Interrupt Coalescing in Xen
with Scheduler Awareness

Michael Peirce & Kevin Boos

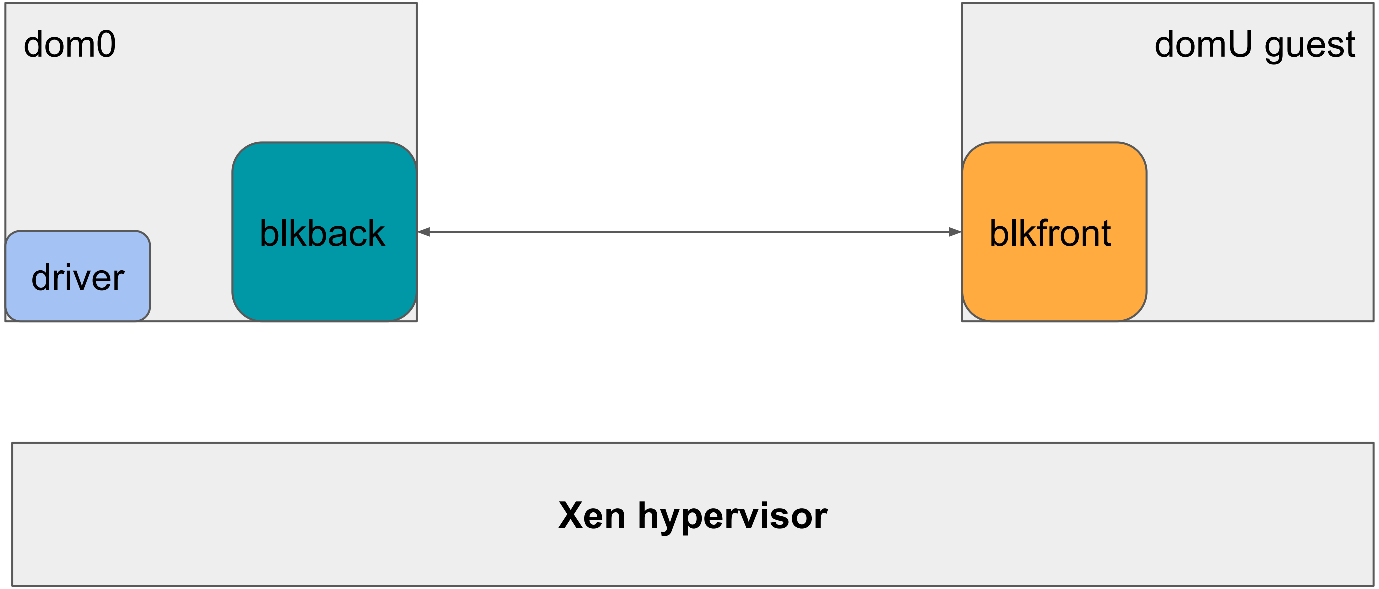
Outline

- Background
- Hypothesis
- vIC-style Interrupt Coalescing
- Adding Scheduler Awareness
- Evaluation

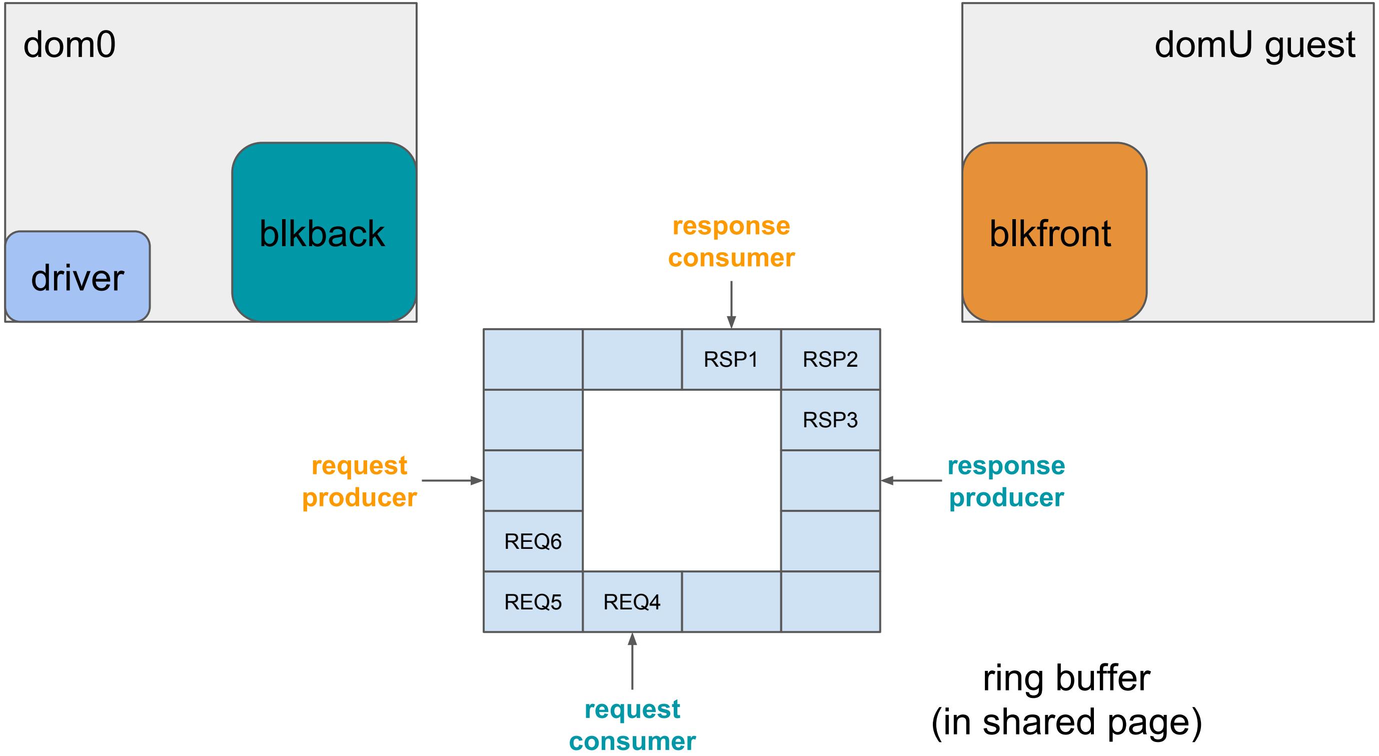
Background

Xen split block drivers

Background: Xen block drivers



Background: ring buffers



dom0

driver

blkback

domU guest

blkfront

response consumer

RSP1

RSP2

RSP3

request producer

response producer

REQ6

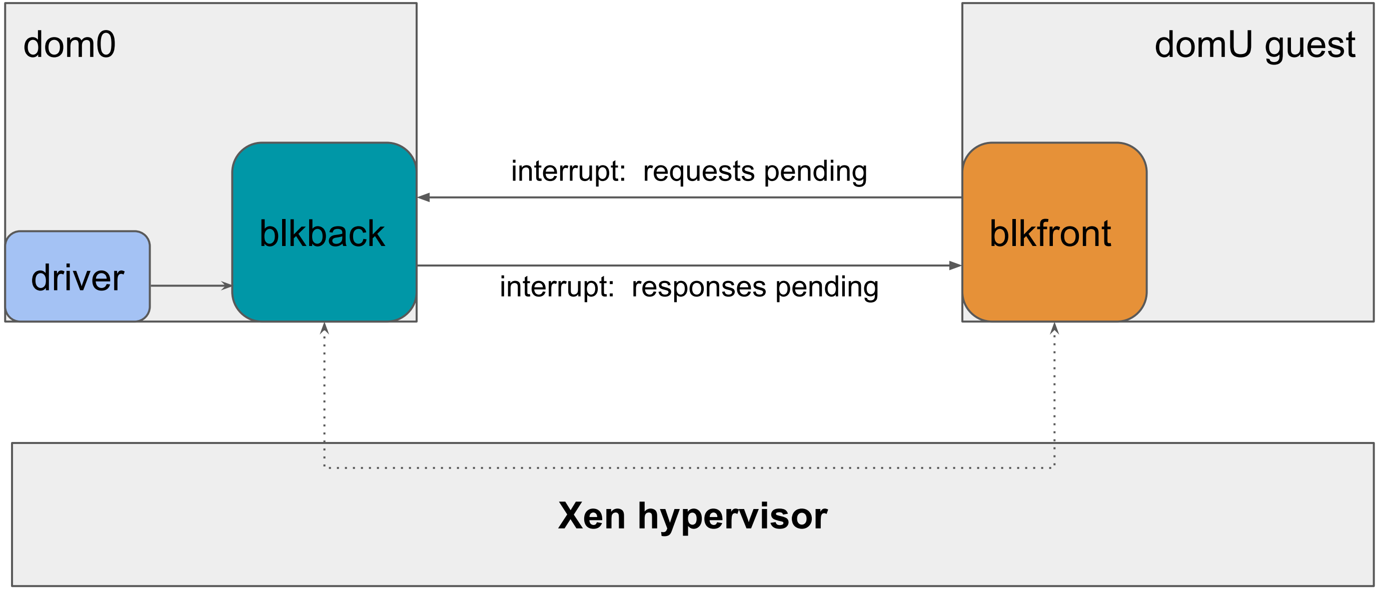
REQ5

REQ4

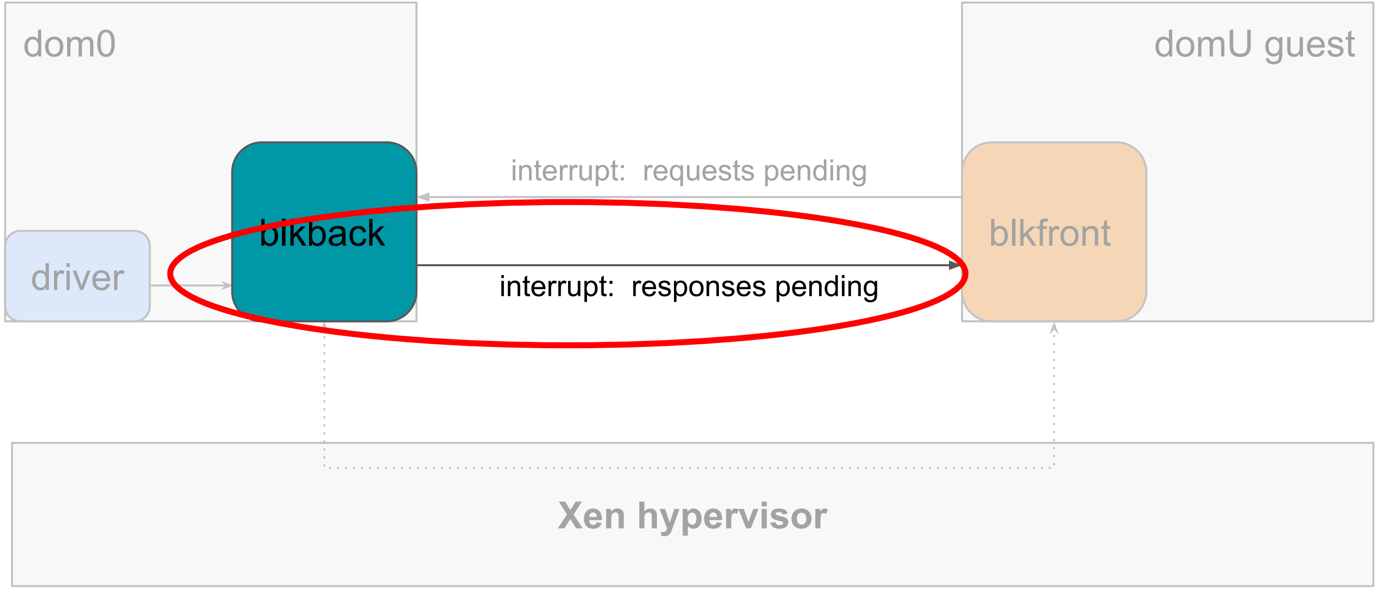
request consumer

ring buffer
(in shared page)

Background: interrupt event channels



Focus on blkback



Hypothesis

Hypothesis

1) Coalescing interrupts in Xen will increase throughput of block devices at minor latency cost (vIC)
   - fewer interrupts reduces CPU overhead

2) Scheduler awareness will improve upon existing coalescing policies by reducing latency
   - less coalescing towards end of timeslice
   - minimal reduction in throughput

Conventional Interrupt Coalescing

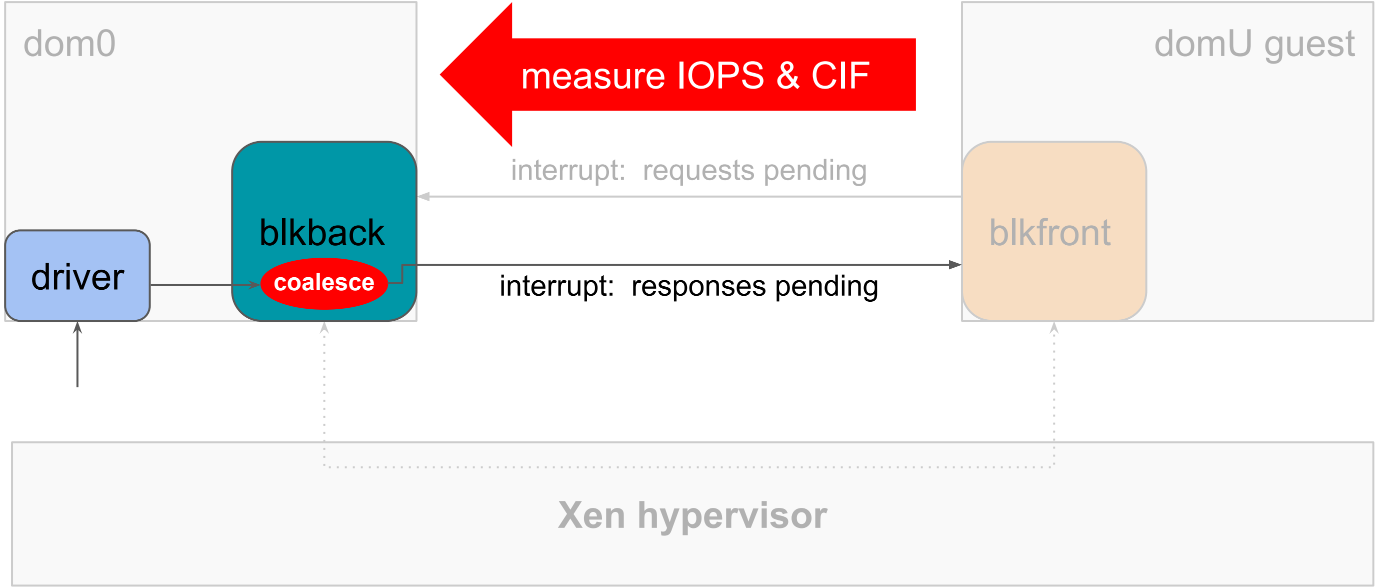
VMware vIC

VMware-style Coalescing (vIC)

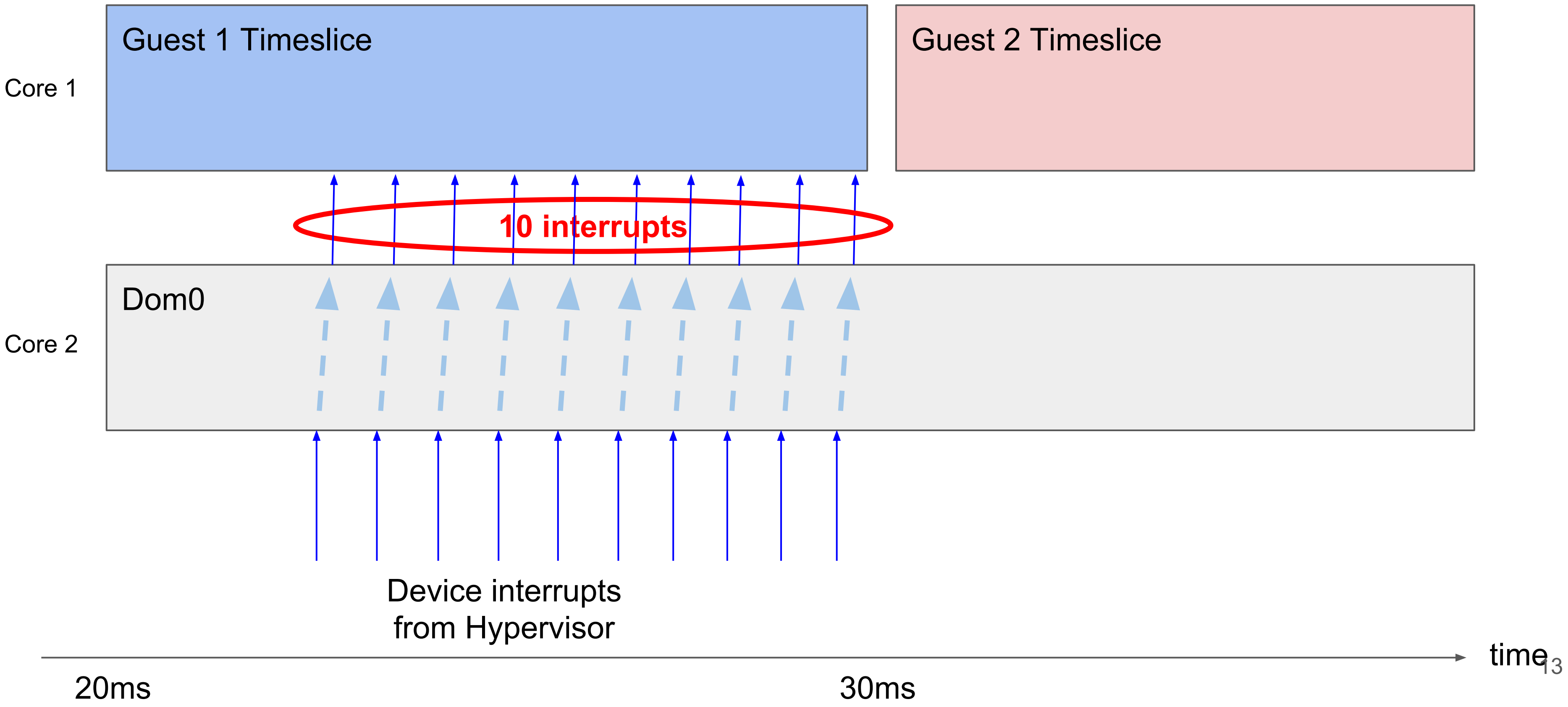
- Interrupt coalescing is absent in Xen
- Added conventional coalescing based on VMware’s vIC
- Interrupt delivery ratio based on configurable parameters:
  - IOPS threshold
  - CIF threshold
  - (Epoch period)

- Implemented in dom0’s kernel, in xen_blkback module
  - On each block_io completion event, decide whether to deliver interrupt

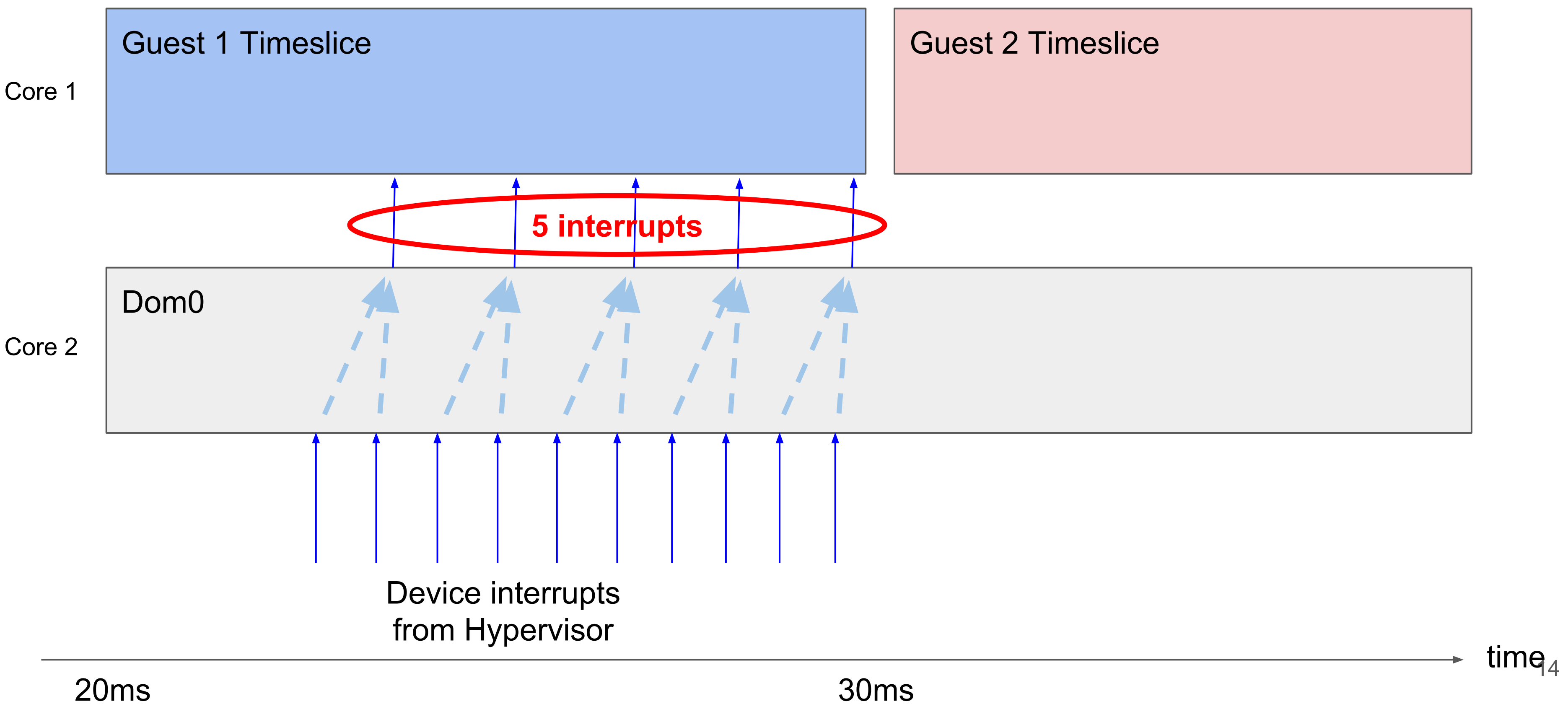
vIC Implementation Diagram



Default Interrupt Delivery (no coalescing)

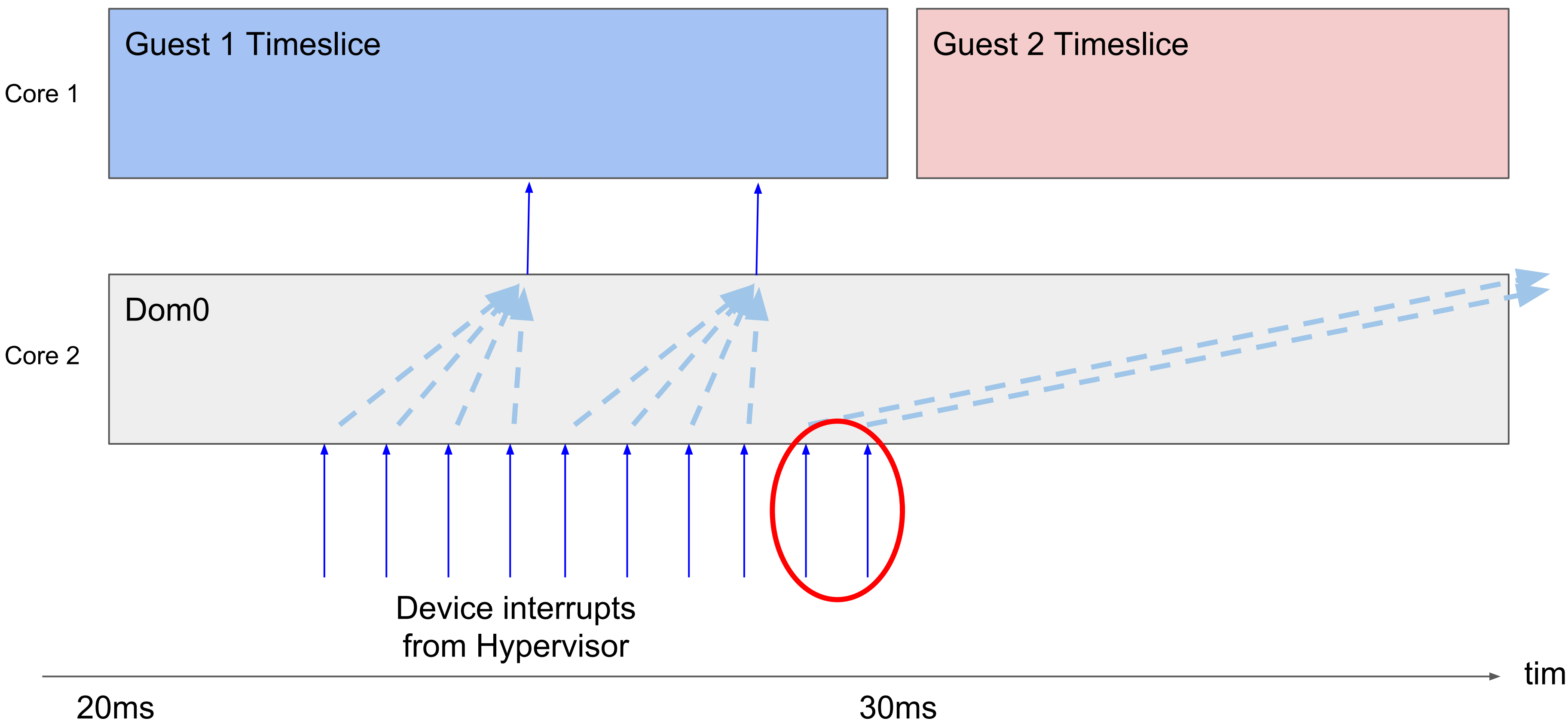


Increasing Disk Throughput in vIC



Scheduler Awareness

Latency Problems in vIC



Guest 1 Timeslice

Guest 2 Timeslice

Core 1

Dom0

Core 2

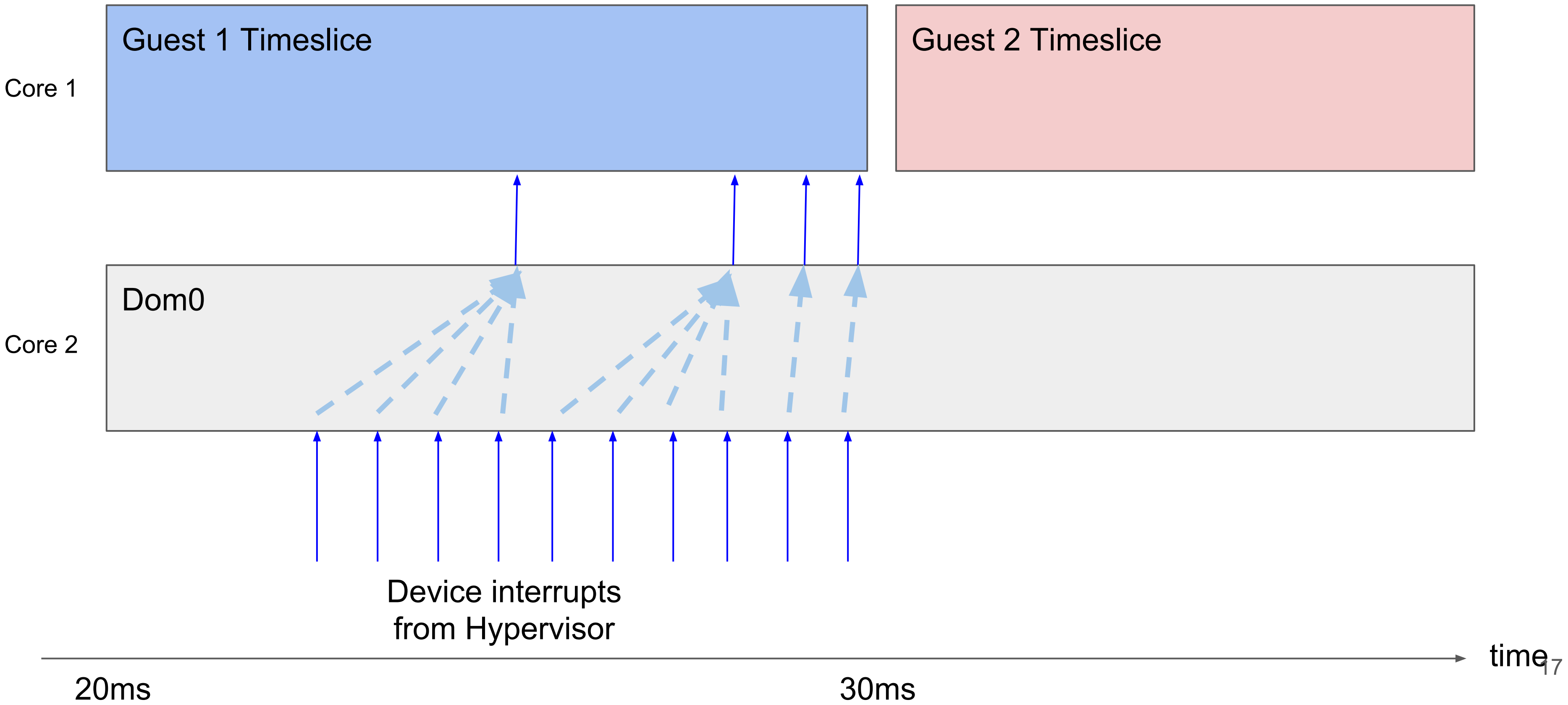
Device interrupts from Hypervisor

time

20ms

30ms

Reducing Latency



Hybrid approach: vIC + scheduler awareness

- Should we use a separate interrupt delivery policy based on scheduler info alone?
  - No, too coarse-grained and unintelligent

- ~~Use scheduler info to configure vIC’s parameters & ratio~~
- **Hard guarantee** that interrupts will be delivered right at the very end of a timeslice
  - “end of timeslice” cutoff is configurable

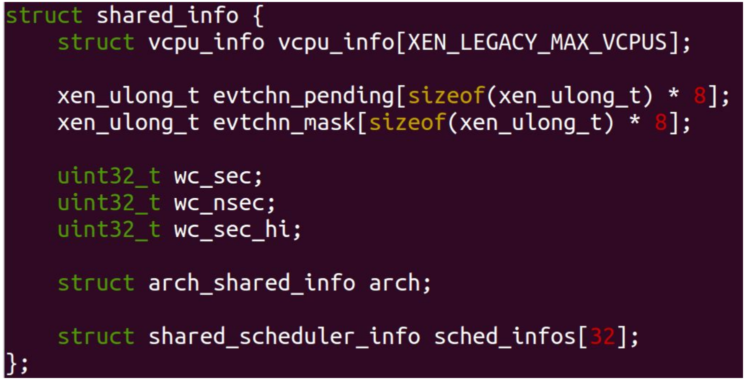
Exposing scheduler info from hypervisor

- Easy way: add hypercall to retrieve scheduler info
  - Pros: easy to implement, info generated on demand
  - Cons: high overhead, long latencies → stale info

- Hard way: shared memory region with dom0
  - Pros: info is fresh, available immediately
  - Cons: info is updated constantly, very difficult to implement

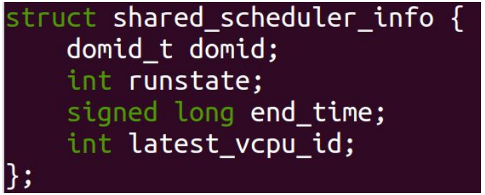
Implementing shared scheduler info

- Xen allocates a shared page for each domain when it boots
  - boot info, arch-specific details, interrupt masks/bit vectors



```
struct shared_info {
    struct vcpu_info vcpu_info[XEN_LEGACY_MAX_VCPUS];

    xen_ulong_t evtchn_pending[sizeof(xen_ulong_t) * 8];
    xen_ulong_t evtchn_mask[sizeof(xen_ulong_t) * 8];

    uint32_t wc_sec;
    uint32_t wc_nsec;
    uint32_t wc_sec_hi;

    struct arch_shared_info arch;

    struct shared_scheduler_info sched_infos[32];
};
```

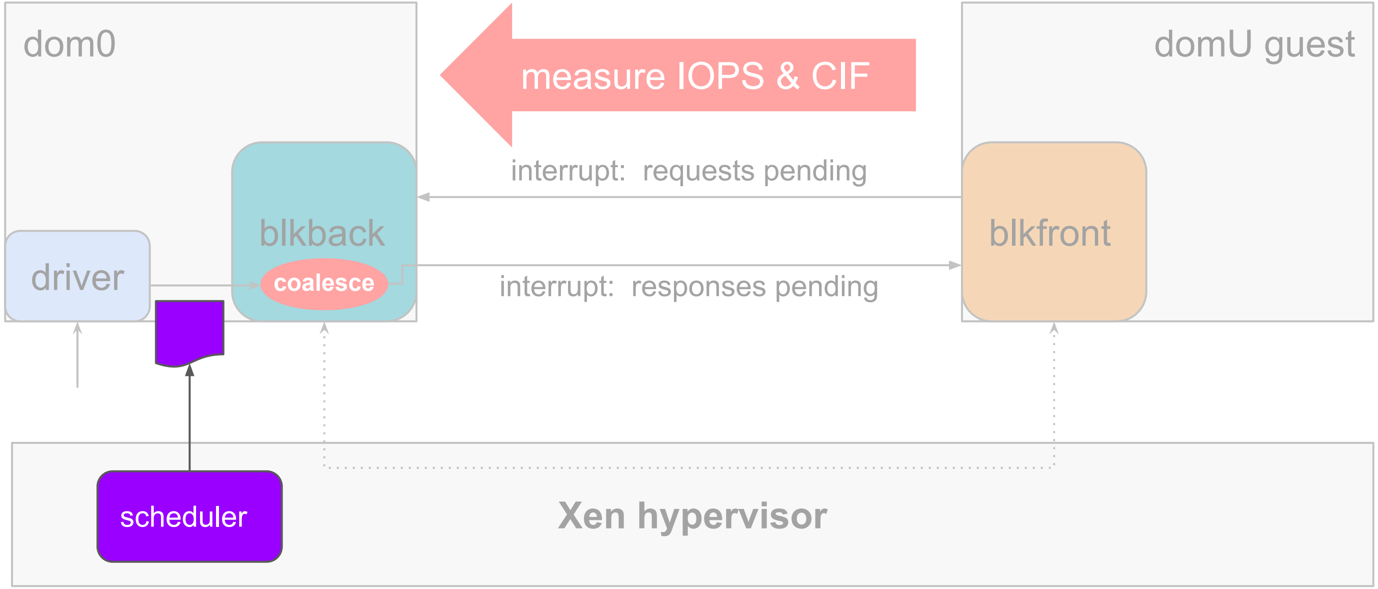
- Added scheduler info to shared page
  - One per domain (except idle & dom0)
  - Only visible in dom0
  - Updated in hypervisor’s `schedule()`



```
struct shared_scheduler_info {
    domid_t domid;
    int runstate;
    signed long end_time;
    int latest_vcpu_id;
};
```

- Much difficulty with time synchronization

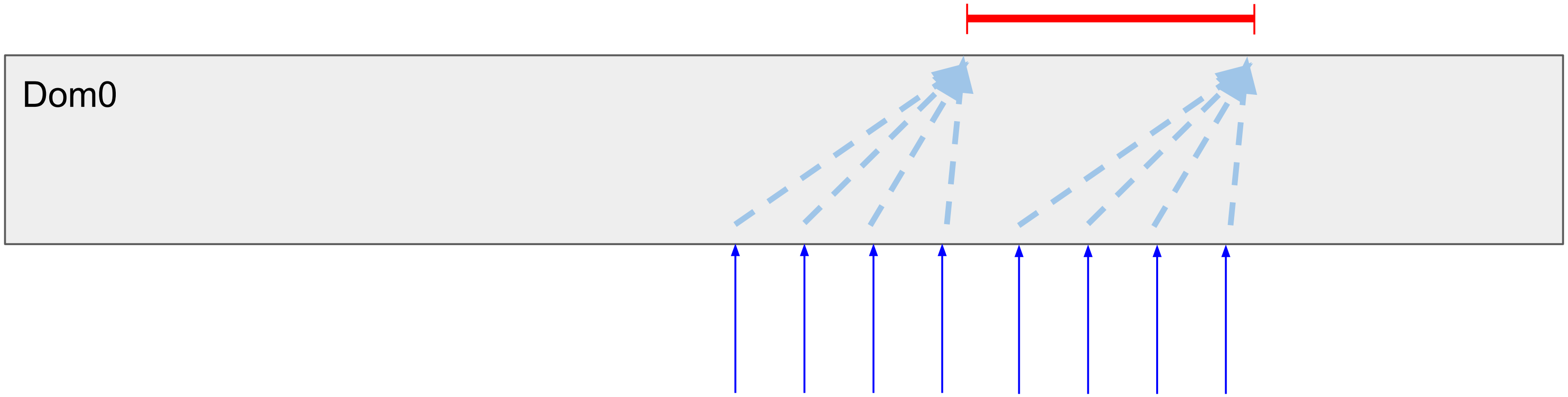
Scheduler Awareness Implementation Diagram



Scheduler Awareness Policy

We choose to deliver an interrupt when:

$$\textit{remaining time in timeslice} < \frac{1}{(\text{Ratio} * \text{IOPS})}$$



Evaluation

Evaluation Setup

- Default credit scheduler enabled
- dom0 pinned to two CPU cores, reserved for dom0 only
- All guests pinned to the same single core
  - Eliminates effects of migration
  - Imitates guest CPU contention on high-density servers

- Tools to generate disk workload:
  - Copy files with dd, small block size to create more I/O requests
  - Custom interrupt injection tool

Evaluation Questions

- Can we achieve higher throughput with minimal latency?

vIC

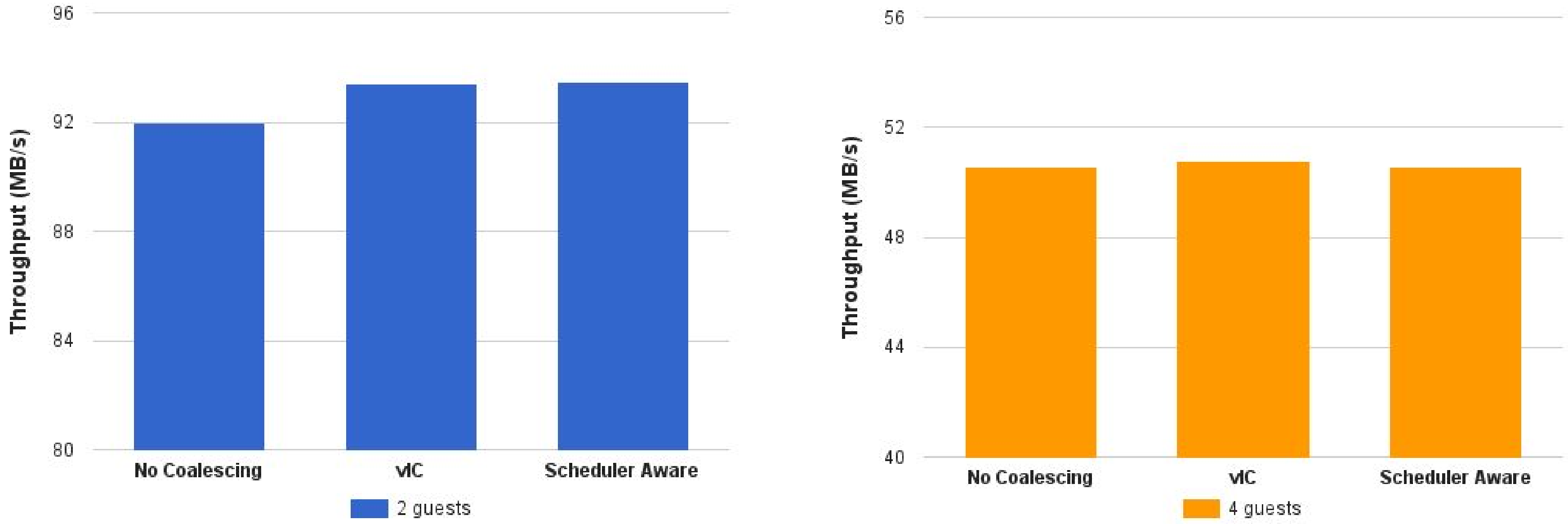
- Can we achieve the same increased throughput as vIC with less latency?

scheduler awareness

Throughput Measurement

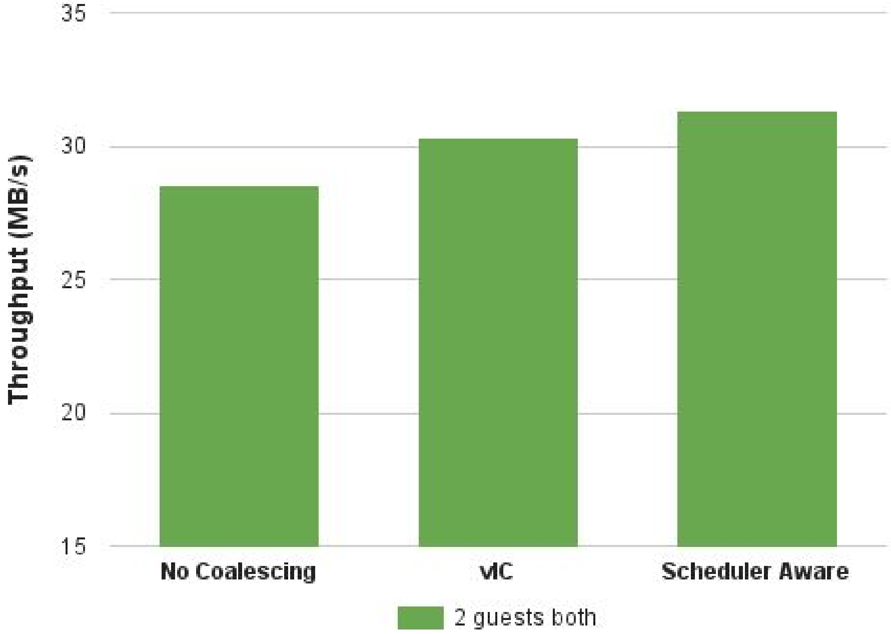
- Copy files using dd tool with small block size of 8 & 512 bytes
  - Measure execution time of 1GB file transfer

Throughput Results



One guest performing I/O, others hogging CPU

Throughput Results

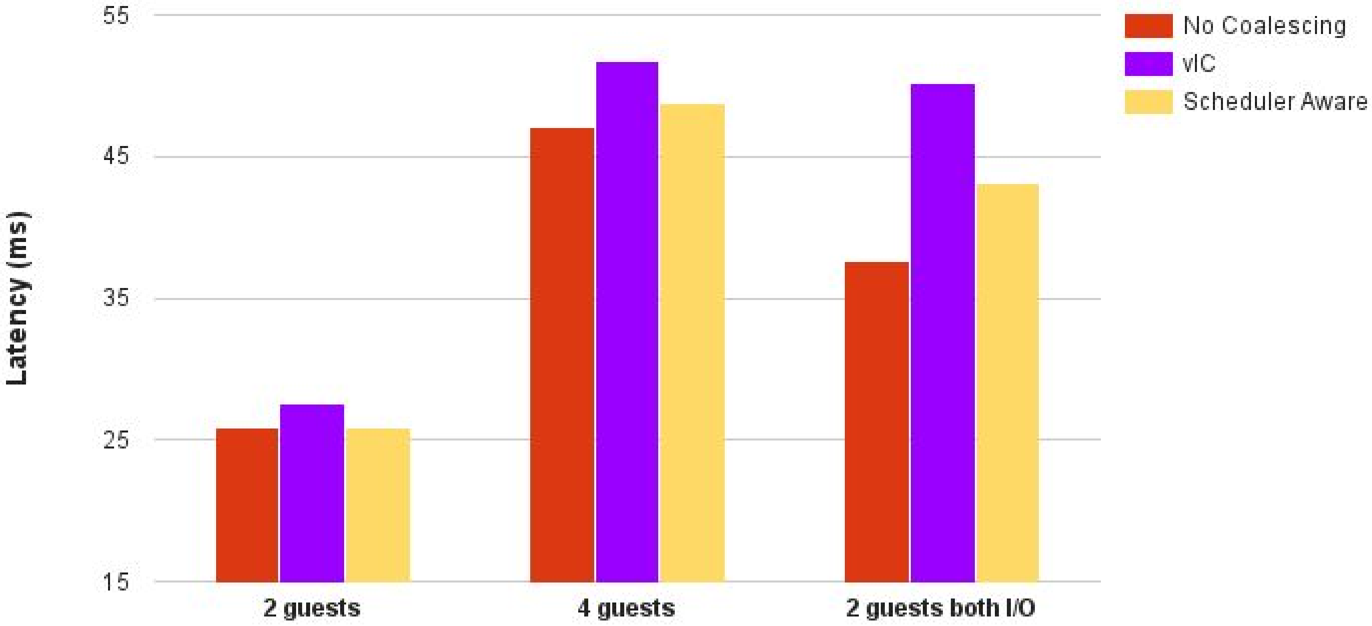


All guests performing I/O, all guests hogging CPU

Latency Measurement

- Instrumented frontend block driver in the guest kernel
  - Assign (guest-specific) unique ID to each request
  - Start timer when request is submitted
  - End timer when response is received

Latency Results



Conclusion

Concluding Remarks

- As expected, interrupt coalescing does increase throughput
- Scheduler awareness reduces latency while maintaining the increased throughput
- Overall effects are less significant than expected
  - Need more demanding test environment

- Future work: change beginning of timeslice behavior

- Our experience developing on Xen was mediocre
  - Tedious, slow, constant reboots
  - Multiple independent code bases (dom0, xen, domU)
  - Limited debug logs, no post-crash log
  - Toolset support and networking is a nightmare