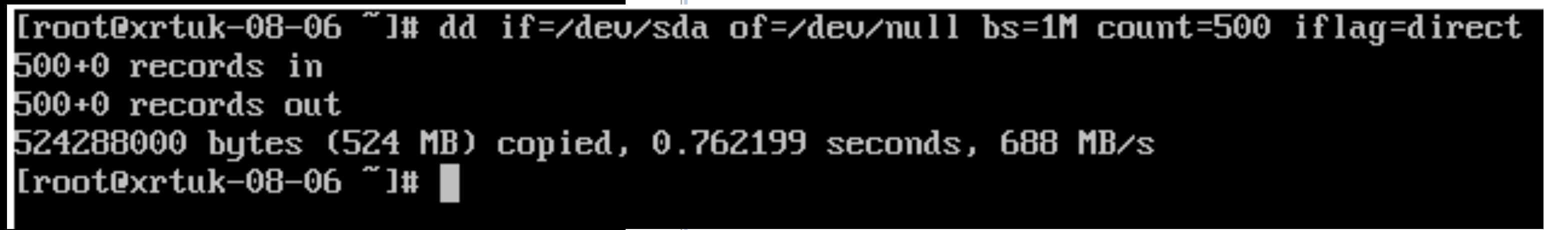


IMPERCEPTIBLE virtualisation overhead

Where do Xen and XenServer stand?

- That’s not always the case...
  - Same test on different hardware (from dom0)





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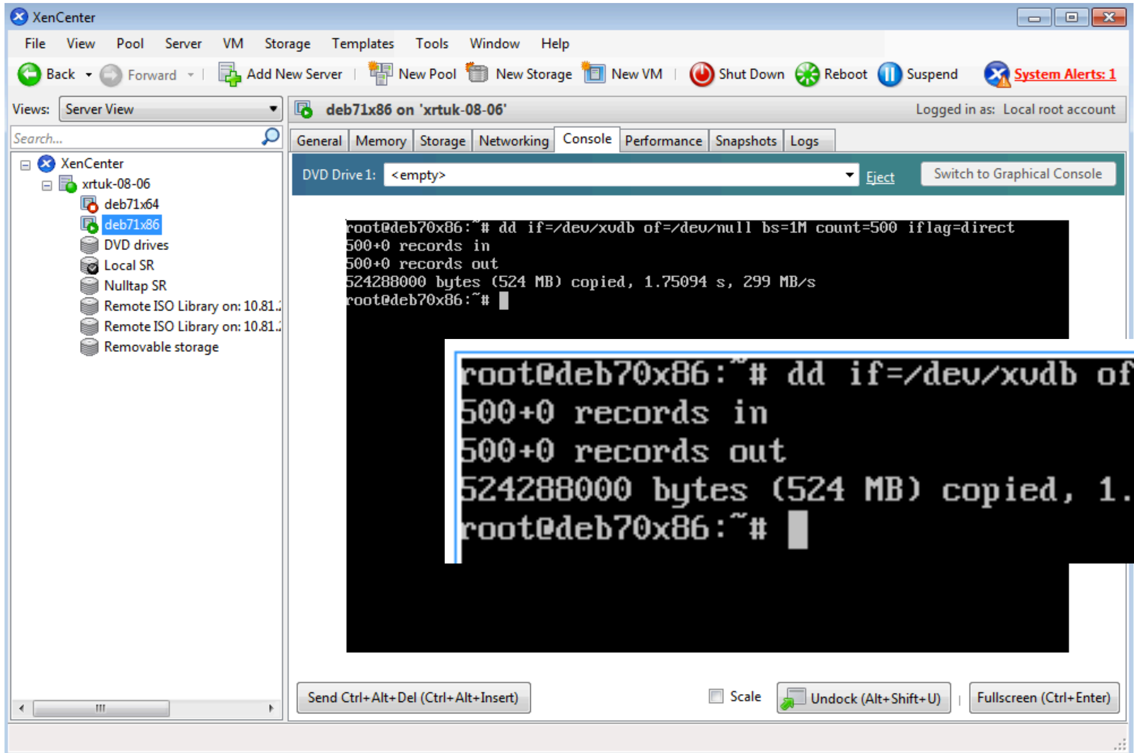
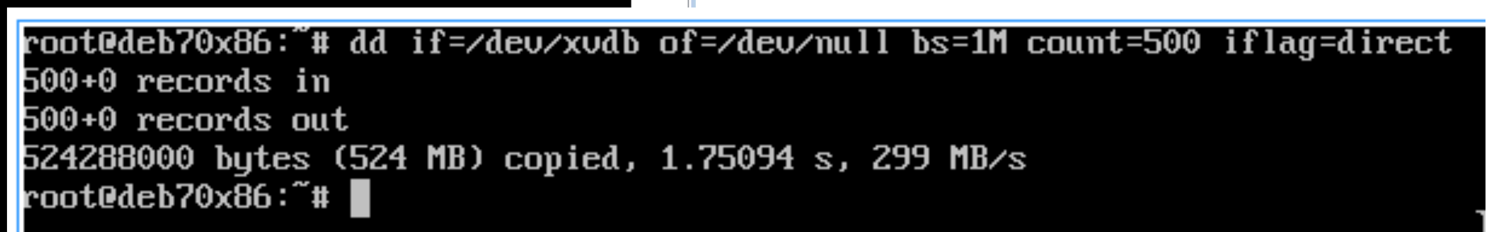




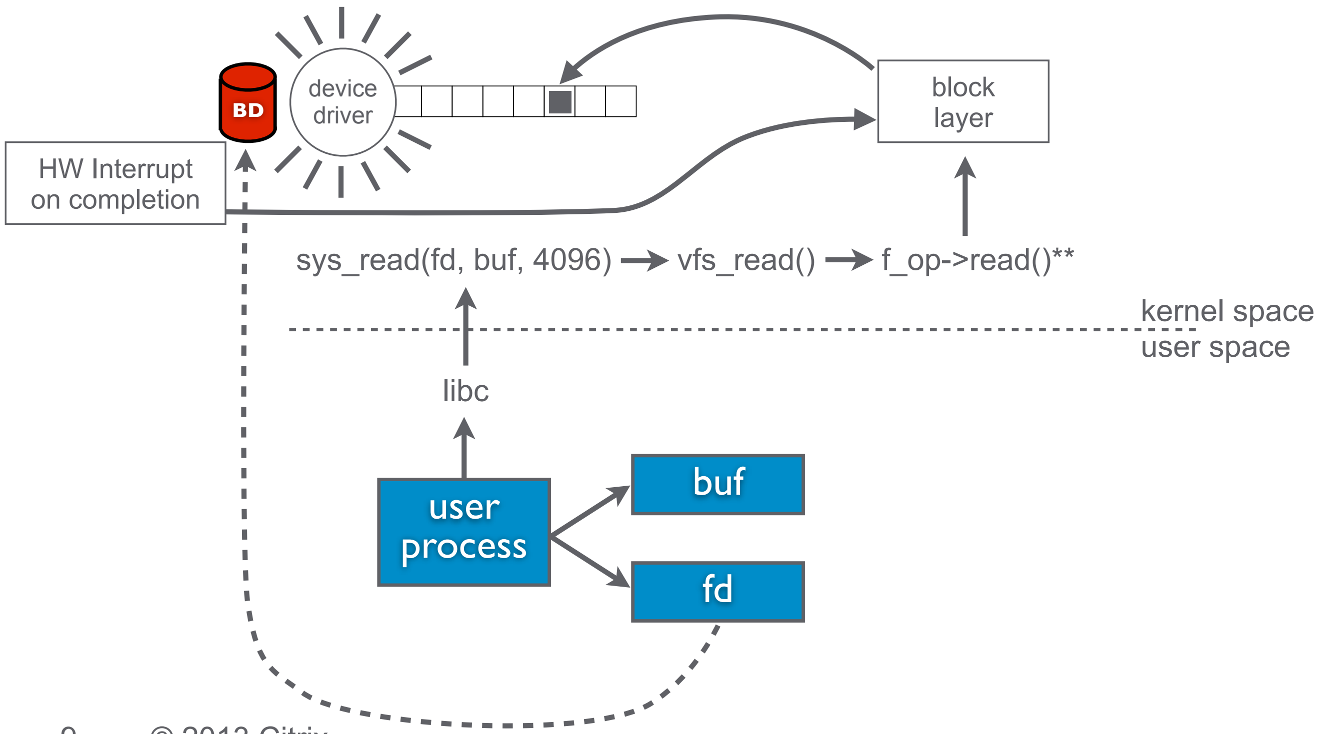
VISIBLE
virtualisation overhead

Current Implementation

How we virtualise storage with Xen

Current Implementation (bare metal)

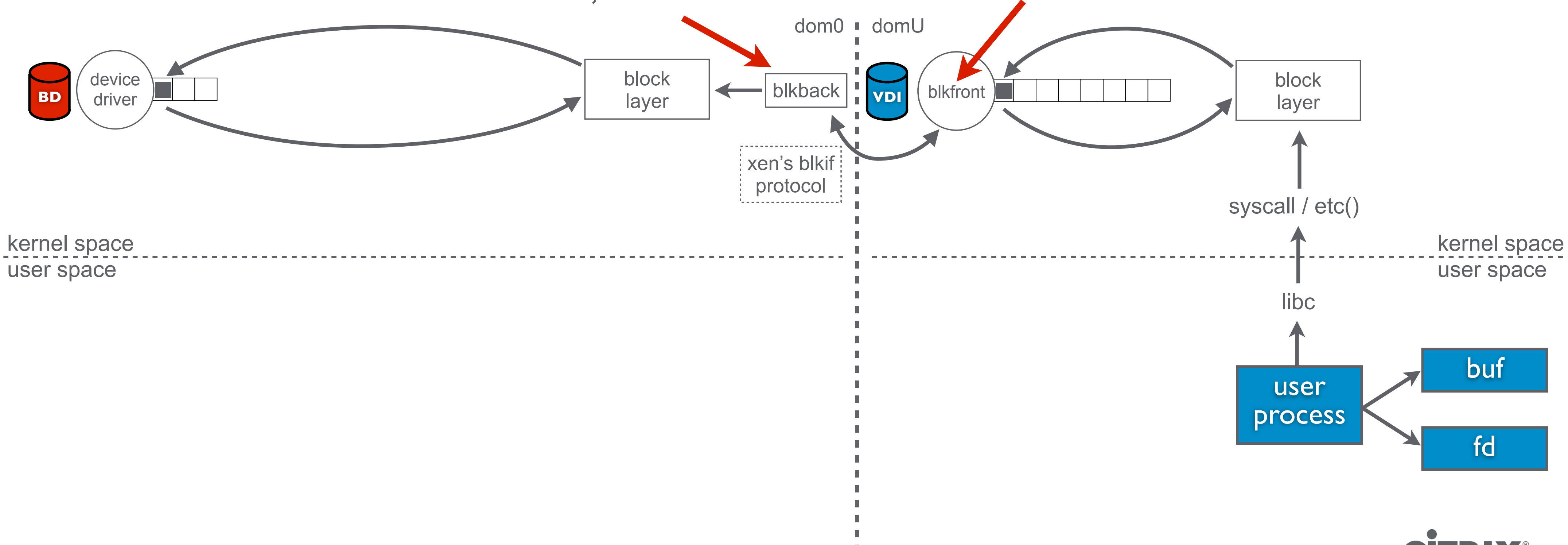
- How does that compare to storage performance again?
  - There are different ways a user application can do storage I/O
    - We will use simple `read()` and `write()` libc wrappers as examples



1. char buf[4096];
2. int fd = open("/dev/sda", O_RDONLY | O_DIRECT);
3. read(fd, buf, 4096);
4. buf now has the data!

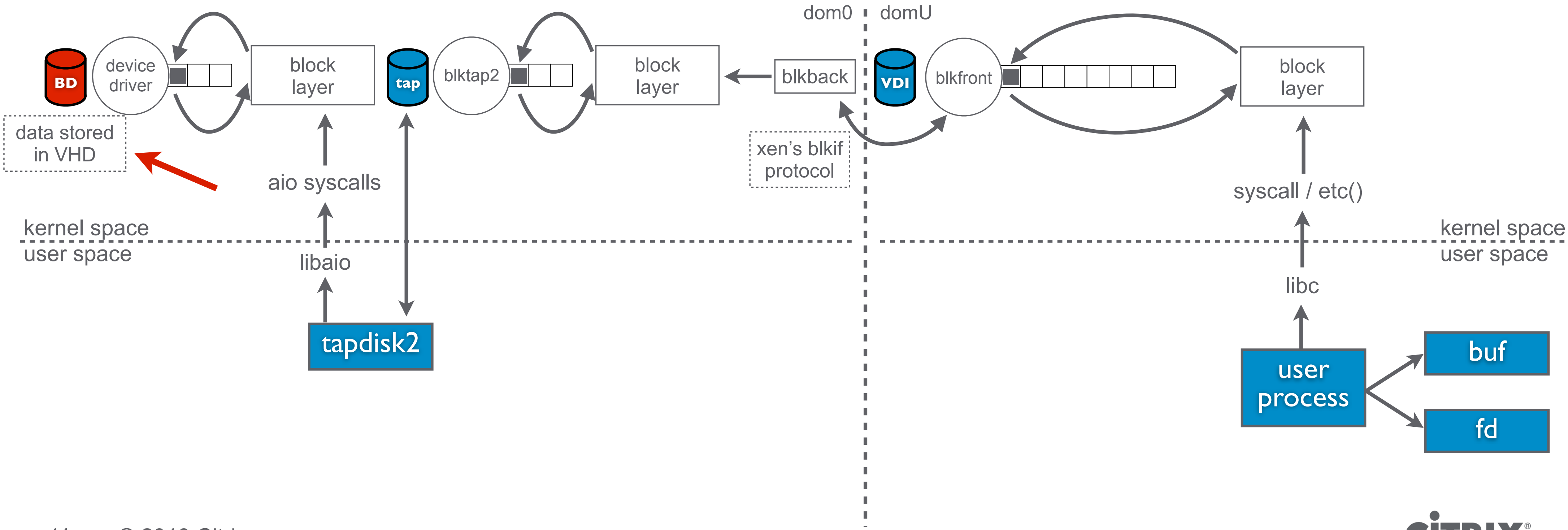
Current Implementation (Xen)

- The "Upstream Xen" use case
  - The virtual device in the guest is implemented by blkfront
  - Blkfront connects to blkback, which handles the I/O in dom0



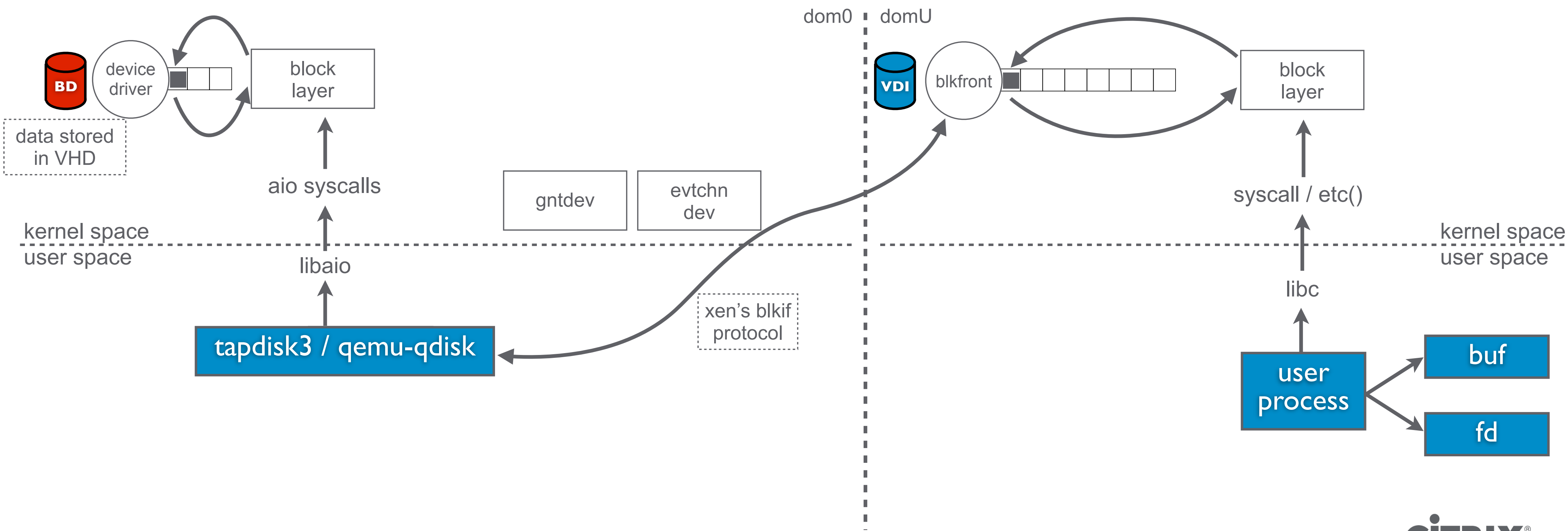
Current Implementation (Xen)

- The XenServer 6.2.0 use case
  - XenServer provides thin provisioning, snapshot, clones, etc. hello VHD
  - This is easily implemented in user space. hello TAPDISK



Current Implementation (Xen)

- The blktap3 and qemu-qdisk use case
  - Have the entire back end in user space

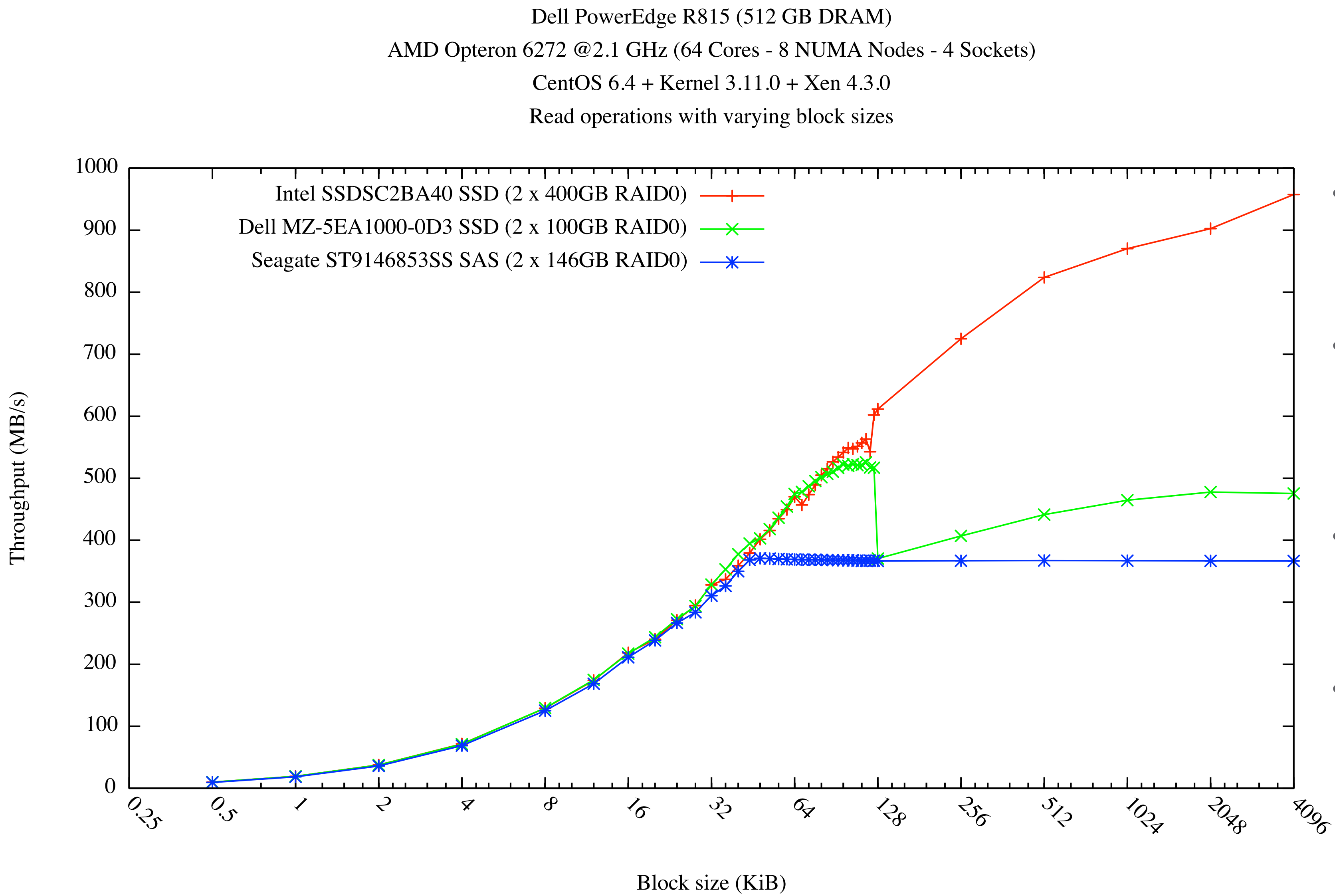


Measurements Over Different Back Ends

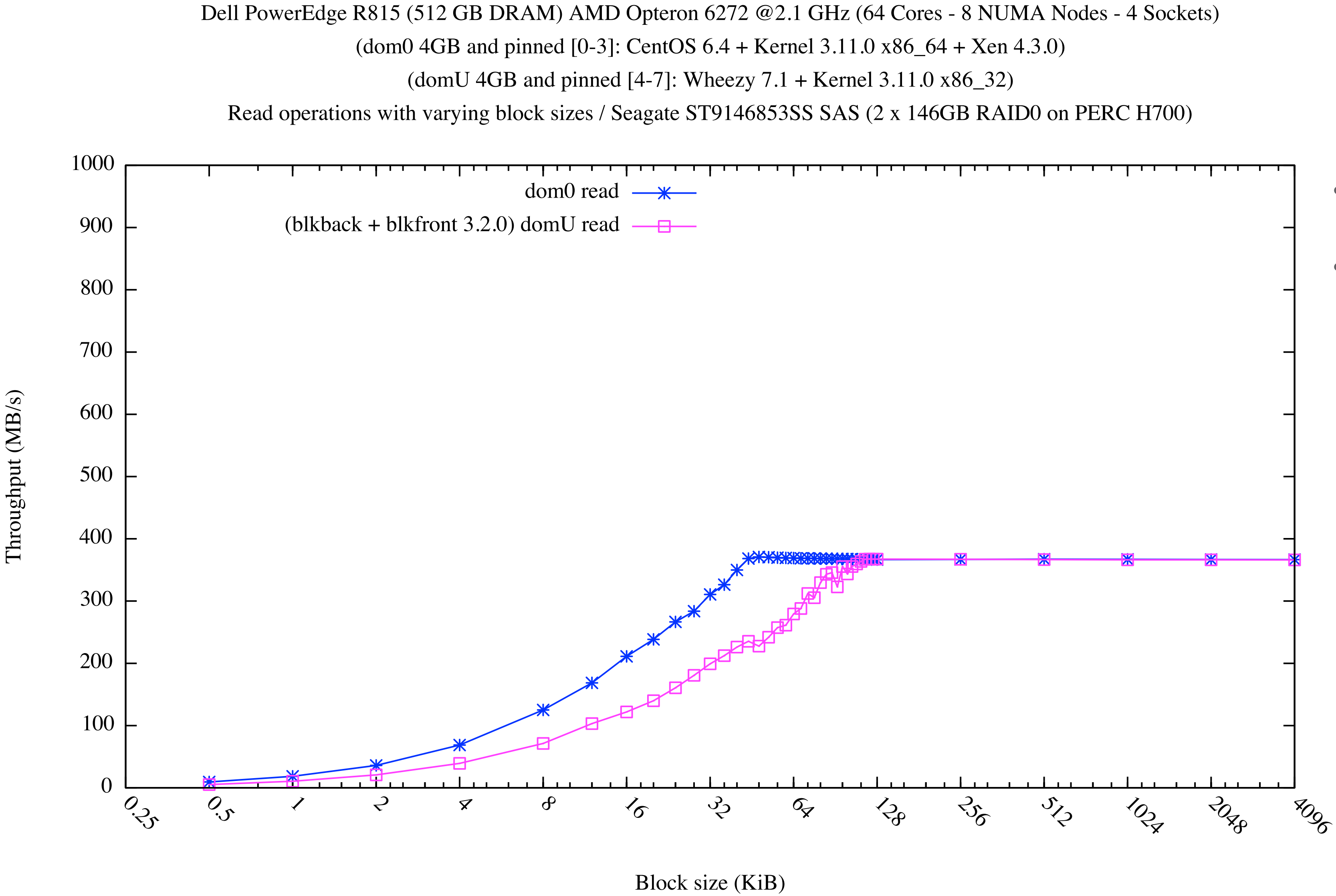
Throughput and latency analysis

Measurement Over Different Back Ends

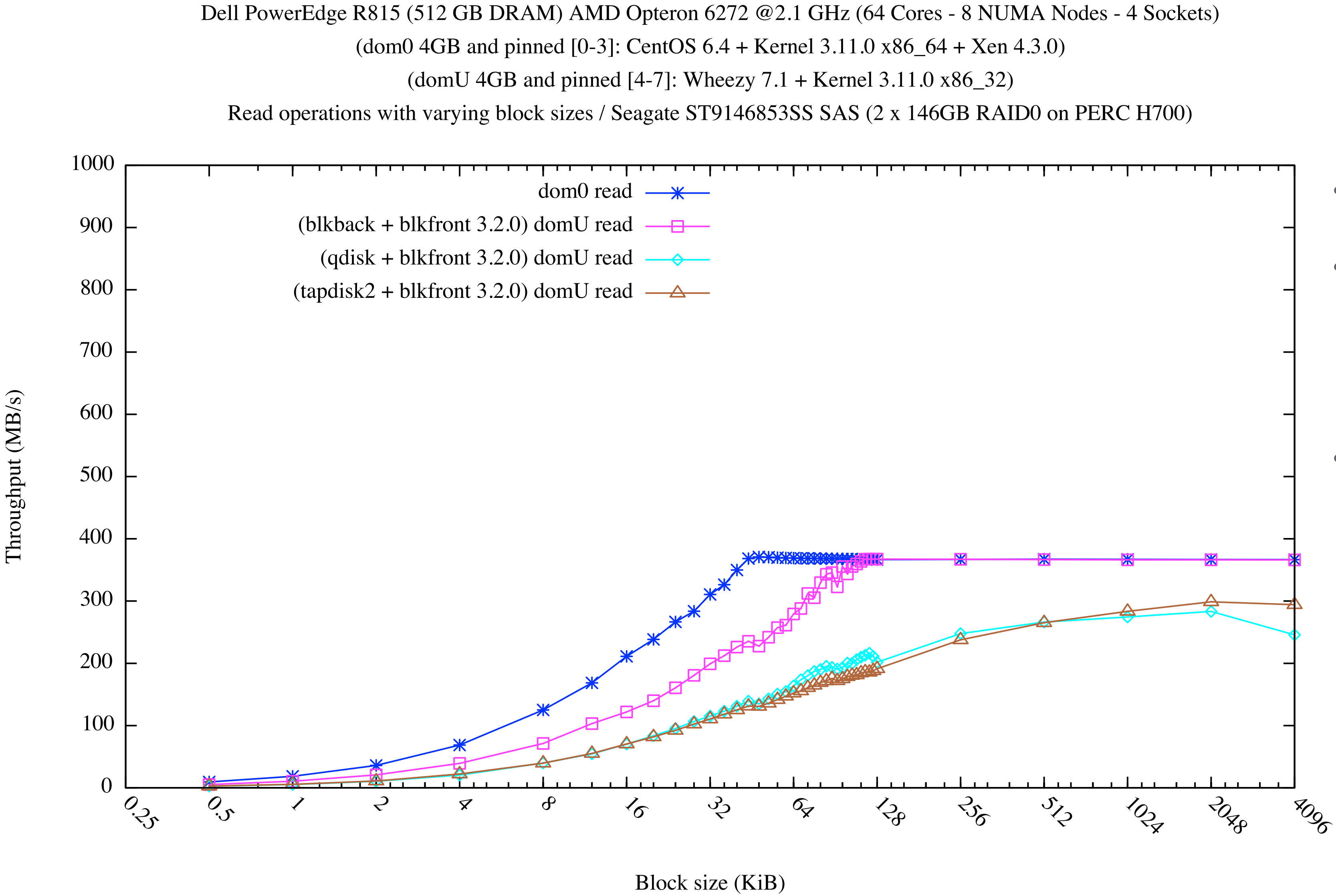
- Same host, different RAID0 logical volumes on a PERC H700
  - All have 64 KiB stripes, adaptive read-ahead and write-back cache enabled



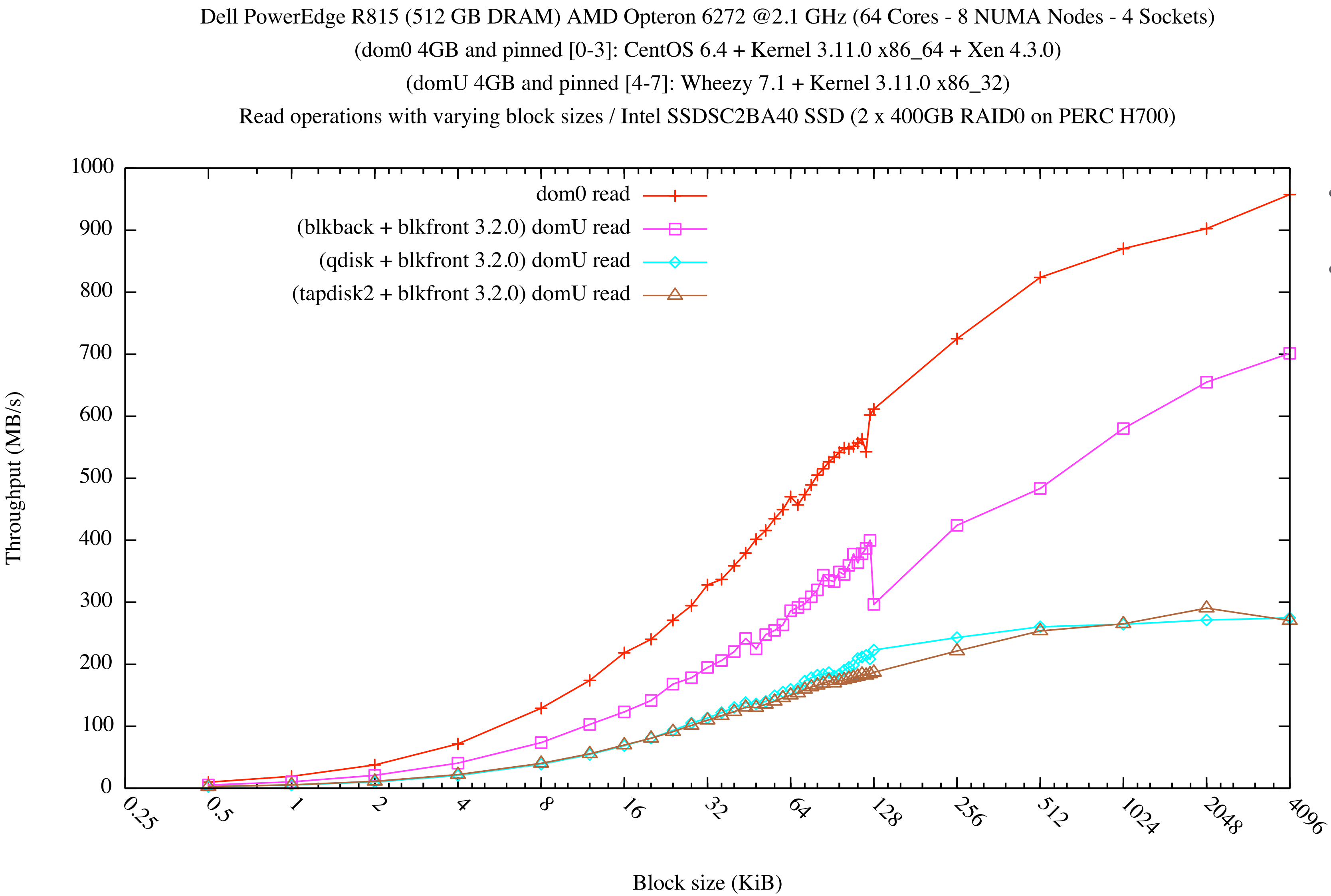
- dom0 had:
  - 4 vCPUs pinned
  - 4 GB of RAM
- It becomes visible that certain back ends cope much better with larger block sizes.
- This controller supports up to 128 KiB per request.
- Above that, the Linux block layer splits the requests.



- Seagate ST (SAS)
- blkback is slower, but it catches up with big enough requests.



- Seagate ST (SAS)
- User space back ends are so slow they never catch up, even with bigger requests.
- This is not always true: if the disks were slower, they would catch up.

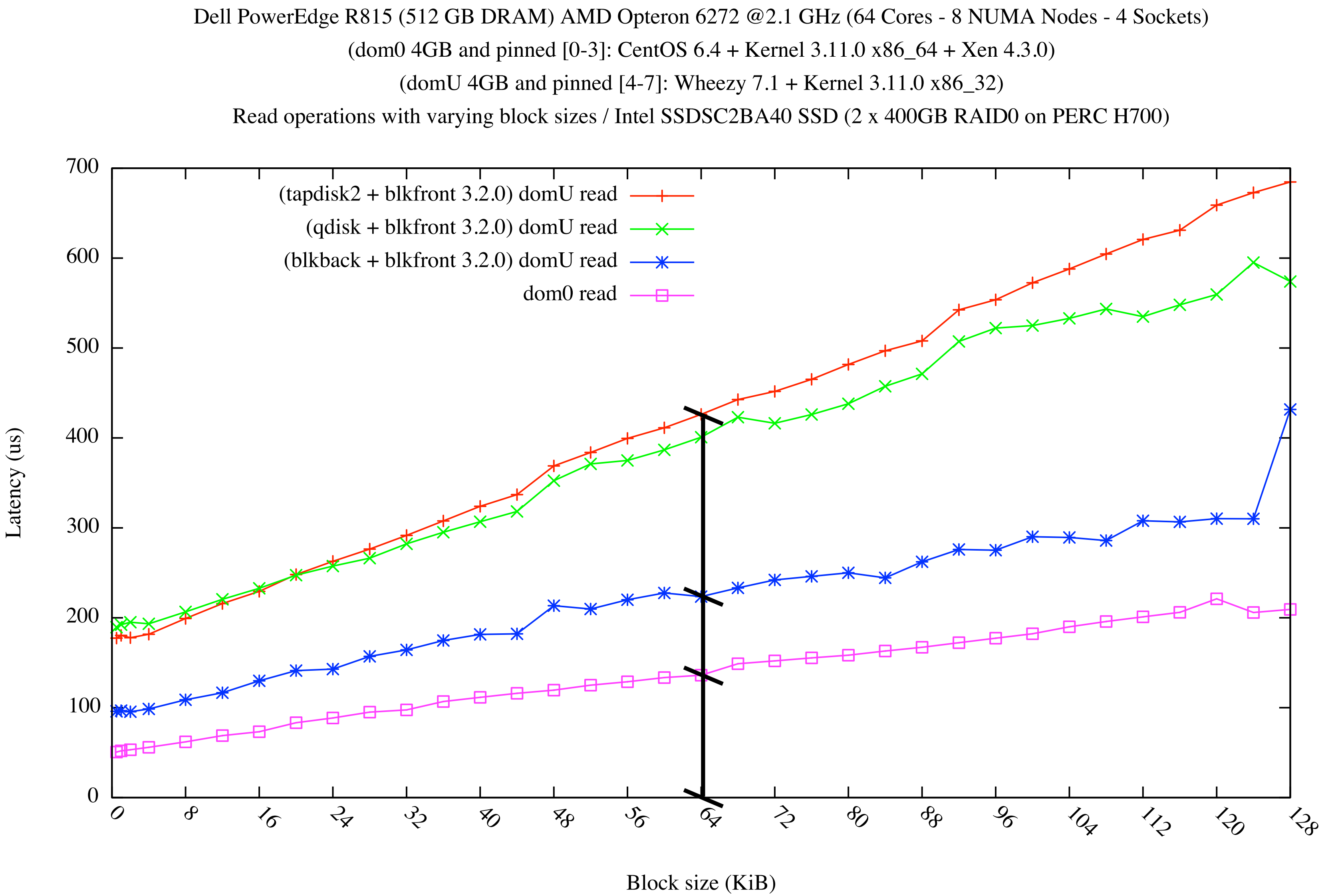


- Intel DC S3700 (SSD)
- When the disks are really fast, none of the technologies catch up.

Measurement Over Different Back Ends

- There is another way to look at the data:

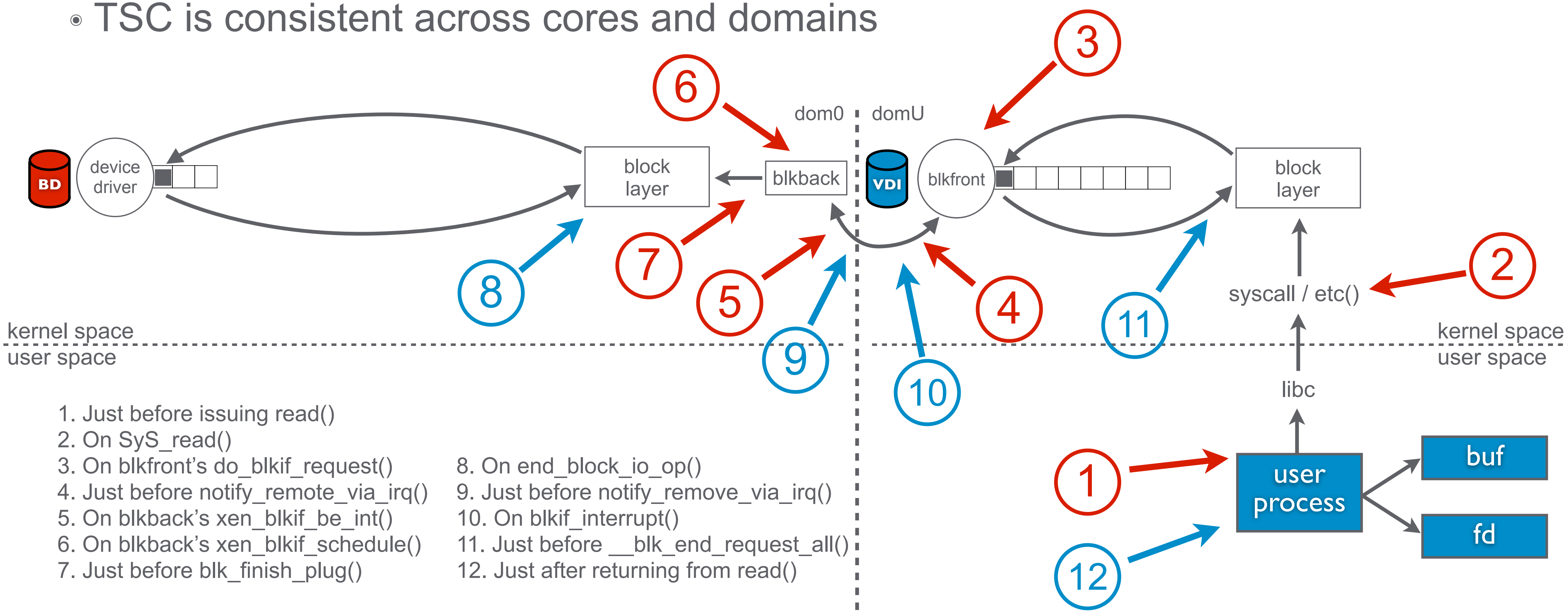
$$\frac{1}{\text{Throughput (data/time)}} = \text{Latency (time/data)}$$



- Intel DC S3700 (SSD)
- The question now is: where is time being spent?
- Compare time spent:
  - dom0
  - blkback
  - qdisk

Measurement Over Different Back Ends

- Inserted trace points using RDTSC
  - TSC is consistent across cores and domains

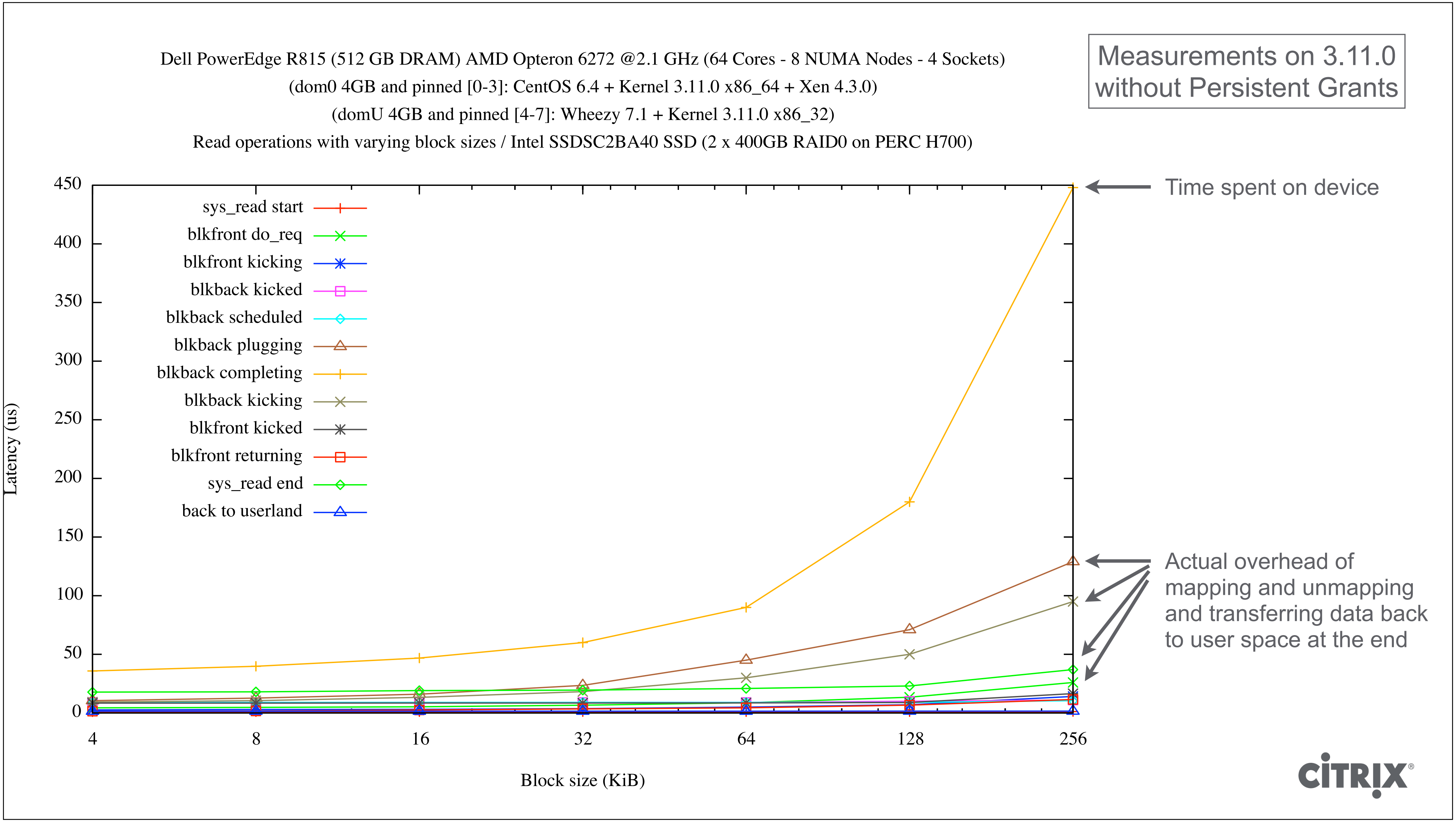


1. Just before issuing read()
2. On SyS_read()
3. On blkfront's do_blkif_request()
4. Just before notify_remote_via_irq()
5. On blkback's xen_blkif_be_int()
6. On blkback's xen_blkif_schedule()
7. Just before blk_finish_plug()
8. On end_block_io_op()
9. Just before notify_remove_via_irq()
10. On blkif_interrupt()
11. Just before __blk_end_request_all()
12. Just after returning from read()

Measurement Over Different Back Ends

- Initial tests showed there is a “warm up” time
- Simply inserting printk()s affect the hot path
- Used a trace buffer instead
  - In the kernel, trace_printk()
  - In user space, hacked up buffer and a signal handler to dump its contents

- Run 100 read requests
  - One immediately after the other (requests were sequential)
  - Used IO Depth = 1 (only one in flight request at a time)
- Sorted the times, removed the 10 (10%) fastest and slowest runs
- Repeated the experiment 10 times and averaged the results


Measurements on 3.11.0
without Persistent Grants
Dell PowerEdge R815 (512 GB DRAM) AMD Opteron 6272 @2.1 GHz (64 Cores - 8 NUMA Nodes - 4 Sockets)
(dom0 4GB and pinned [0-3]: CentOS 6.4 + Kernel 3.11.0 x86_64 + Xen 4.3.0)
(domU 4GB and pinned [4-7]: Wheezy 7.1 + Kernel 3.11.0 x86_32)
Read operations with varying block sizes / Intel SSDSC2BA40 SSD (2 x 400GB RAID0 on PERC H700)
Latency (us)
450
400
350
300
250
200
150
100
50
0
sys_read start
blkfront do_req
blkfront kicking
blkback kicked
blkback scheduled
blkback plugging
blkback completing
blkback kicking
blkfront kicked
blkfront returning
sys_read end
back to userland
4
8
16
32
64
128
256
Block size (KiB)
Time spent on device
Actual overhead of
mapping and unmapping
and transferring data back
to user space at the end
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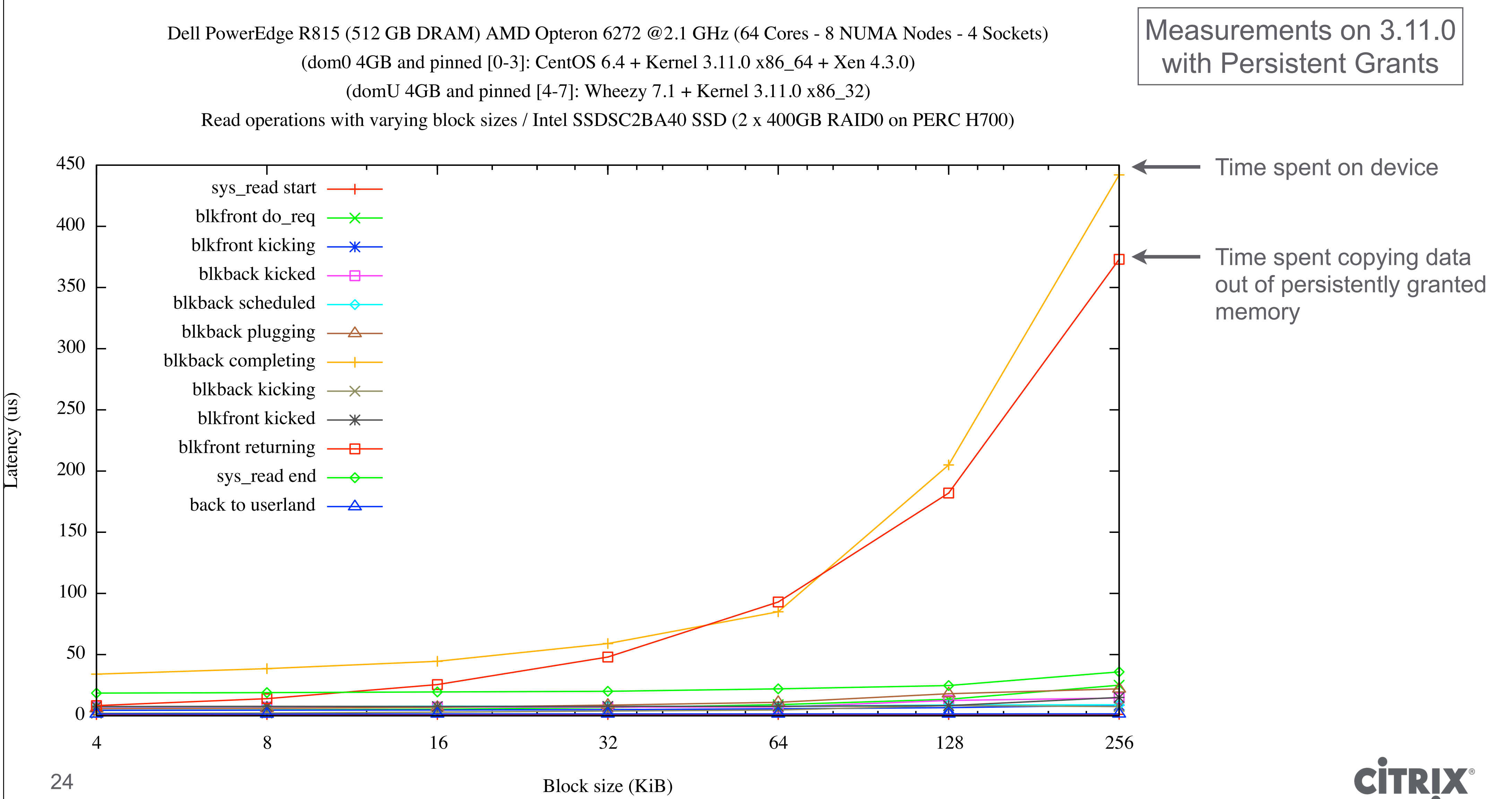

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blkback scheduled
blkback plugging
blkback completing
blkback kicking
blkfront kicked
blkfront returning
sys_read end
back to userland
Time spent on device
Time spent copying data out of persistently granted memory

Measurement Over Different Back Ends

- The penalty of copying can be worth taking depending on other factors:
  - Number of dom0 vCPUs (TLB flushes)
  - Number of concurrent VMs performing IO (contention on grant tables)

- Ideally, blkfront should support both data paths

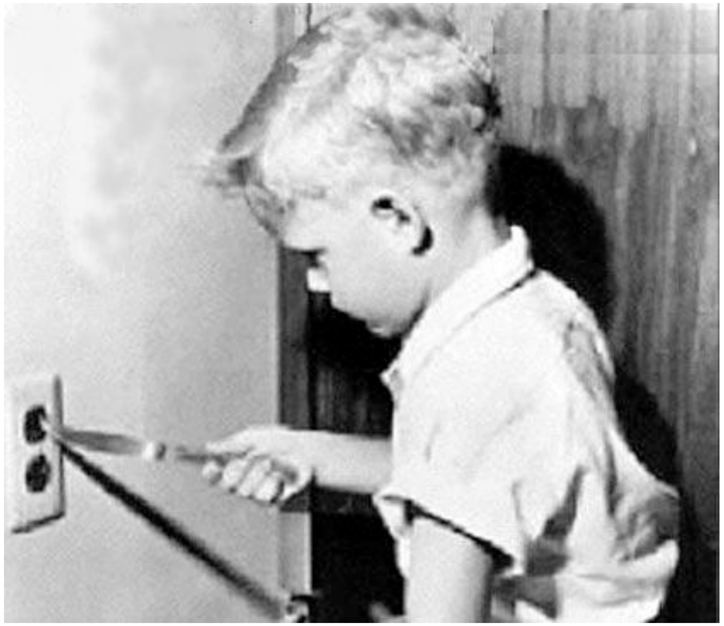
- Administrators can profile their workloads and decide what to provide

Proposals for Improving

What else can we do to minimise the overhead?

New Ideas

• How can we reduce the processing required to virtualise I/O ?



New Ideas

- Persistent Grants
  - **Issue**: grant mapping (and unmapping) is expensive
  - **Concept**: back end keeps grants, front end copies I/O data to those pages
  - **Status**: currently implemented in 3.11.0 and already supported in qemu-qdisk

- Indirect I/O
  - **Issue**: blkif protocol limit requests to 11 segs of 4 KiB per I/O ring
  - **Concept**: use segments as indirect mapping of other segments
  - **Status**: currently implemented in 3.11.0

New Ideas

- Avoid TLB flushes altogether (Malcolm Crossley)
  - **Issue**:
    - When unmapping, we need to flush the TLB on all cores
    - But in the storage data path, the back end doesn't really access the data
  - **Concept**: check whether granted pages have been accessed
  - **Status**: early prototypes already developed

- Only grant map pages on the fault handler (David Vrabel)
  - **Issue**:
    - Mapping/unmapping is expensive
    - But in the storage data path, the back end doesn't really access the data
  - **Concept**: Have a fault handler for the mapping, triggered only when needed
  - **Status**: idea yet being conceived

New Ideas

- Split Rings
  - **Issue**:
    - blkif protocol supports 32 slots per ring for requests or responses
    - this limits the total amount of outstanding requests (unless multi-page rings are used)
    - this makes inefficient use of CPU caching (both domains writing to the same page)
  - **Concept**: use one ring for requests and another for responses
  - **Status**: early prototypes already developed

- Multi-queue Approach
  - **Issue**: Linux’s block layer does not scale well across NUMA nodes
  - **Concept**: allow device drivers to register a request queue per core
  - **Status**: scheduled for Kernel 3.12

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