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NICTA

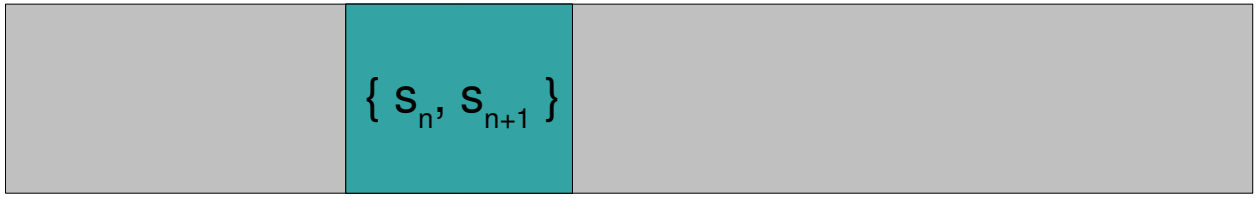
I/O Scheduling

Performance

Mechanisms

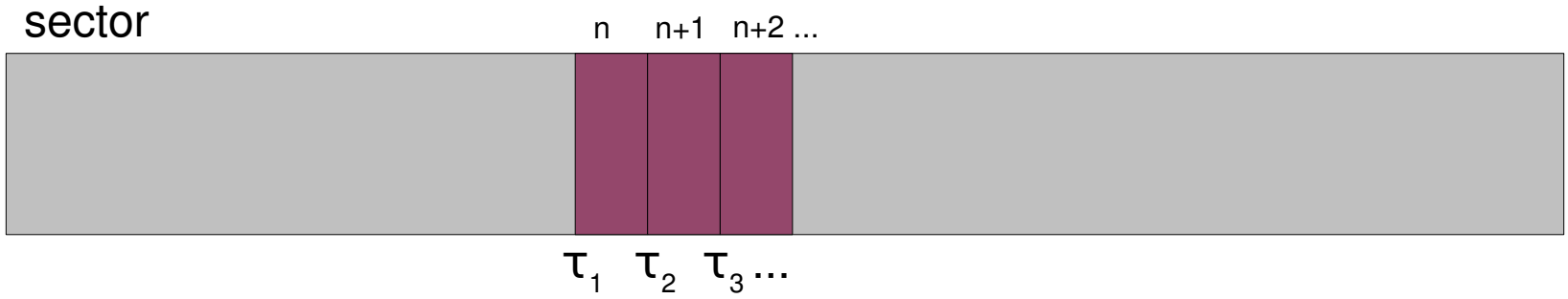
- Reordering
  - don't (necessarily) issue the I/Os in arrival order
  - SATF, SSTF, SCAN, CSCAN, etc.

- Merging



- Delaying
  - non-work-conserving schedulers

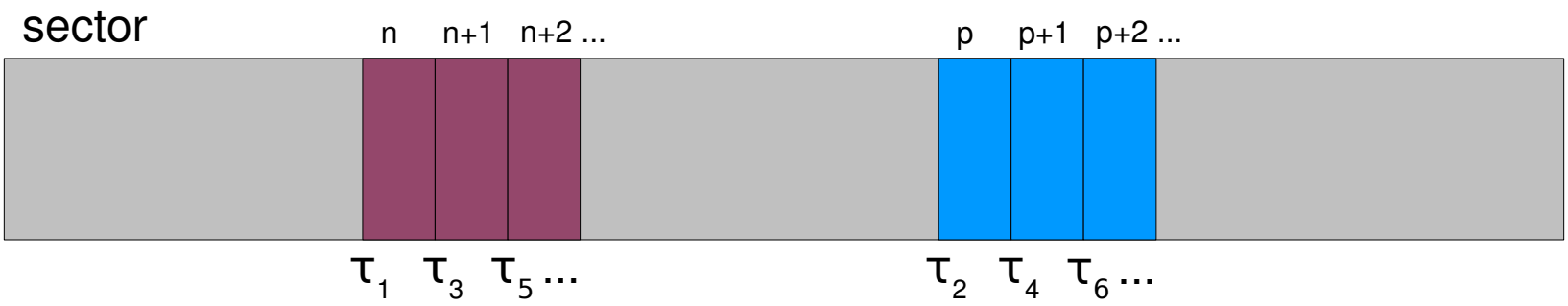
Anticipation



- synchronous: wait for completion before next issue
- sequential: contiguous sector addresses

- thinktime: time from completion → issue

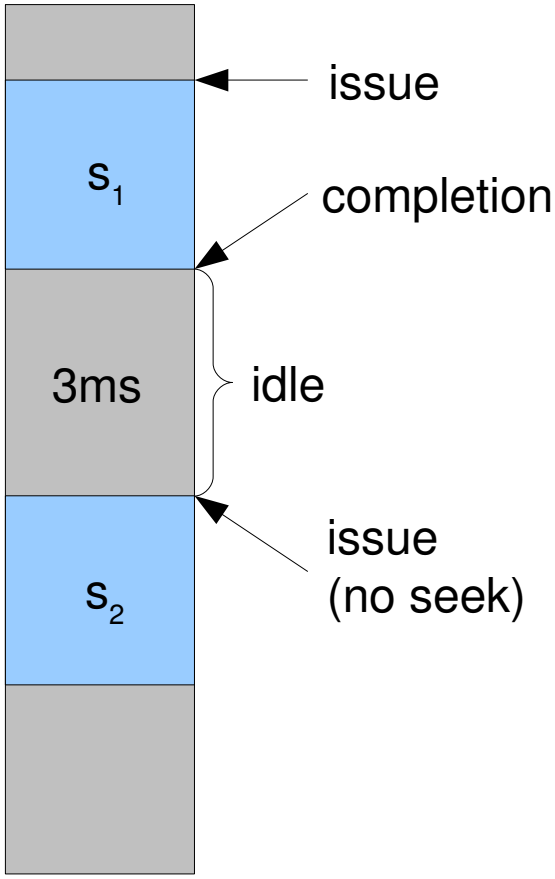
Anticipation

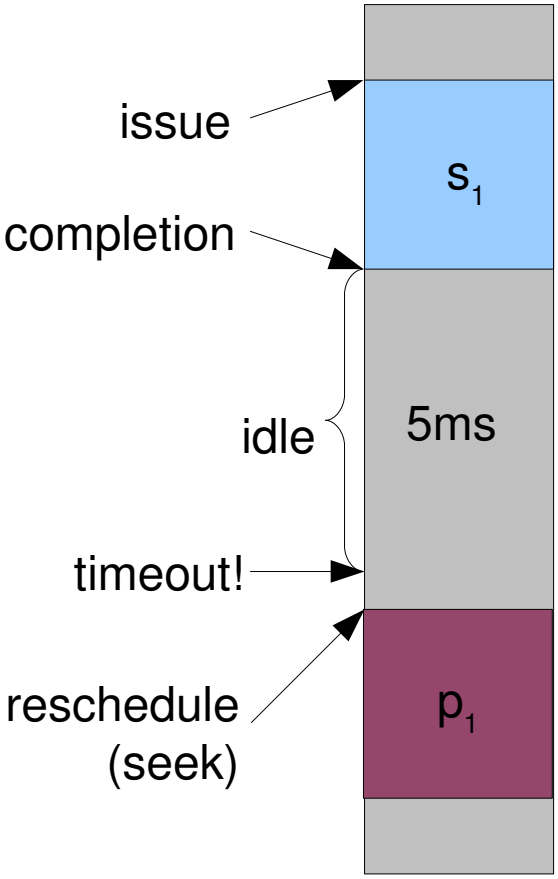


problem: deceptive idleness

Anticipation

idea: give a process time to issue a new request





Anticipation

- good performance if:

$$t_{antic} < t_{seek} \text{ (average)}$$

- huge performance hit if we get it wrong!

- Iyer and Druschel (SOSP'01)

  Anticipatory scheduling: A disk scheduling framework to overcome deceptive idleness in synchronous I/O

  – Apache: +29% and +71%
  – AFS: +8%
  – TPC-B: +2—60%

Anticipation

- Linux “as” (Nick Piggin '02)

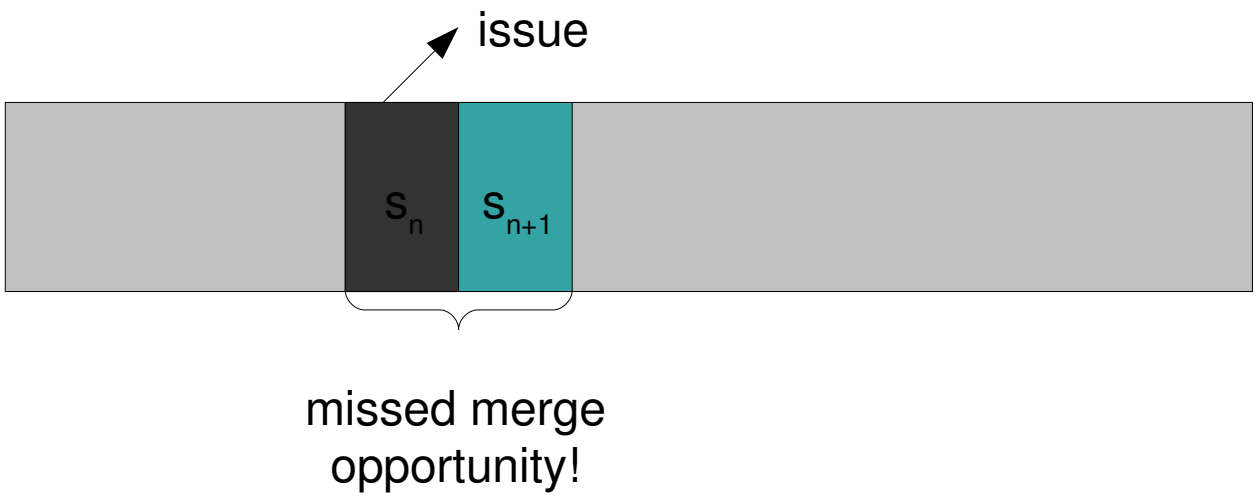
- When to anticipate?
  - seek distance is “small”
  - thinktime is “small”

- Other considerations
  - nearby requests
  - >1 request issued
  - write issued
  - hardware queueing
  - process disappeared

```
struct as_io_context {
    /* IO History tracking */
    /* Thinktime */
    unsigned long last_end_request;
    unsigned long ttime_total;
    unsigned long ttime_samples;
    unsigned long ttime_mean;
    /* Layout pattern */
    unsigned int seek_samples;
    sector_t last_request_pos;
    u64 seek_total;
    sector_t seek_mean;
};
```

Plugging

- Merging: combine sector-adjacent requests
- What happens if the queue is empty?



- Plugging: delay new I/O streams

Fair Queueing

Fair Queueing

- Goal: distribute disk resources “fairly” to users and/or processes

- Proportional bandwidth
  - a disk is not a fixed-bandwidth device!
  - available bandwidth depends on access pattern
  - result: poor utilisation

- Proportional time
  - allocate disk in time-slices (c.f. CPU scheduling)
  - e.g. Linux's CFQ

CFQ

- Completely “Fair” Queueing
  - Jens Axboe, 2003
  - currently at v3

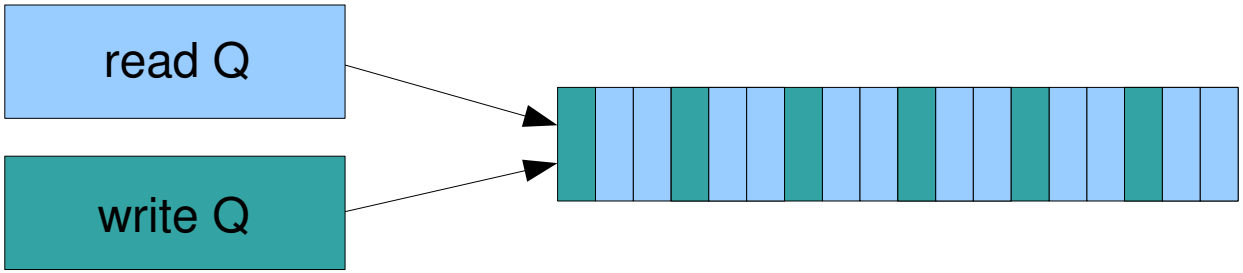
- one queue per thread
  - rb-tree sorted by sector
- service each queue round-robin
- 100ms default time-slice

Reads vs. Writes

- reads: usually synchronous
  - something is waiting for the result
  - latency sensitive!
- writes: usually asychronous
  - coming from the buffer-cache
- prefer reads

Reads vs. Writes

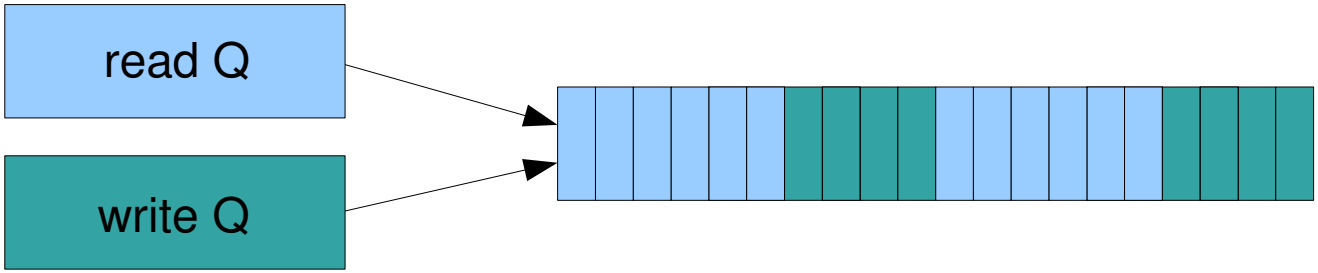
- solution: handle reads and writes separately
- issue x reads for every write



- problem: lost spatial locality!

Reads vs. Writes

- solution: batching

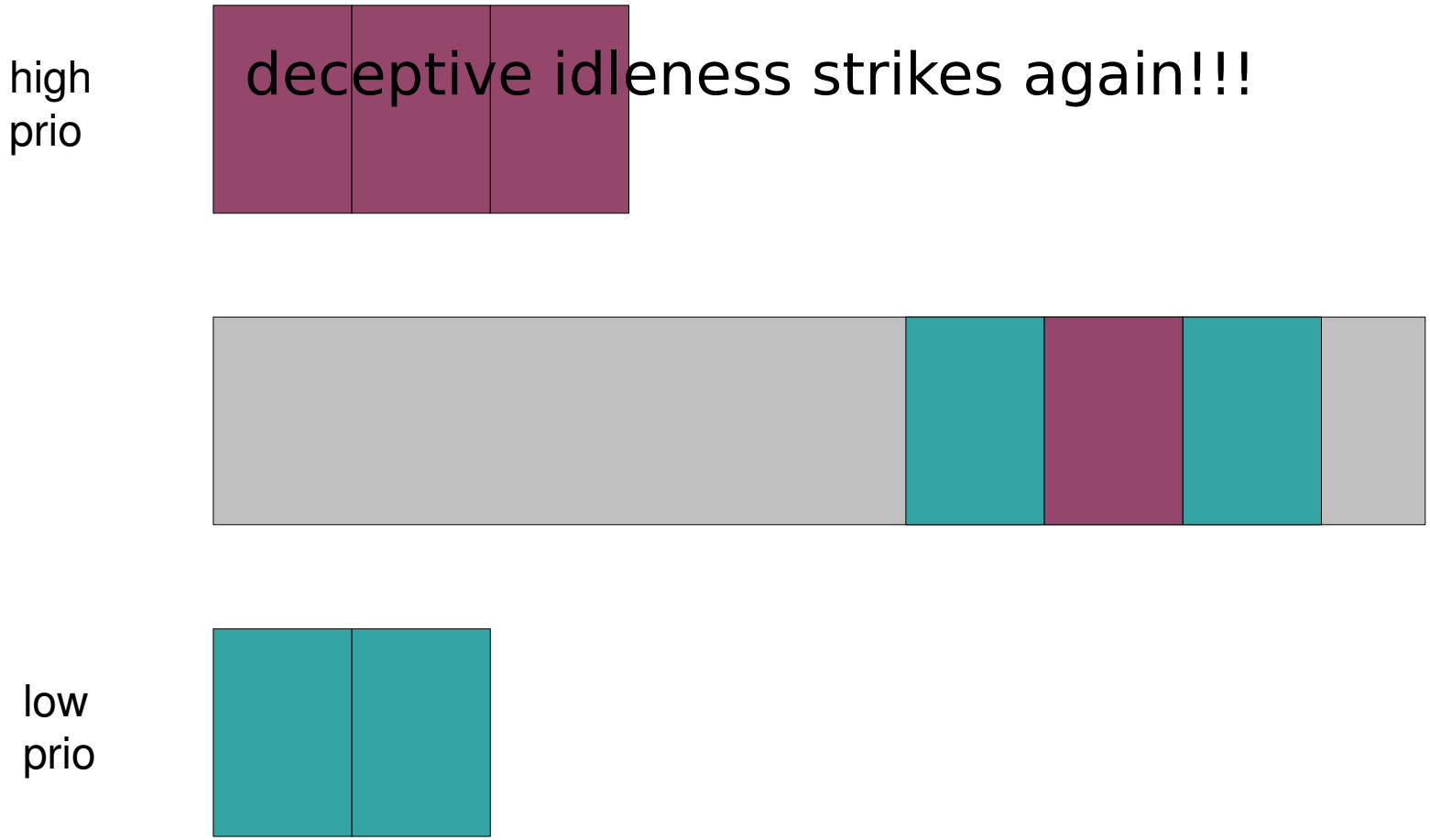


- as: issue reads for 500ms, writes for 125ms
- deadline: 2 read batches for each write batch
  - 16 requests per batch
- CFQ: lump all writes in a single queue

I/O Priorities

- some threads are more equal than others
- scale time-slice length and scheduling frequency
- CFQ
  - real-time
  - best-effort
  - idle

I/O Priorities



I/O Priorities

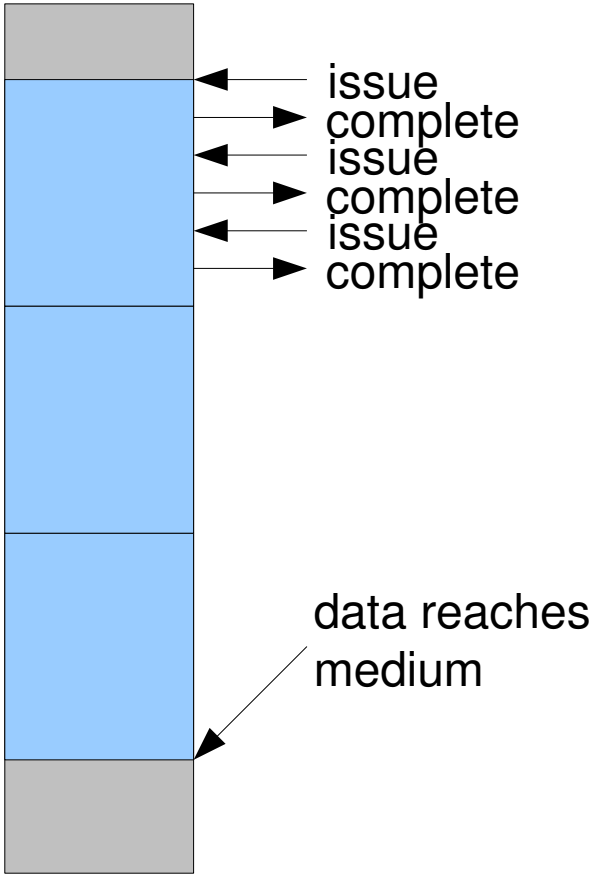
- solution: priority “grace period”
- idle *x* ms before switching to lower priority

- CFQ:
  - wait 100ms before servicing idle class
  - anticipate even for non-sequential I/O

- idle class: you must be root – why?

Hardware

Write-back Buffering



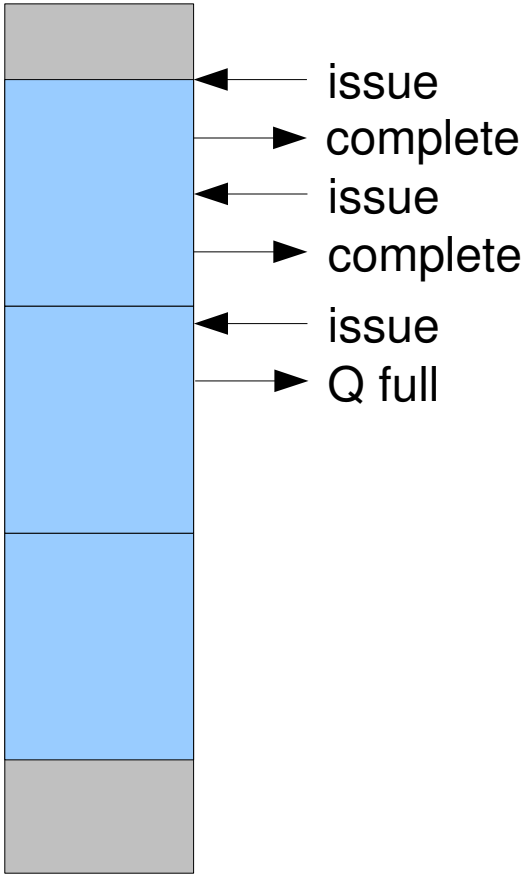
- reduce perceived latency
- overlap disk access with bus traffic
- disk can schedule
- lose your data with well-timed power loss

Write-back Buffering

- can issue many buffered-writes per time-slice
- writes can “escape” the time-slice

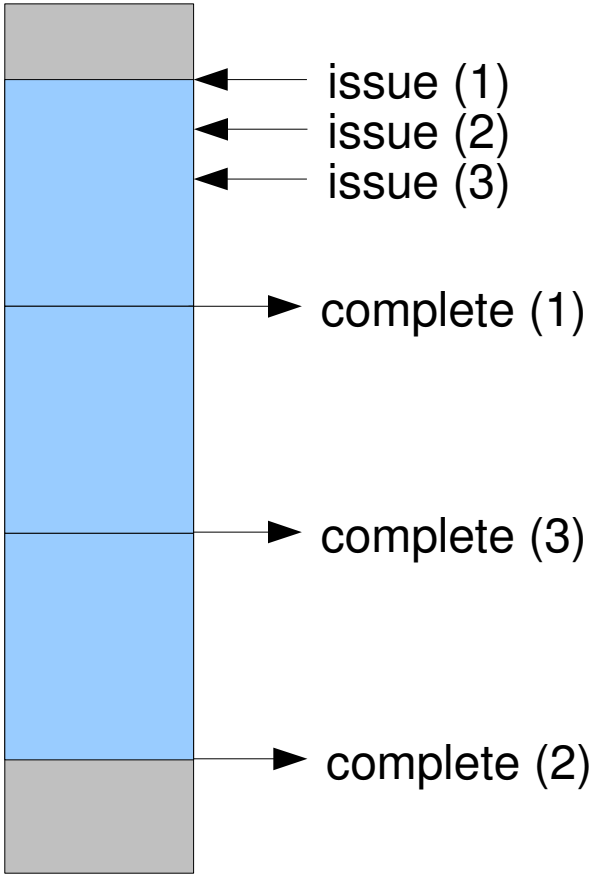
- solution: don't use write-back!
- CFQ: limit #writes per slice
- buffer flush

Write-back Buffering



- no completion events
  - when can we try again?
- solution: disable write-back!
- “adversary effect”

TCQ: Tagged Command Queueing



- overlap disk and bus access
- disk can schedule
- completion events!
  - no adversary effect
  - explicit flush unnecessary
- problem: can issue many I/Os in a short period

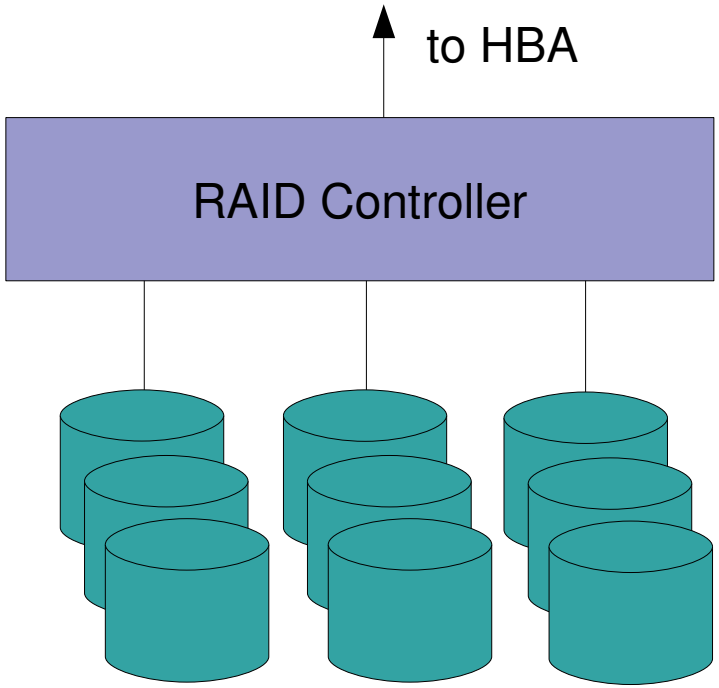
RAID

- is I/O scheduling useful?

- properties:
  - black box
  - huge queues

- seek-limiting: no gain
- merging: very important!
- fairness
- anticipation: tiny arrays only

- key tradeoff: queue depth



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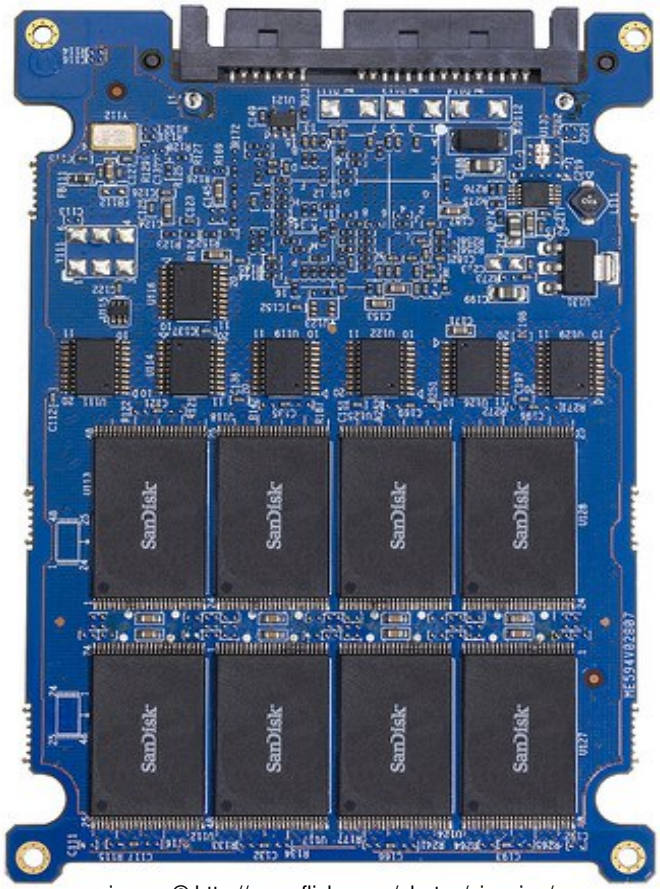
Solid State Drives

... or, why nobody cares about I/O scheduling



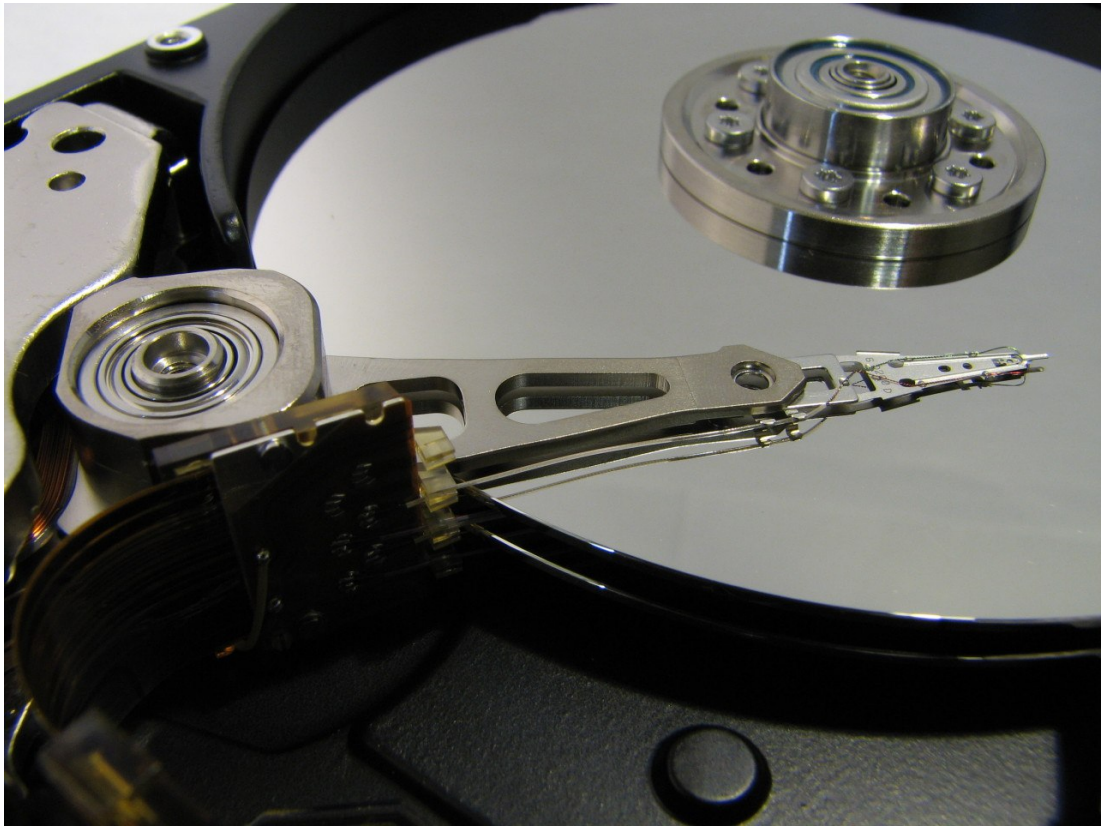


image © http://www.flickr.com/photos/ciaociao/

SSD

- huge IOPS
- locality (mostly) irrelevant

- scheduling SSDs:
  - ???

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From **imagination** to **impact**