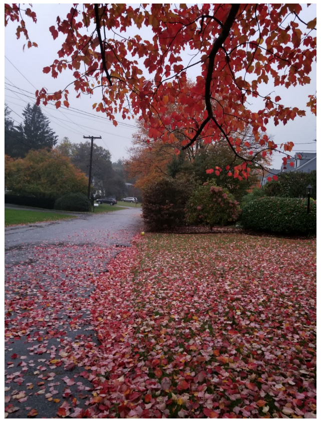
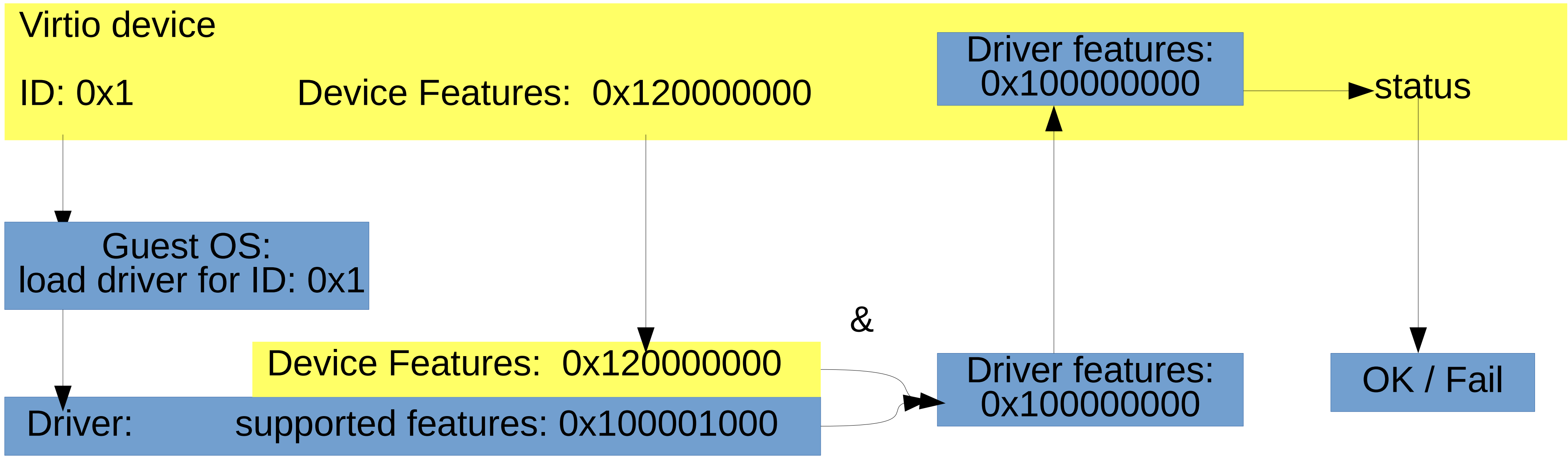
The future of virtio: riddles, myths and surprises

Michael S. Tsirkin
Jens Freimann

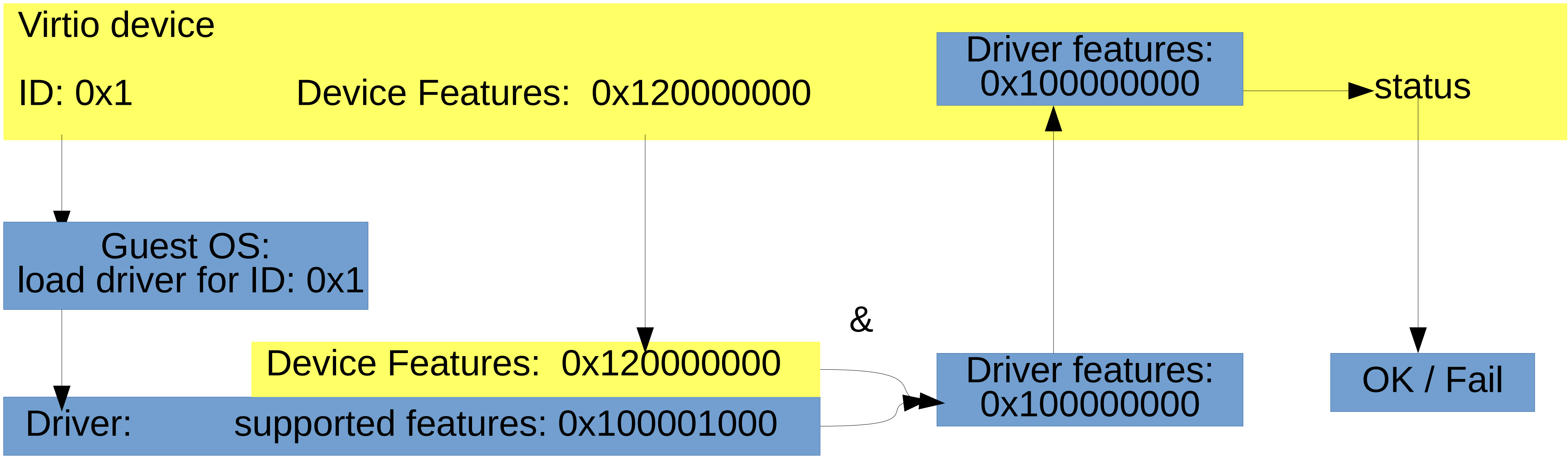
Fall 2017



Virtio initialization


Virtio device
ID: 0x1
Device Features: 0x120000000
Driver features: 0x100000000
status
Guest OS: load driver for ID: 0x1
&
Device Features: 0x120000000
Driver:
supported features: 0x100001000
Driver features: 0x100000000
OK / Fail

Virtio initialization



Myth #1: “changing virtio would break existing drivers”

- Really:
  feature negotiation can ensure compatibility
- Forward and backward
- For devices and drivers

- Let’s see it in action ...

Virtio input: add multitouch feature

- Feature bit: VIRTIO_INPUT_F_MULTITOUCH = 0
- New (multi-touch aware) device: device features = 0x1
- New driver: supported features = 0x1
- Driver features: 0x1 & 0x1 = 0x1
- Device and driver:

```
if (driver_features &
            (1 << VIRTIO_INPUT_F_MULTITOUCH))
     enable multi-touch support
```

- Updated device & driver: multi-touch enabled!

Compatibility: existing drivers

- Device features = 0x1
- Driver supported = 0x0
- Driver features = 0x0
- 0x0 & (1 << VIRTIO_INPUT_F_MULTITOUCH) == 0
- Device: option 1: disable multi-touch: compatible!
- Device: option 2: set status = fail
  Not worse than building a new device!
  Can suggest upgrading a driver.

Compatibility: existing devices

- Device features: 0x0
- Driver supported: 0x1
- Driver features: 0x0
- 0x0 & (1 << VIRTIO_INPUT_F_MULTITOUCH) == 0
- Driver: option 1: disable multi-touch
- Driver: option 2: set status = fail
  Can suggest upgrading a device.

Compatibility: virtio 0.9 versus 1.0

- virtio 1.0 – made default Jul 2016
- Switched devices to a different register layout
- Gated by a feature bit:

```
/* v1.0 compliant. */
#define VIRTIO_F_VERSION_1          32
```

- No one noticed!

Myth #2
Changing virtio requires writing a specification

- Absolutely the right thing to do
- Does not have to be step 0!

- Virtio priorities:
  - Code compatibility
  - IPR compatibility
  - Interface compatibility

Code compatibility: avoid conflicting with others ✓

- New device: reserve an ID. Spec patch:

```
diff --git a/content.tex b/content.tex
@@ -3022,3 +3022,5 @@ Device ID  &  Virtio Device    \\
 \hline
+23        &   misc device \\
+\hline
 \end{tabular}
```

- Existing device: reserve a feature bit. E.g. :

```
@@ -4800,5 +4802,6 @@ guest memory statistics
 \item[VIRTIO_BALLOON_F_DEFLATE_ON_OOM (2) ] Deflate balloon on
    guest out of memory condition.
+\item[VIRTIO_BALLOON_F_XXXX (3) ] Reserved for
+    feature XXXX.
 \end{description}
```

How to get it in the spec?

- git clone https://github.com/oasis-tcs/virtio-spec
  Edit :)
- sh makeall.sh (needs xelatex, e.g. from texlive)
- virtio-comment-subscribe@lists.oasis-open.org
- Patch: virtio-comment@lists.oasis-open.org
- If no comments – email, ask for a vote ballot
- Total time: up to 2 weeks

IPR compatibility: allow others to implement compatible devices ✓

- Open-source an implementation
- Subscribe to virtio-dev@lists.oasis.org
- Agree to IPR rules (non-assertion mode)
- Send a copy of the patches (e.g. qemu, linux, dpdk) to virtio-dev@lists.oasis.org
- Virtio GPU at this point now.

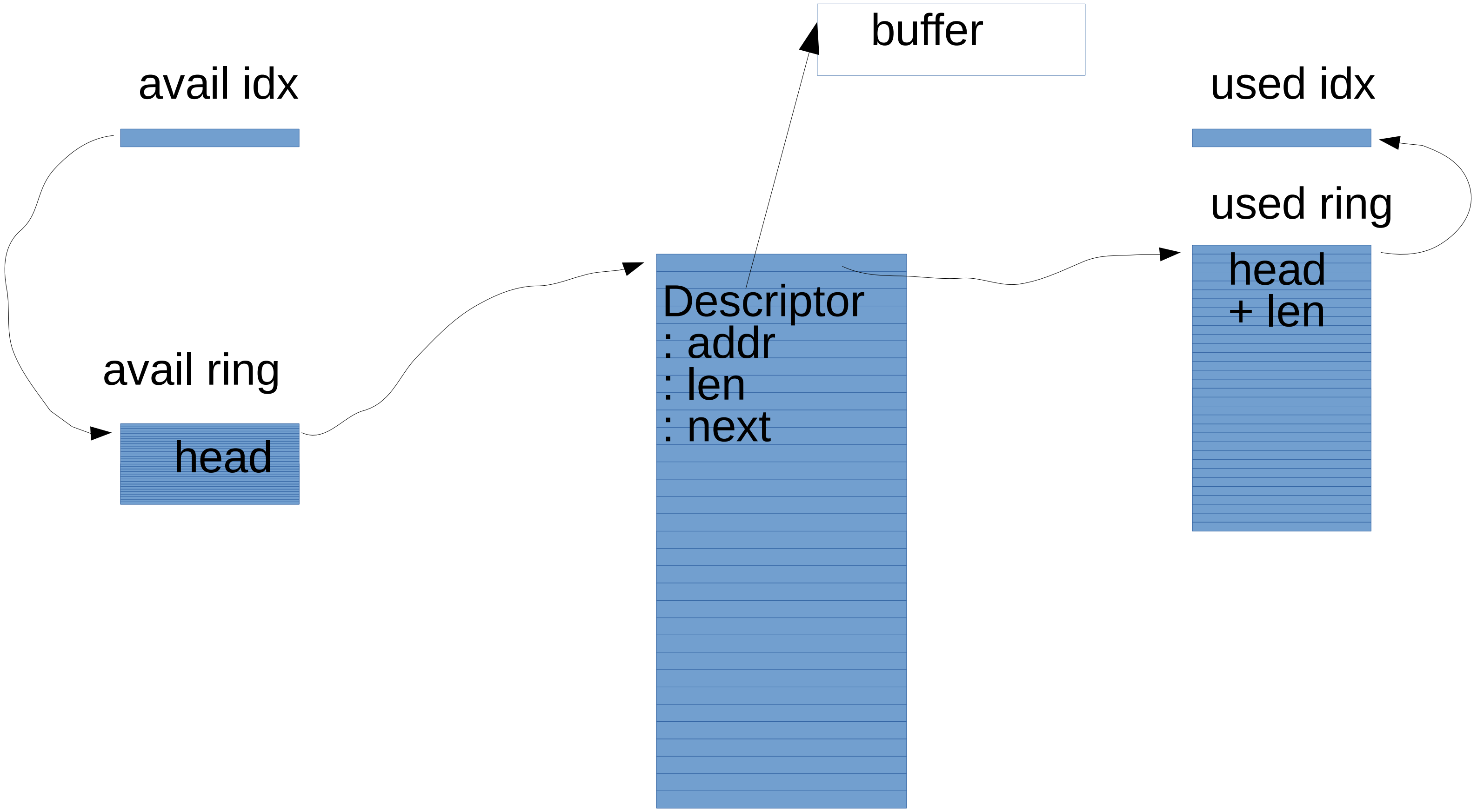
Interface compatibility

- Document assumptions for inter-operability
- Virtio membership is not required
- Membership is open - members vote on ballots
- Hints:
  - Document device and driver separately
  - Use MUST/SHOULD/MAY keywords
  - Ask for help!
- Virtio crypto and input at this point

Myth #3
virtio has lowest possible overhead for host/guest communication

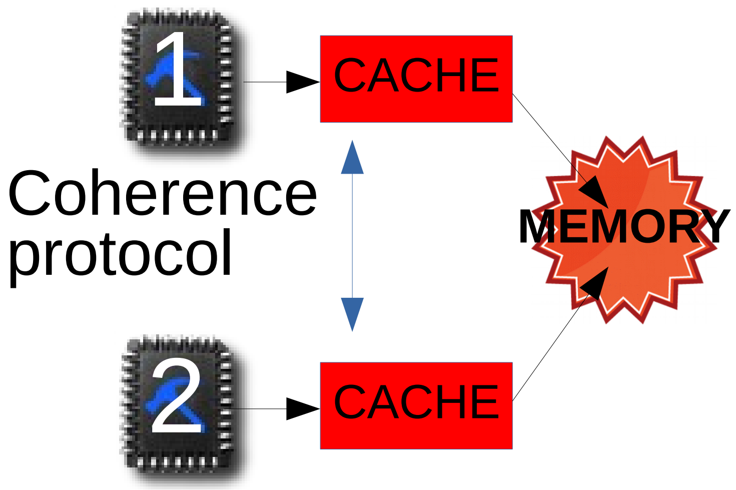
- “Efficient: Virtio devices consist of rings of descriptors for both input and output, which are neatly laid out to avoid cache effects from both driver and device writing to the same cache lines”.
- True - but is this really efficient?

Virt queue: shared memory host/guest communication



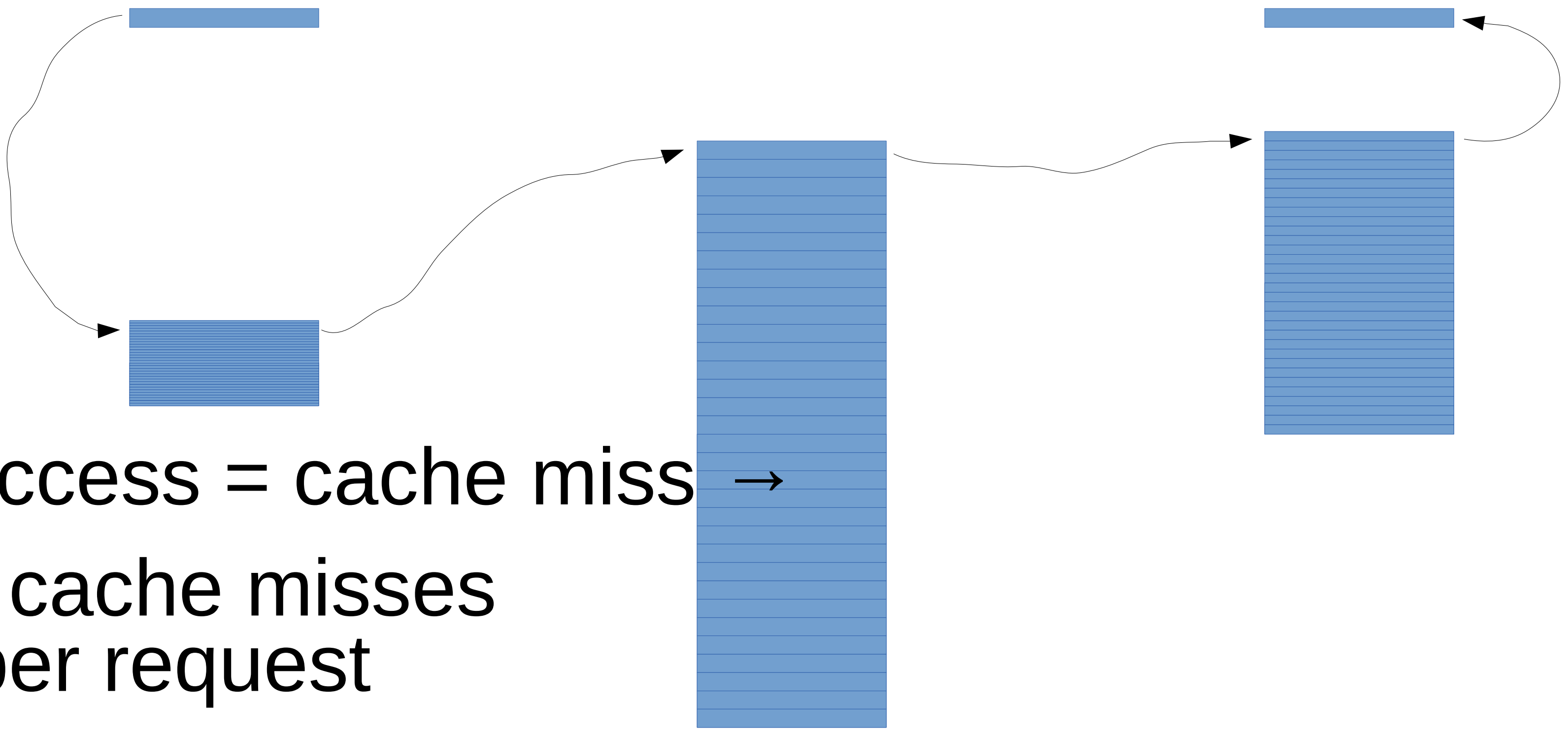
CPU caching

- Communication through shared memory requires cache synchronization (invalidate, miss, ...).



- This impacts latency.

Counting misses: no batching

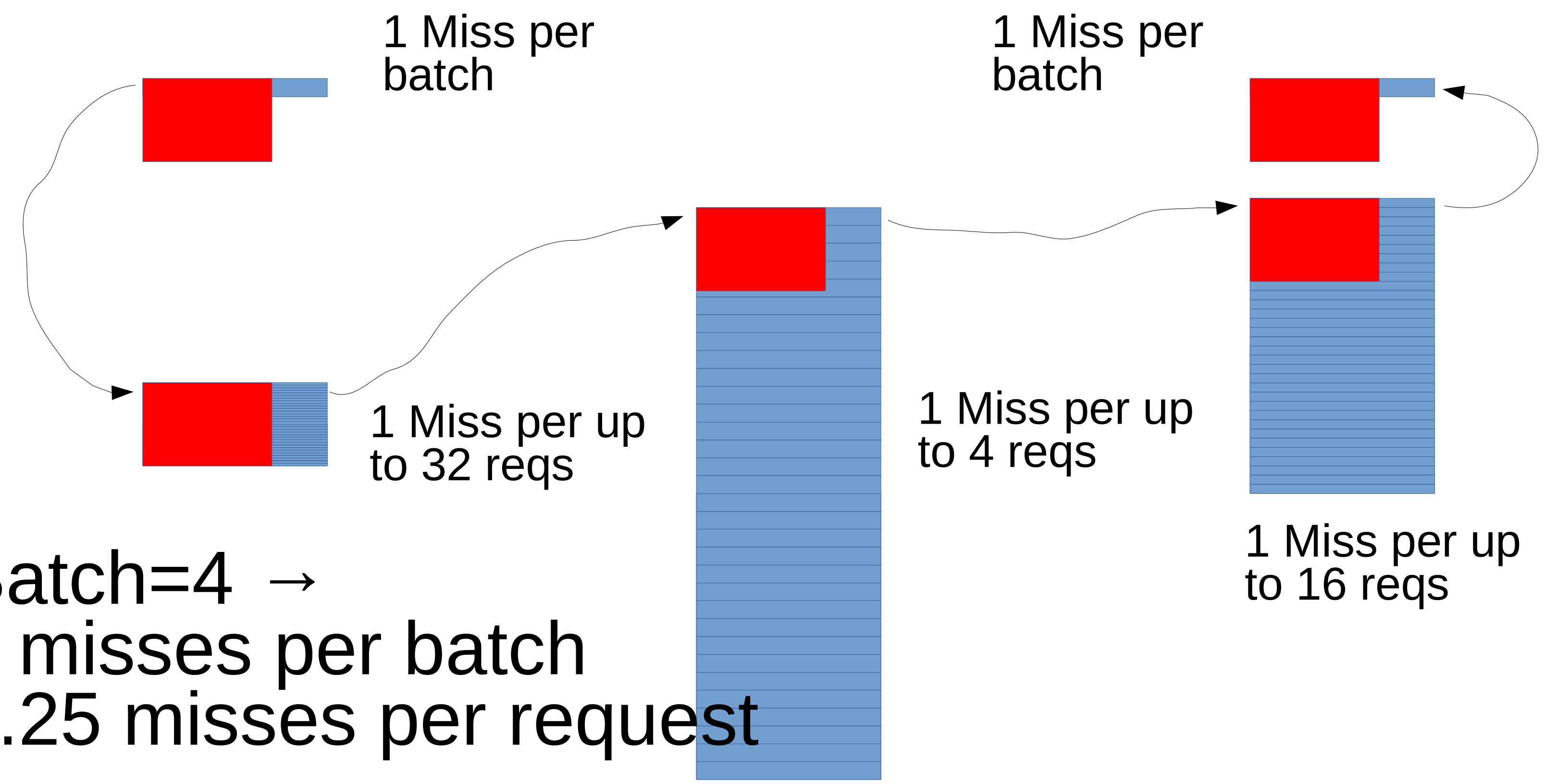


- Access = cache miss →

  5 cache misses
   per request

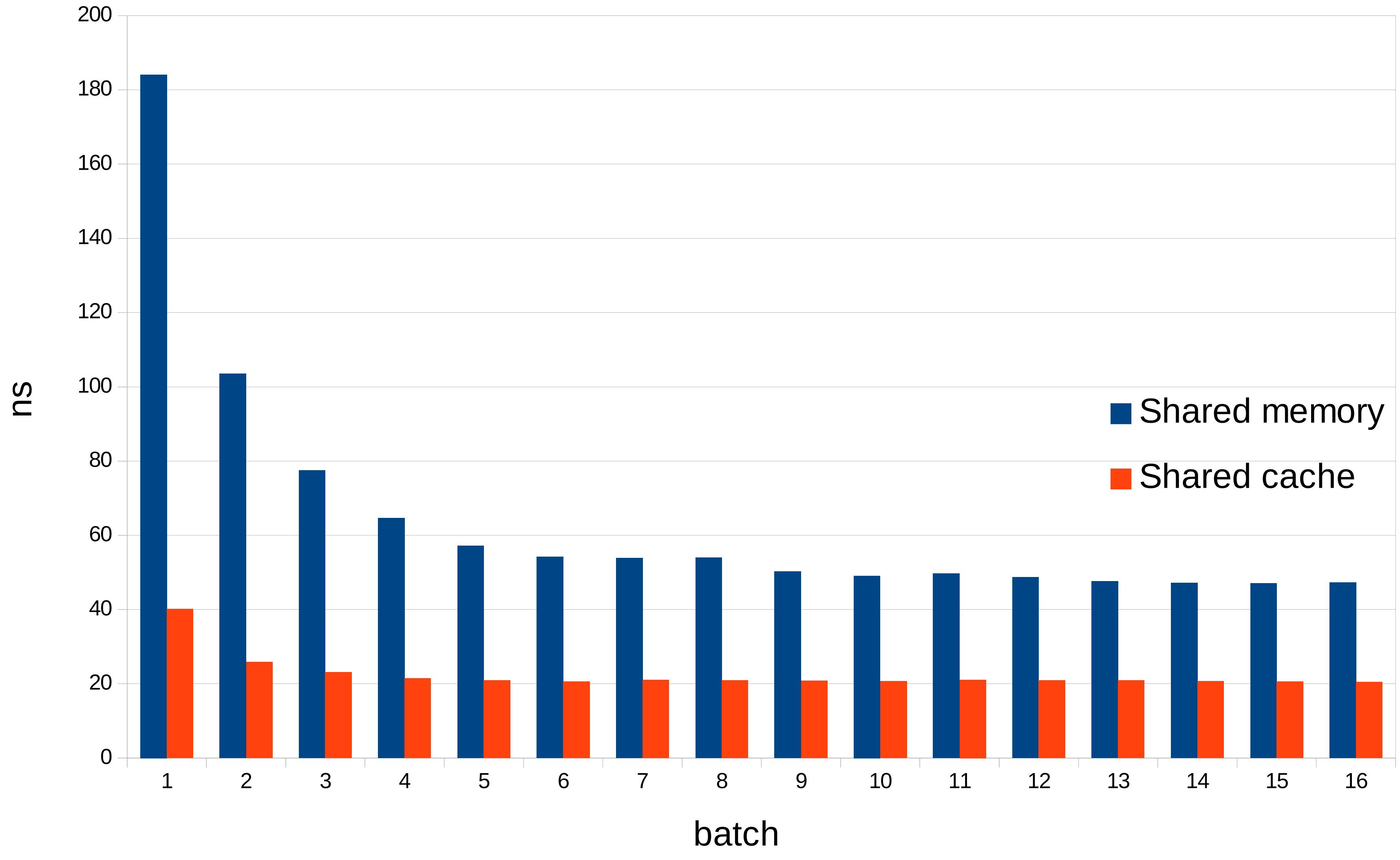
Counting misses: batching

- Virtio 1.0 queue layout: batching



- Batch=4 →
  5 misses per batch
  1.25 misses per request

Cache miss cost



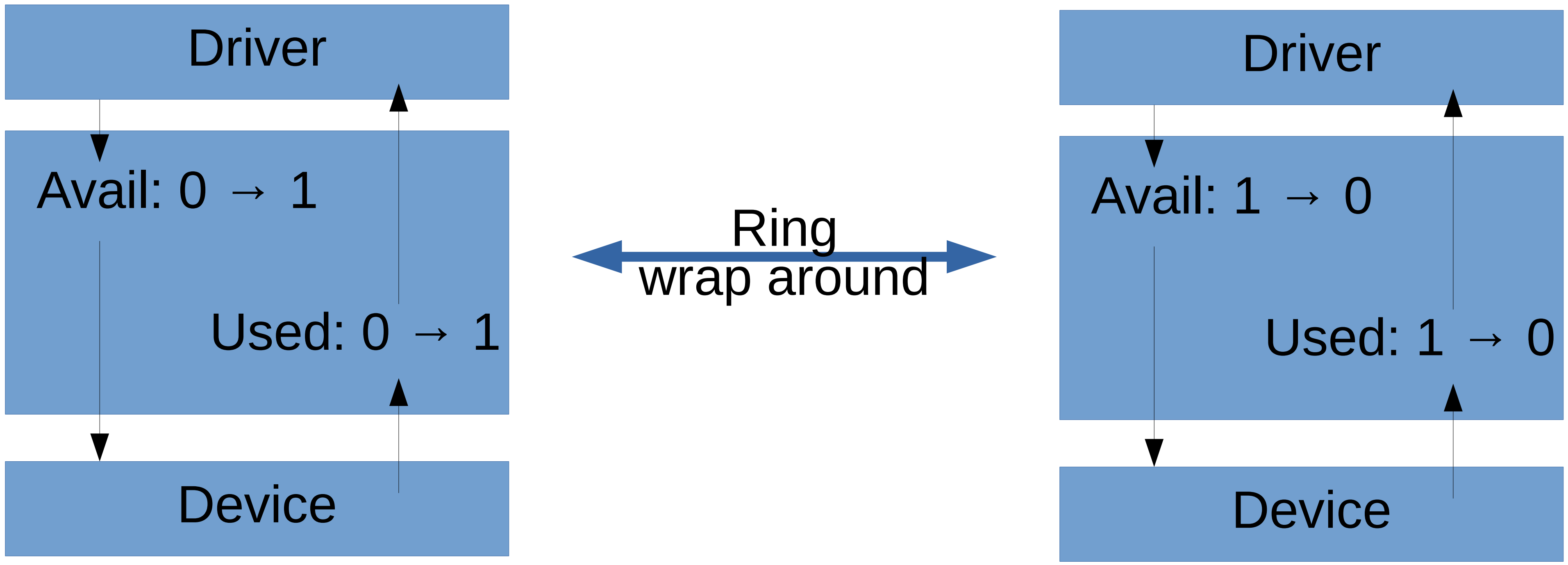
Reducing the overhead

- Information is spread across too many data structures
- Tighter packing will save cache misses.
- How about packing everything in a single data structure?

Descriptor ring

- Driver writes out available descriptors in a ring
- Device writes out used descriptors in the same ring
- Descriptor: addr, len, avail, used
- To mark a descriptor available, flip the avail bit
- To mark a descriptor as used, flip the used bit

Descriptor states



Avail = used: ok for guest to produce

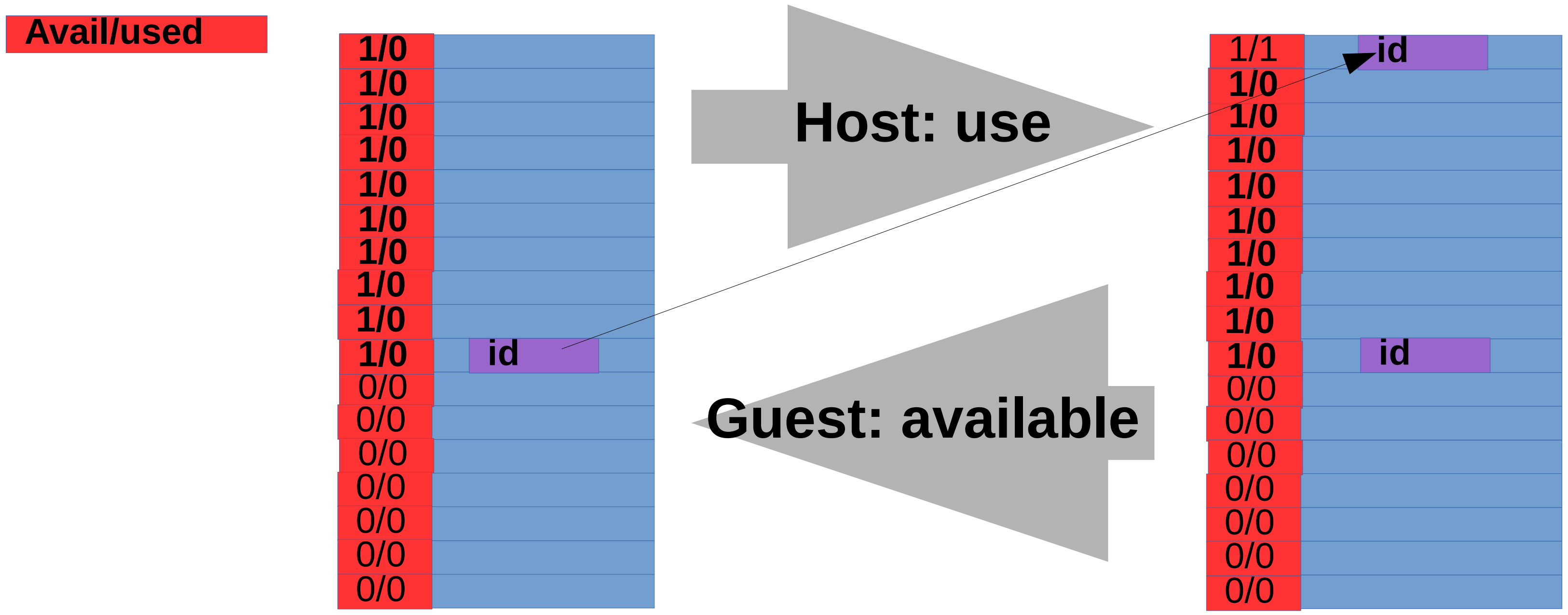
Avail != used: ok for host to consume

Host: pseudo code (in-order)

```
static int used = 1;
while(desc[idx].avail == used)     ←miss?
    relax();
process(&desc[idx]);
desc[idx].used = used;         ←miss?
idx = idx + 1;
if (idx == size)
        Idx = 0;
        used = !!used;
```

Out-of-order: descriptor id

- Guest: available 9
- Host: used 1

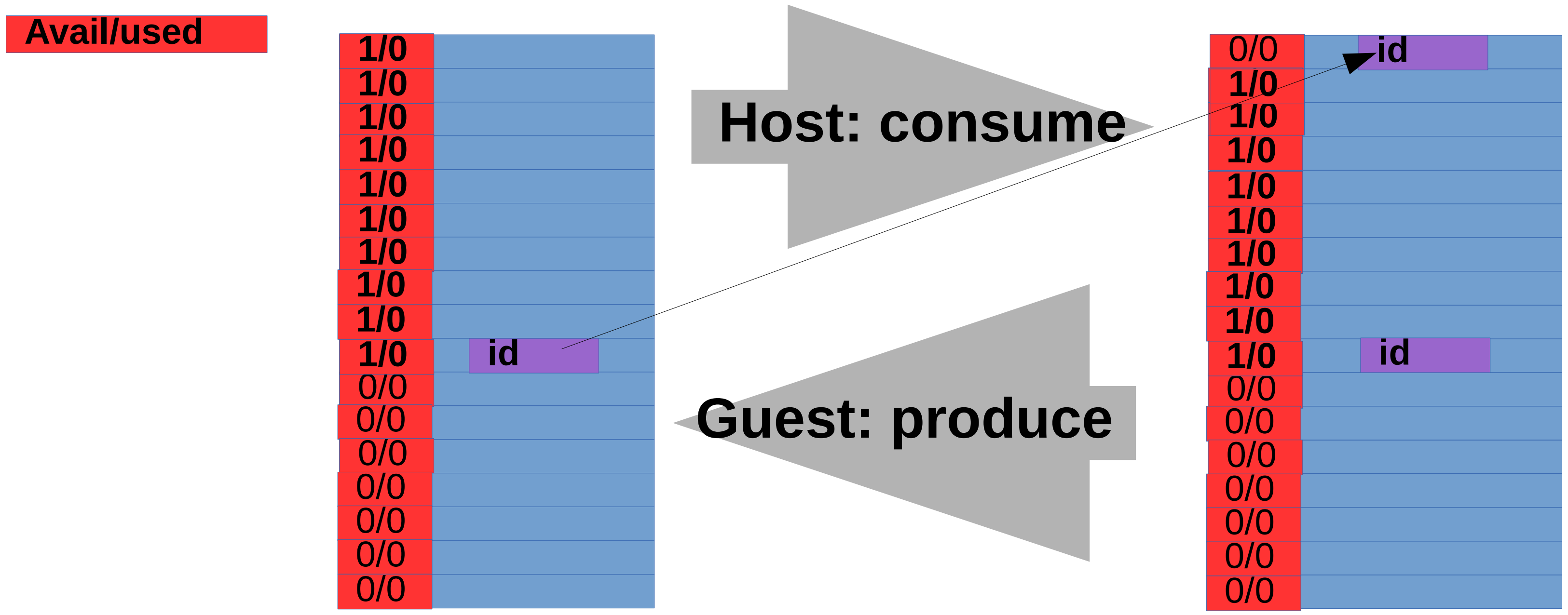


CPU caching

- Both host and guest incur misses on access
- No batching: 2 to 4 misses per descriptor
- Batch=4:
  2 to 4 misses per batch
  4 descriptors per cache line →
  0.5 to 1 misses per descriptor
- Better than virtio 1.0 even in the worst case

In-order: descriptor id

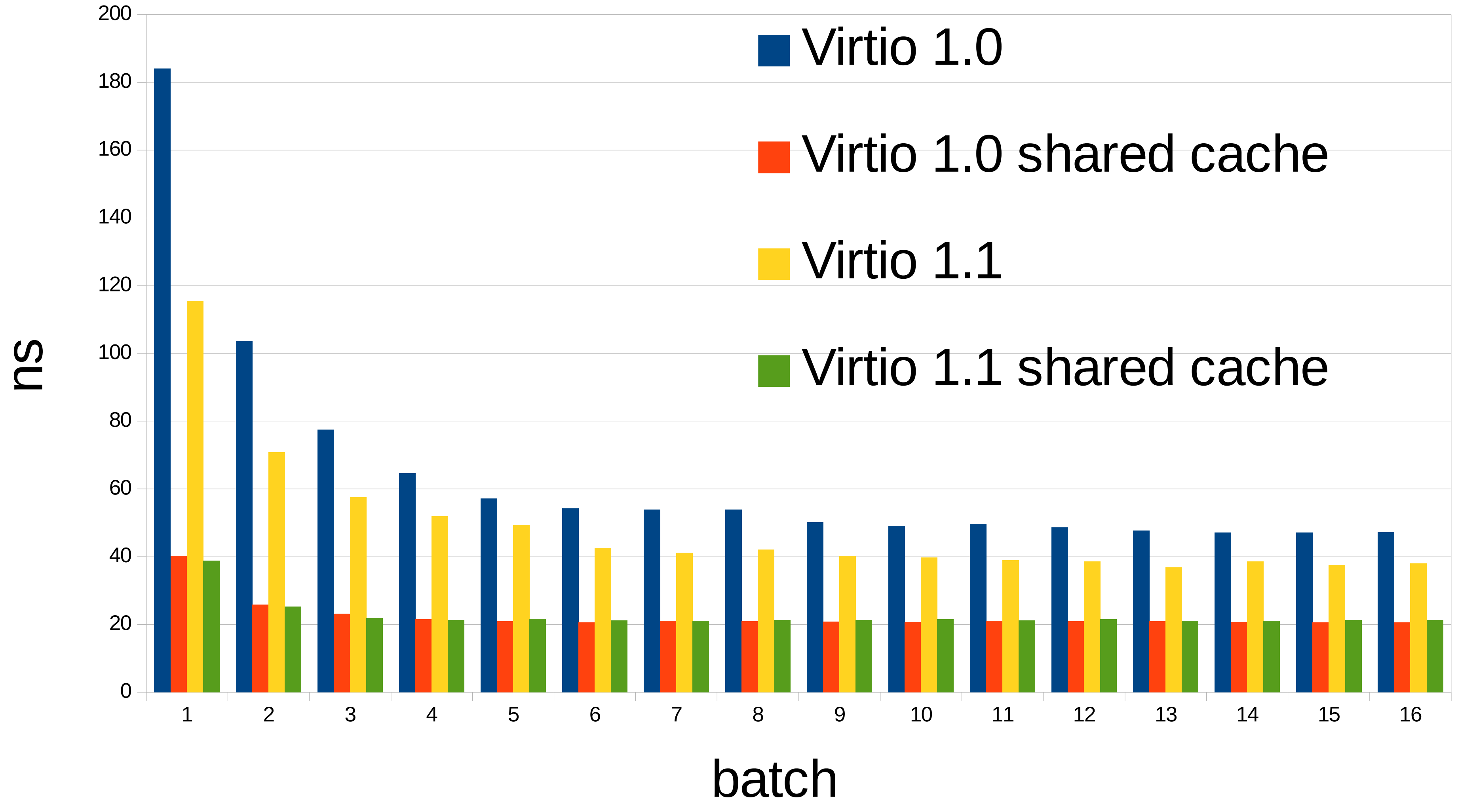
- Guest: produced 9
- Host: consumed 9



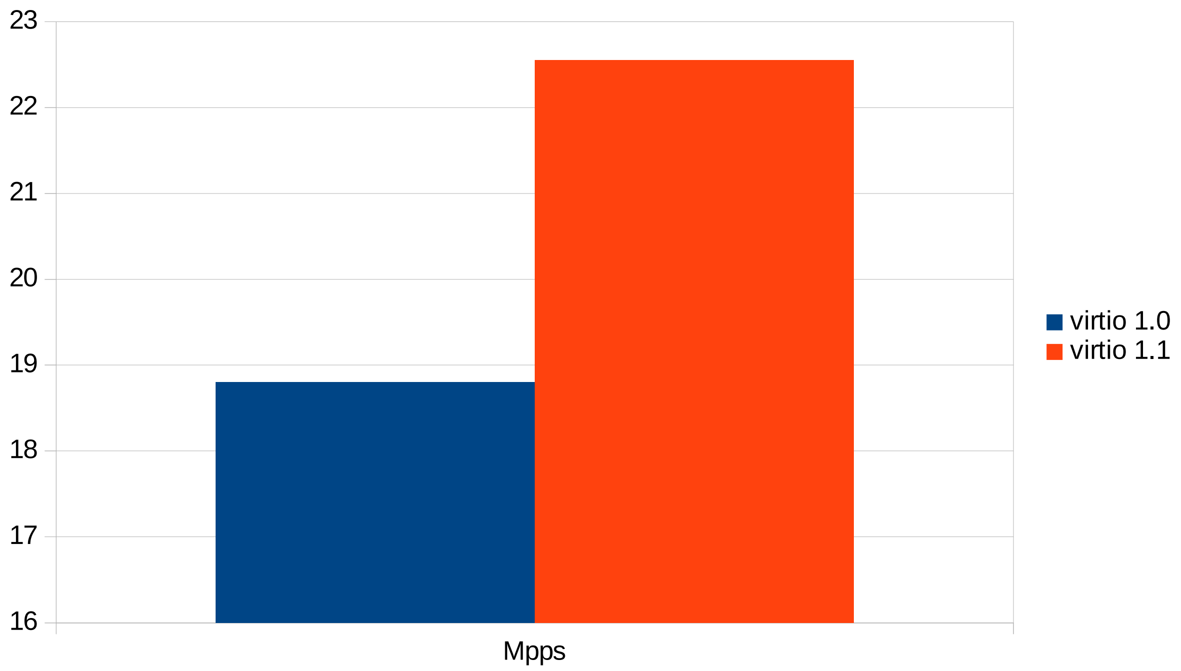
One write per batch of descriptors

Driver ensures avail != used

Request processing: comparison



64 byte packet throughput



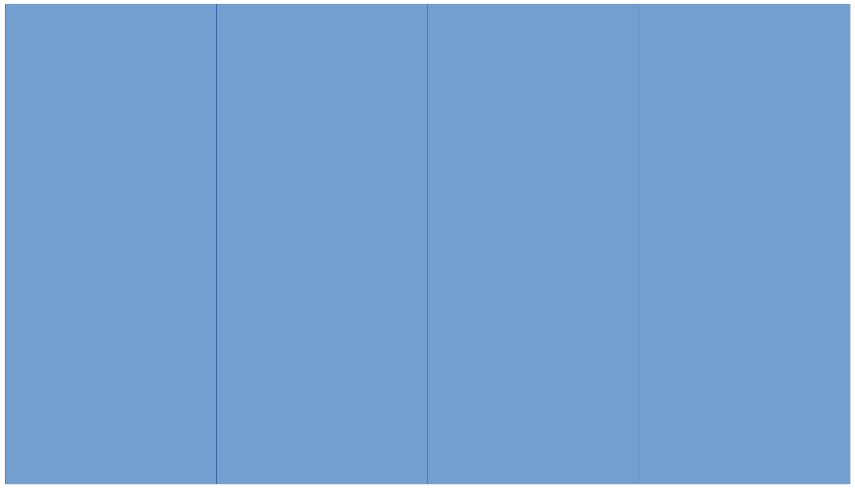
Virtio queue is not optimal
we will fix it

Riddle #1: event suppression

- Each queue has two event index structures
- Which descriptor should trigger an interrupt
- Can we put this in the descriptor itself?
- Should we?
- Just use polling?

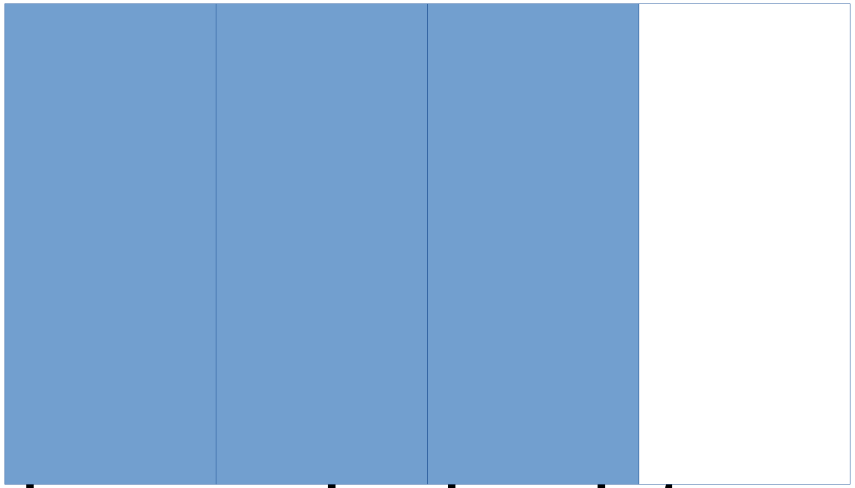
Riddle #2: why powers of 2?

2 VQs * 1K descriptors



fills a 32K cache

2VQs * 0.75K descriptors



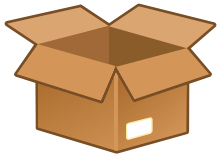
free cache for data

Powers of two: pseudo code

```
unsigned next_power_of_two(unsigned index, unsigned size)
{
        return (index + 1) & (size - 1);
}

unsigned next_non_power_of_two(unsigned index, unsigned
size)
{
        return ++index >= size ? 0 : index;
}
```

Surprise #1: hardware is special



- Let’s assume a pass-through device implementing virtio. Shouldn’t this just work?
- Maybe – but not optimally!
- Hypervisor: processes descriptors one by one
- Hardware: can process many in parallel
- Needs to be told how many are available
- Include number of available entries in a kick

Surprise #2: writes are expensive

- PCI Express payload is full dword.
- Flipping single bits across PCIE is expensive
- In-order processing will help reduce number of writes

Summary

- Virtio 1.1 is shaping up to be a big release
  - Performance
  - Hardware offloads

- Join the fun
  - Still lots of open questions
  - Implementation and benchmarking of the new features
  - Virtio BoF tomorrow

redhat.