Advanced disk scheduling

"Freeblock scheduling"

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PARALLEL DATA LABORATORY

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Outline

- Freeblock scheduling: some theory
- Freeblock scheduling: applied
- Some details
- Q & A

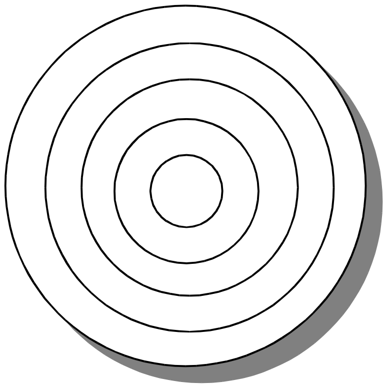
Some theory: preview

- Next few slides will review & show that:
  - disks are slow
    - mechanical delays (seek + rotational latencies)
  - there is nothing we can do during a seek
  - **there is a lot we can do during a rotation**
    - rotational latencies are very large
    - while rotation is happening go to nearby tracks and do useful work
  - "*freeblock scheduling*" = utilization of rotational latency gaps (+ any idle time)

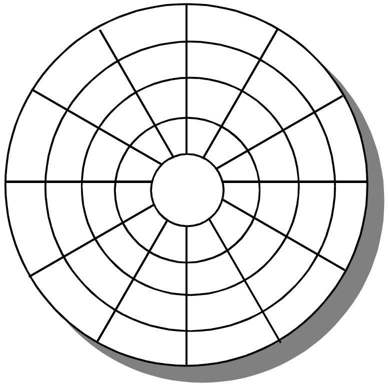
Are disks slow?

- Are the xfer speeds that slow?
  - no, xfer speeds of 200MB/s are pretty good
- So what is slow?
  - workload often not sequential
  - disk head has to move from place to place
  - seek (~ 4ms) + rotation (~ 3ms)
- Effective bandwidth can be very low
  - ~ 10-30MB/s
  - even when SPTF is used

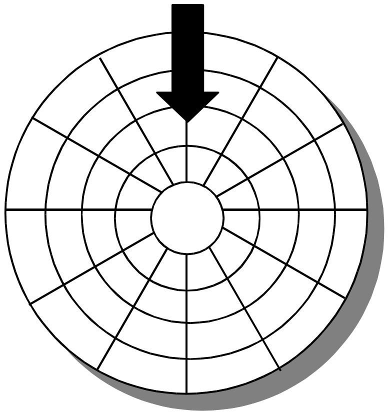
Surface organized into tracks



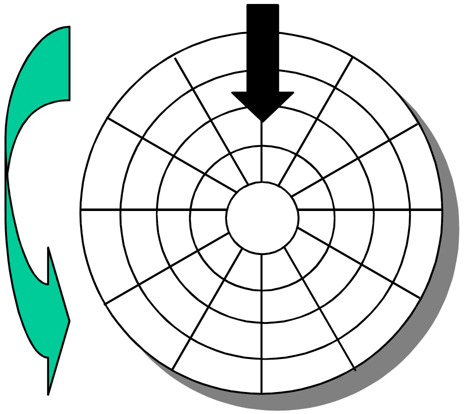
Tracks broken up into sectors



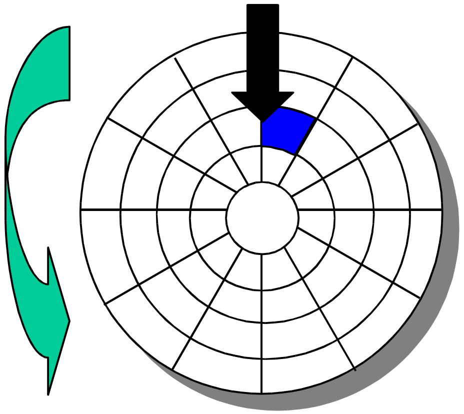
Disk head position



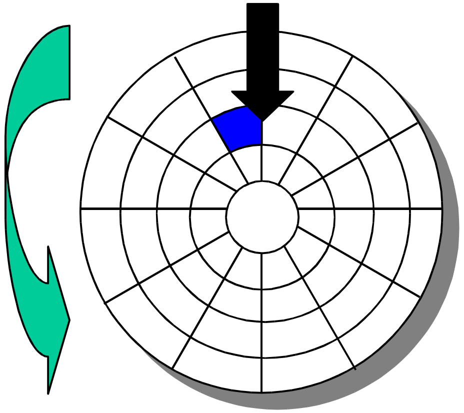
Rotation is counter-clockwise



About to read blue sector

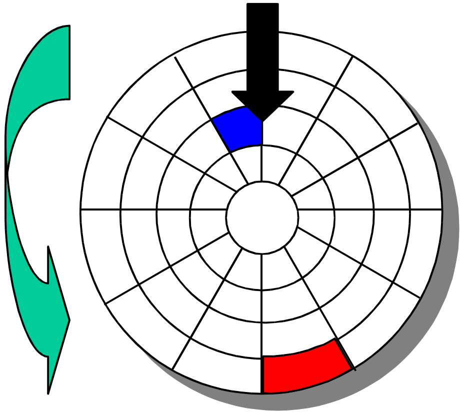


After reading blue sector

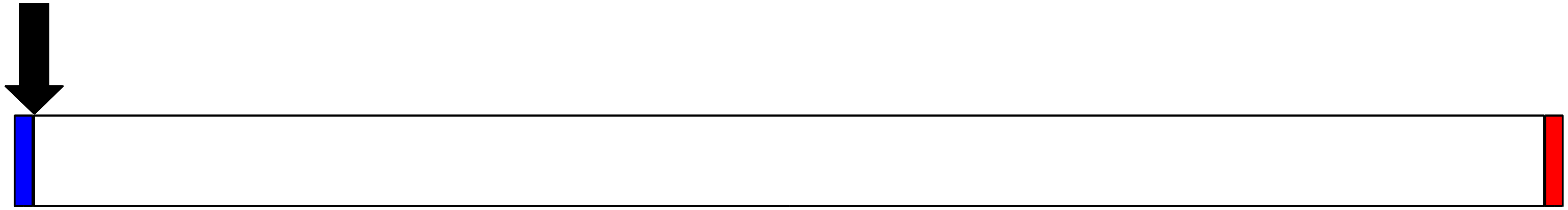


After BLUE read

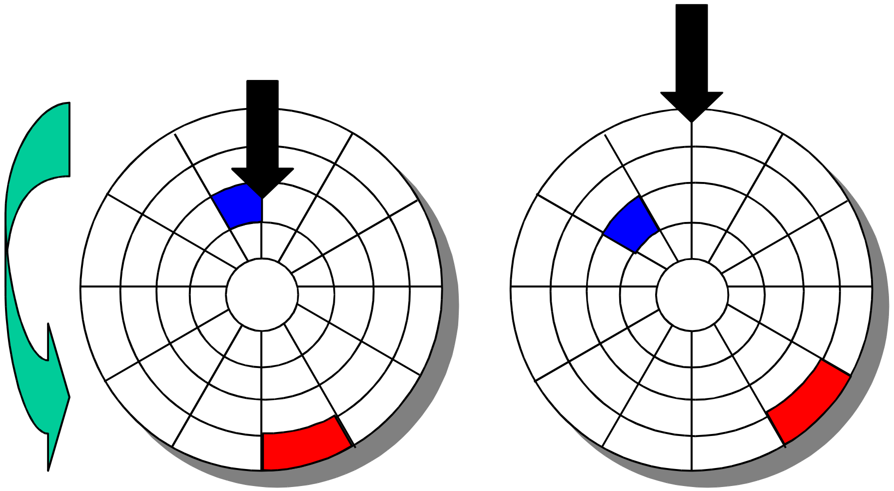
Red request scheduled next



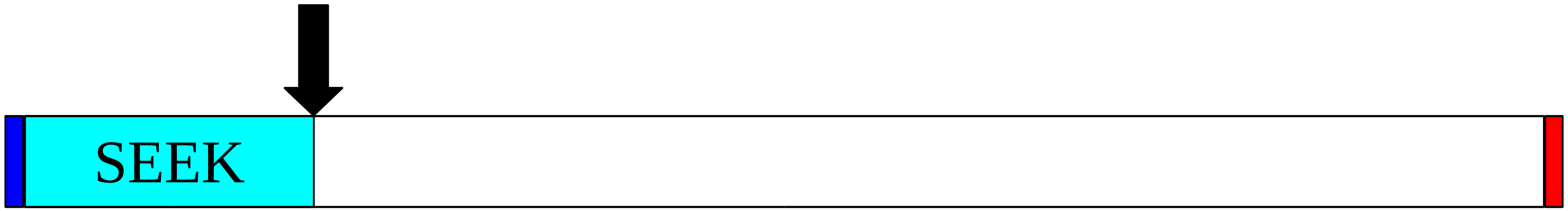
After BLUE read



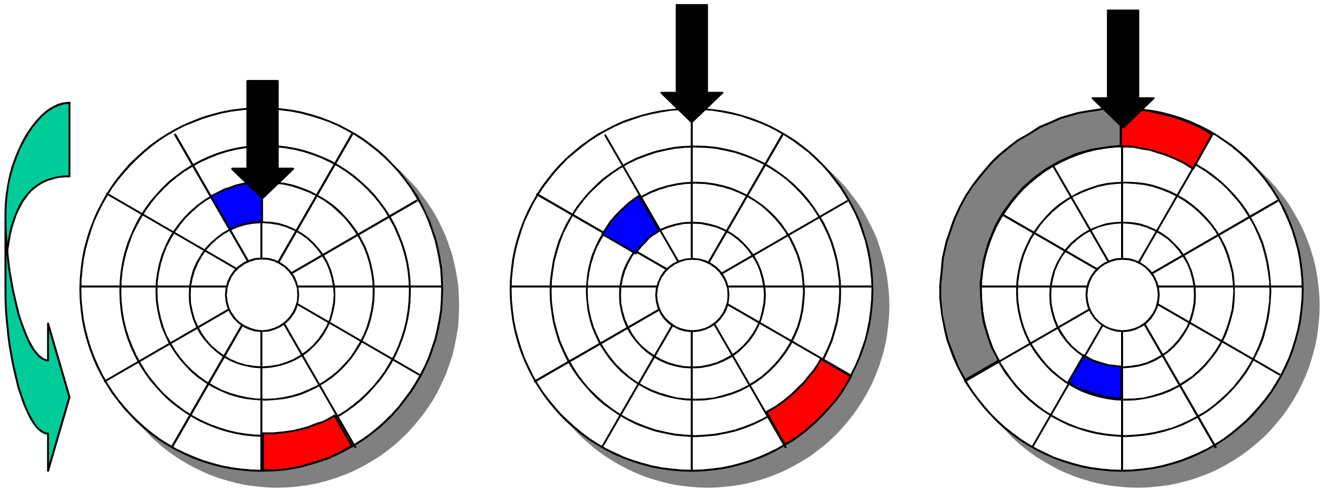
Seek to Red's track



After BLUE read   Seek for RED

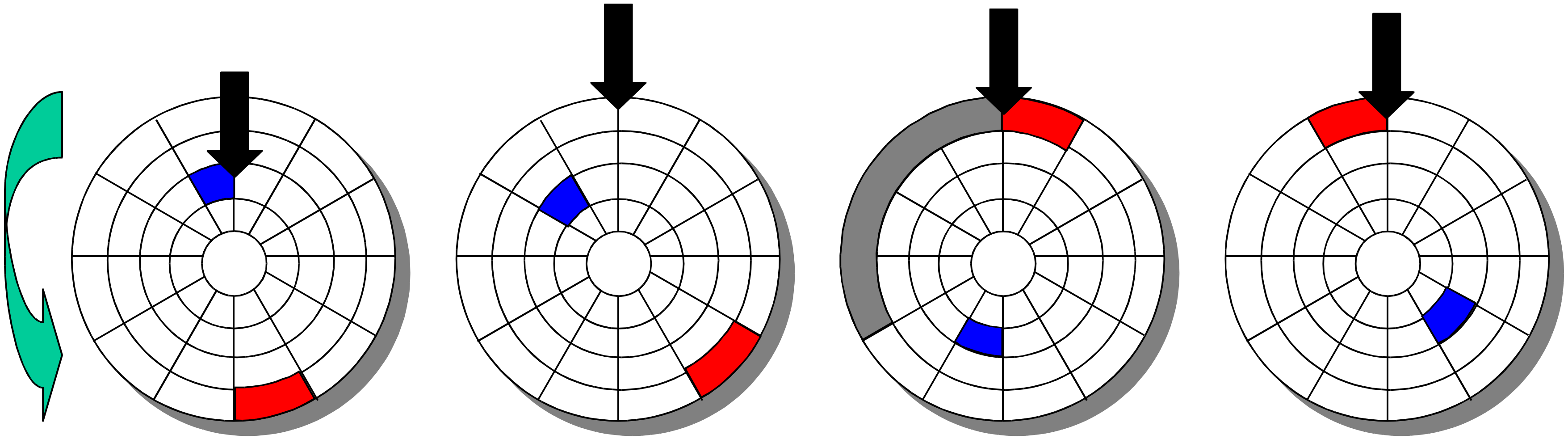


Wait for Red sector to reach head



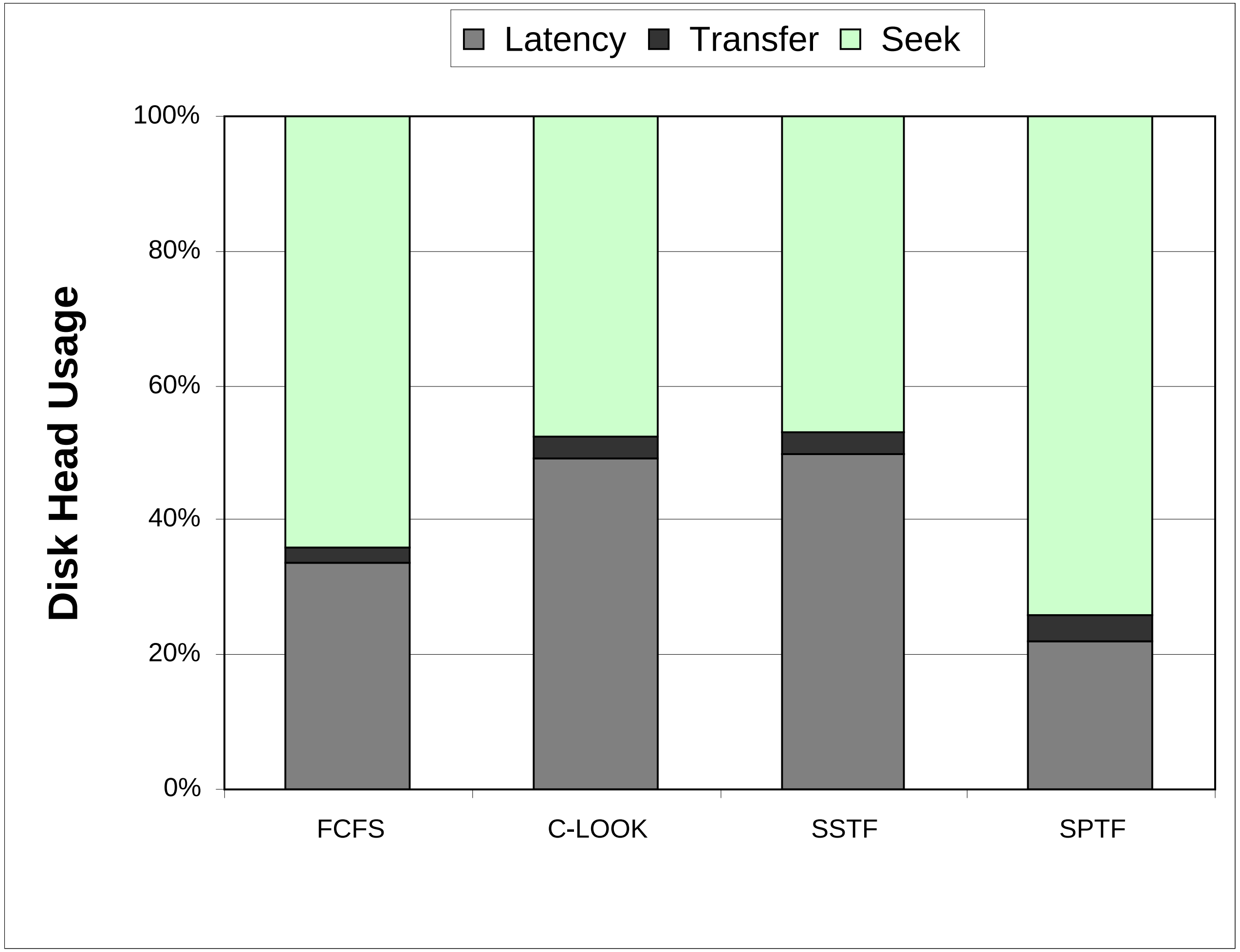
After BLUE read　　Seek for RED　　Rotational latency

Read Red sector

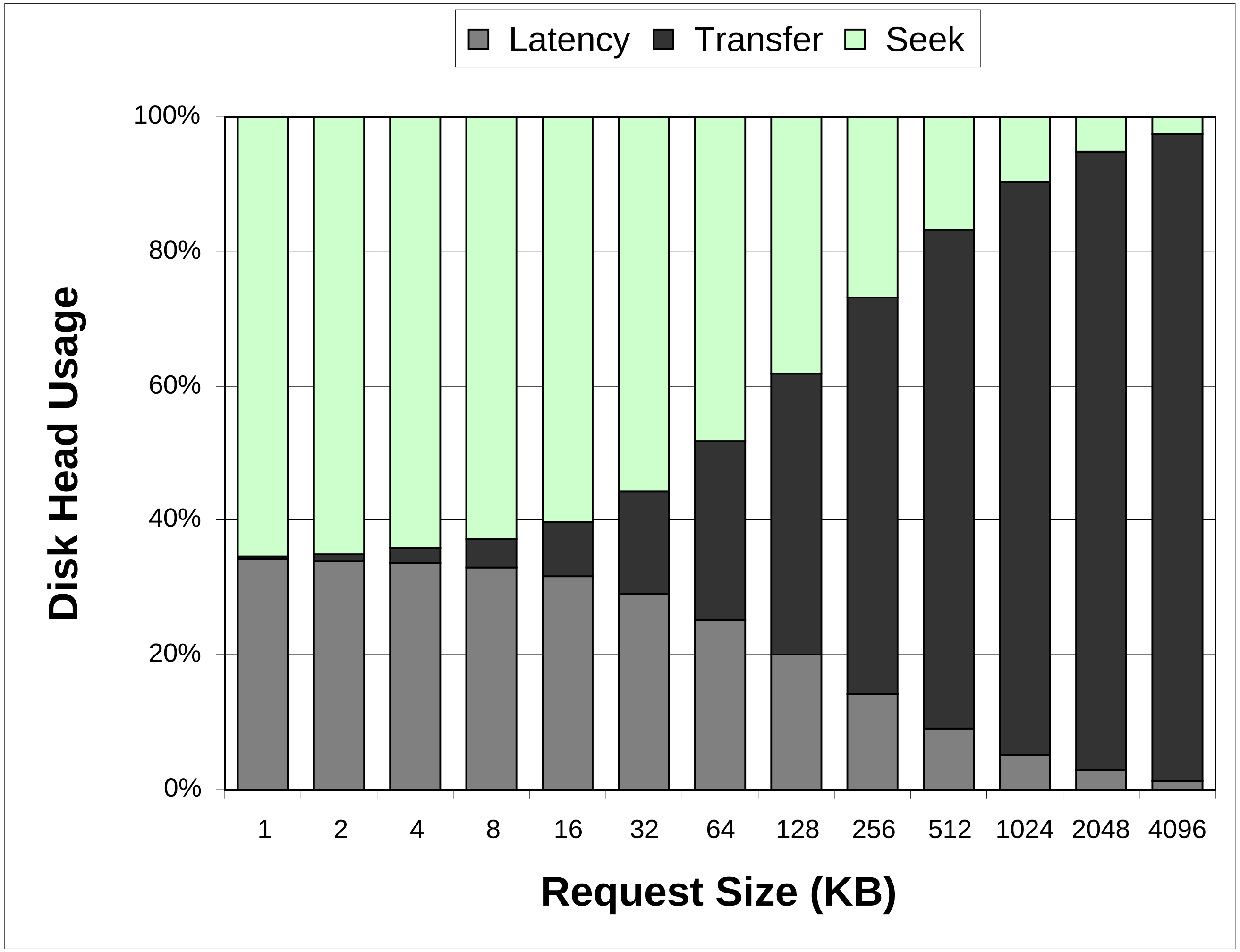


After BLUE read　　Seek for RED　　Rotational latency　　After RED read

Scheduling algorithm Impact



Impact of Request Sizes



What can we do?

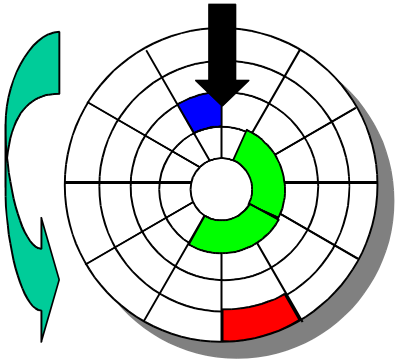
- Nothing we can do during a seek
  - disk head <u>has</u> to move to the right track
- Rotational latency is fully wasted
  - let's use this latency

- During a rotational latency
  - go to nearby tracks and do useful work
  - then, just-in-time, seek back to the original request

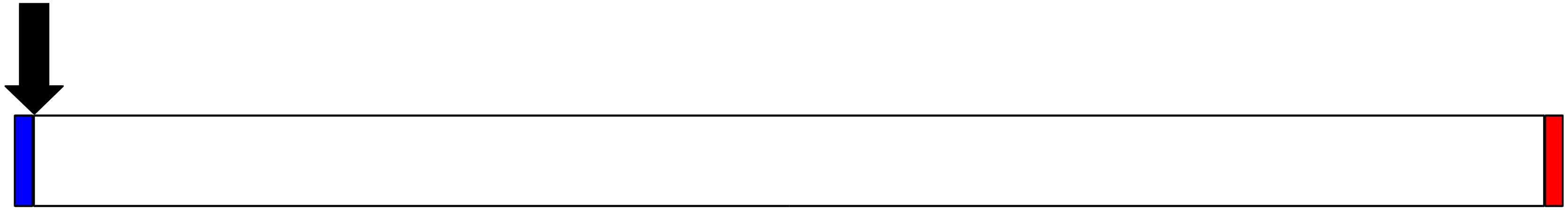
A quick glance ahead…

- What kind of “useful work” are we doing?
  - work that belongs to a “background” app
  - things like backup, defrag, virus scanning
- What do we really gain?
  - background apps <u>don’t interfere</u> with fore. apps
  - background apps still <u>complete</u>
- What’s in it for me?
  - can run defrag + virus scanner + backup in the background while working on your homework and you won’t notice they are running

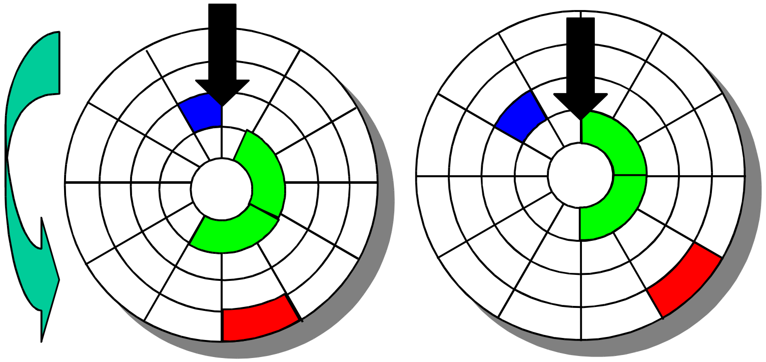
Rotational latency gap utilization



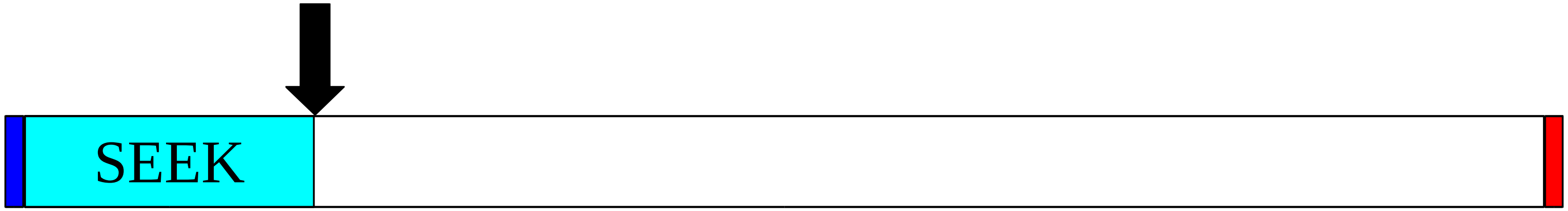
After BLUE read



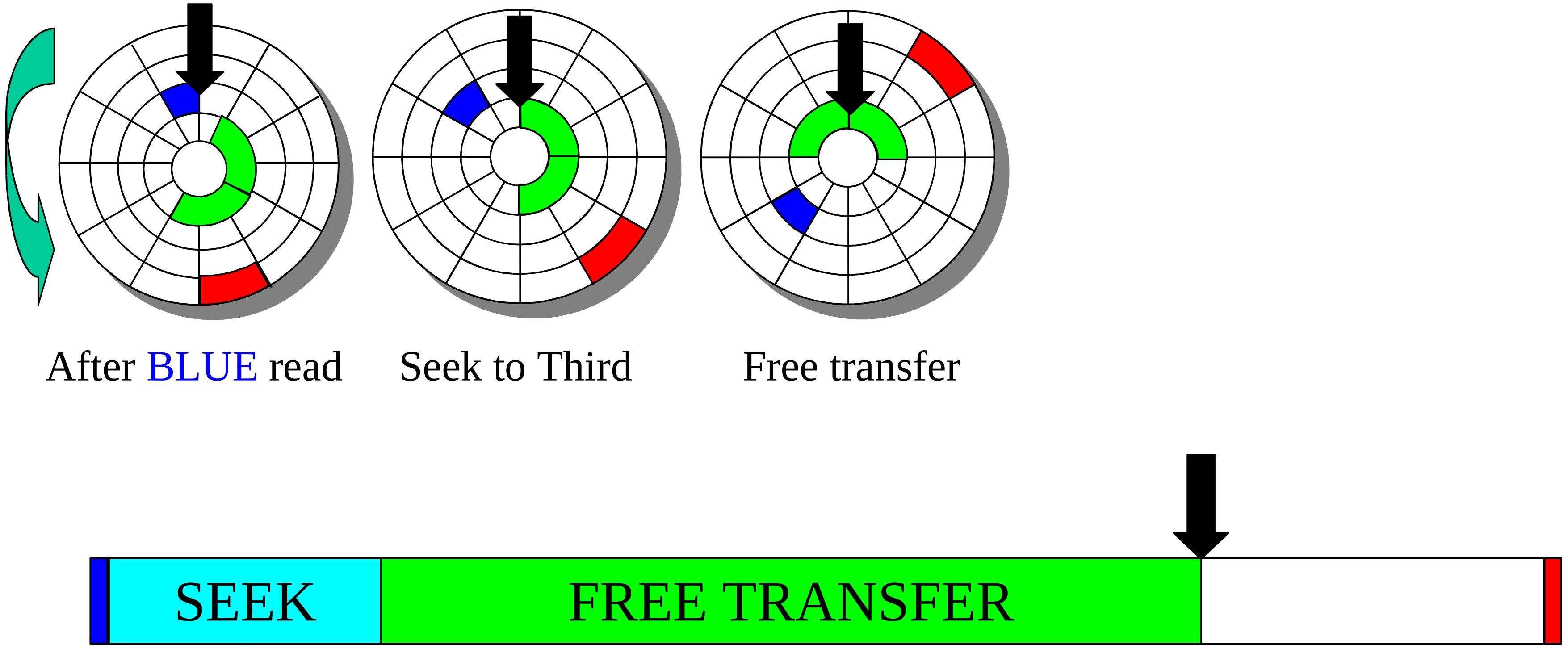
Seek to Third track



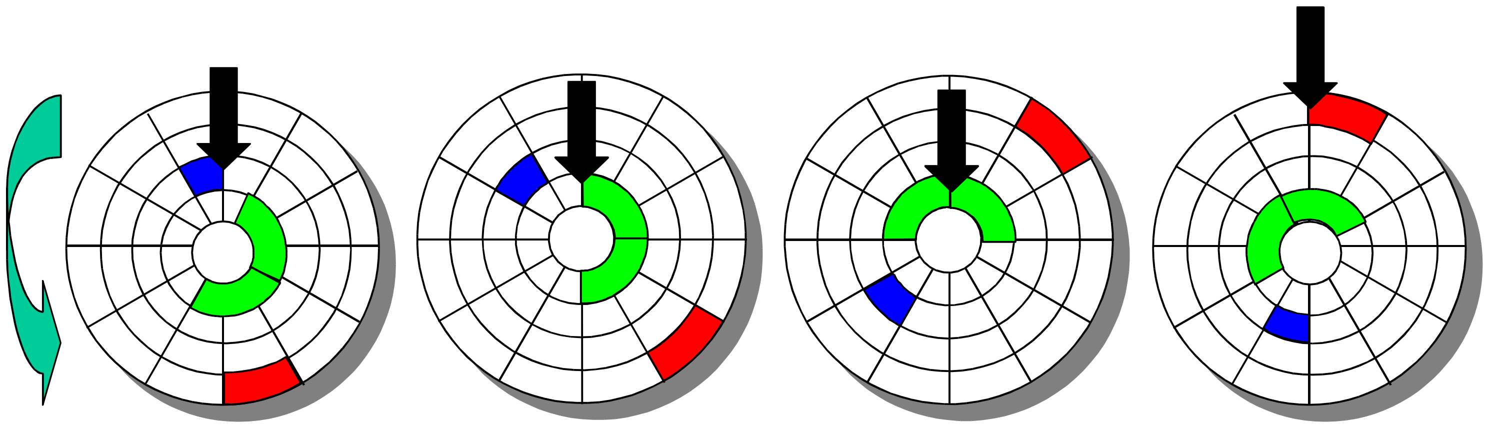
After BLUE read   Seek to Third



Free transfer

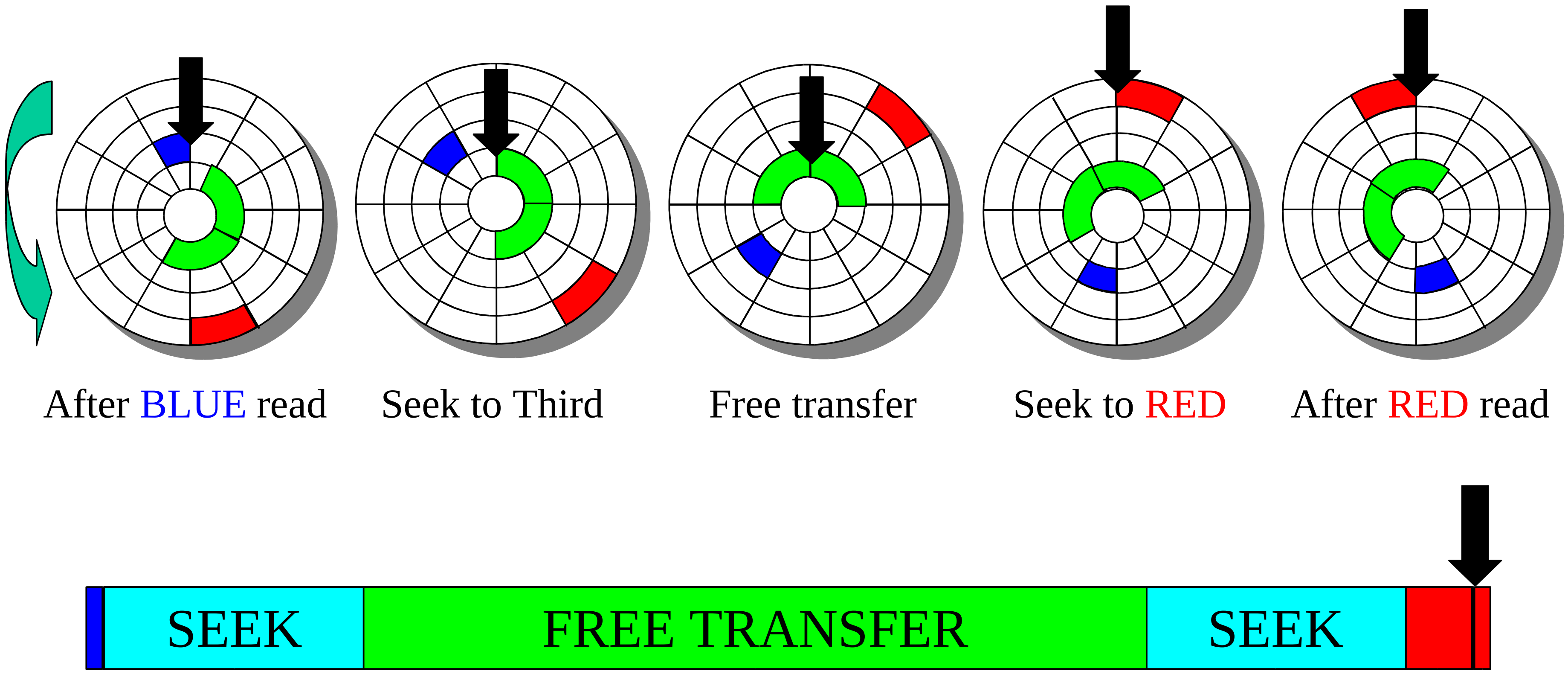


Seek to Red's track



After BLUE read   Seek to Third   Free transfer   Seek to RED

Read Red sector



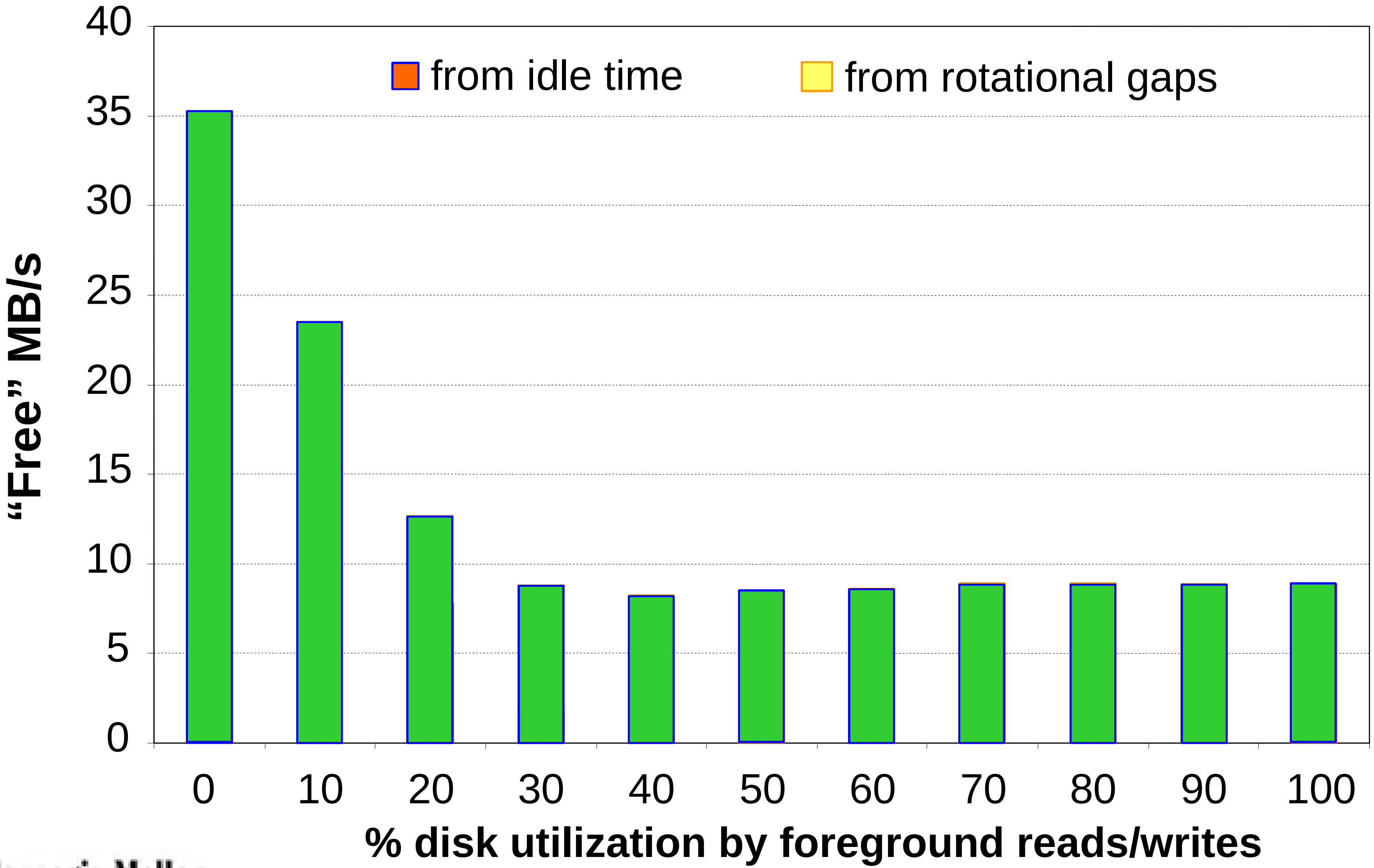
Final theory details

- Scheduler also uses disk idle time
  - high end servers have little idle time

- Idle time + rotational latency usage = "*freeblock scheduling*"

  (it means we are getting things for free)

Steady background I/O progress



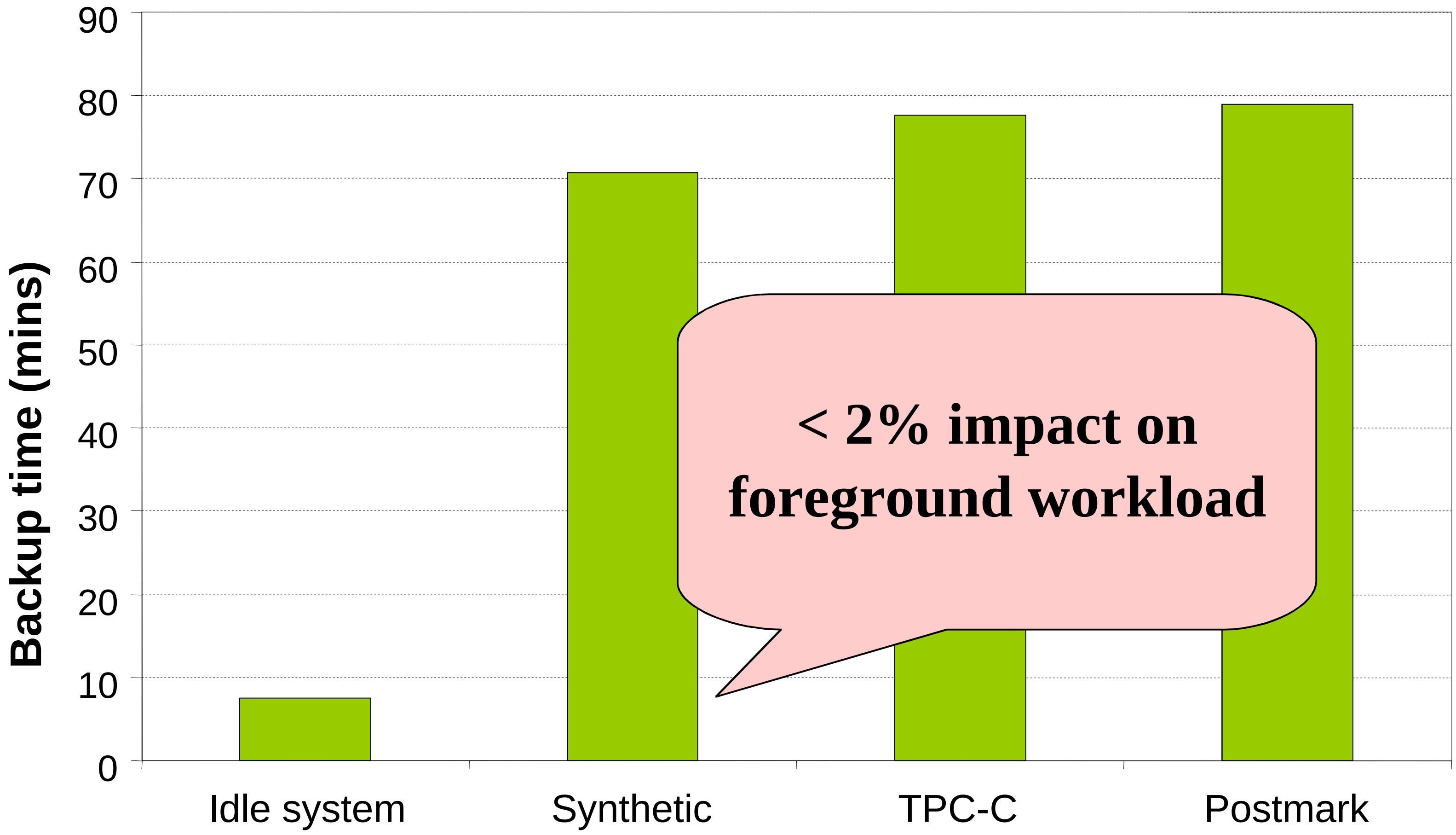
Applied freeblocks: preview

- Next few slides will show that:
  - we can build background apps
    - that do not interfere with foreground apps
    - that complete eventually
    - things like *backup*, *defrag*, *virus scanners*, etc
    - imagine the possibilities…

App 1: Backup

- Frequent backup improves data reliability and availability
  - companies take very frequent backups
  - a backup every 30 mins is not uncommon
- Our experiment:
  - disk used is 18GB
  - we want to back up 12GB of data
  - <u>goal</u>: back it up for free

Backup completed for free



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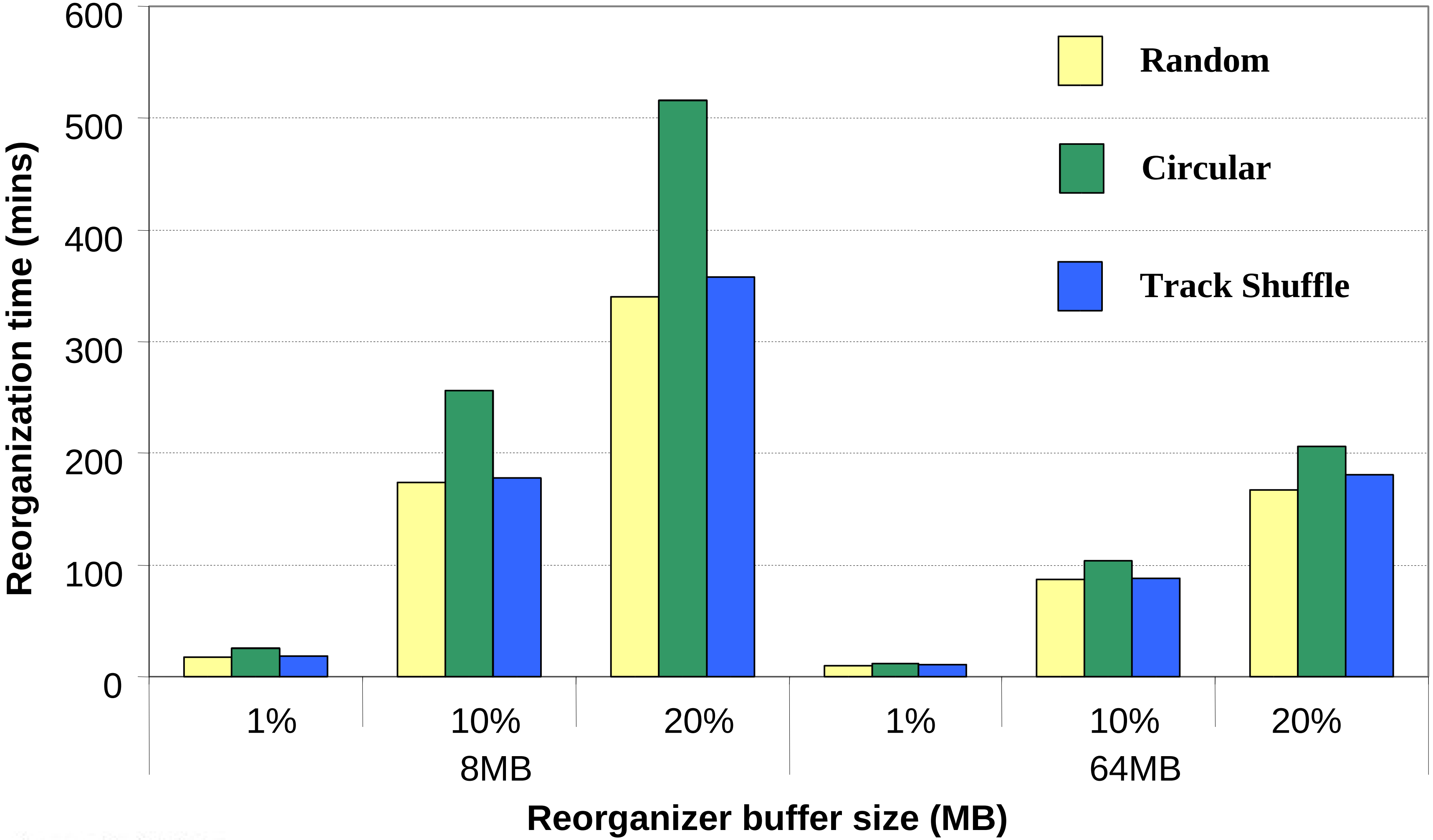
App 2: Layout reorganization

- Layout reorganization improves access latencies
  - defragmentation is a type of reorganization
  - typical example of background activity

- Our experiment:
  - disk used is 18GB
  - we want to defrag up to 20% of it
  - goal: defrag for free

Disk Layout Reorganized for Free!



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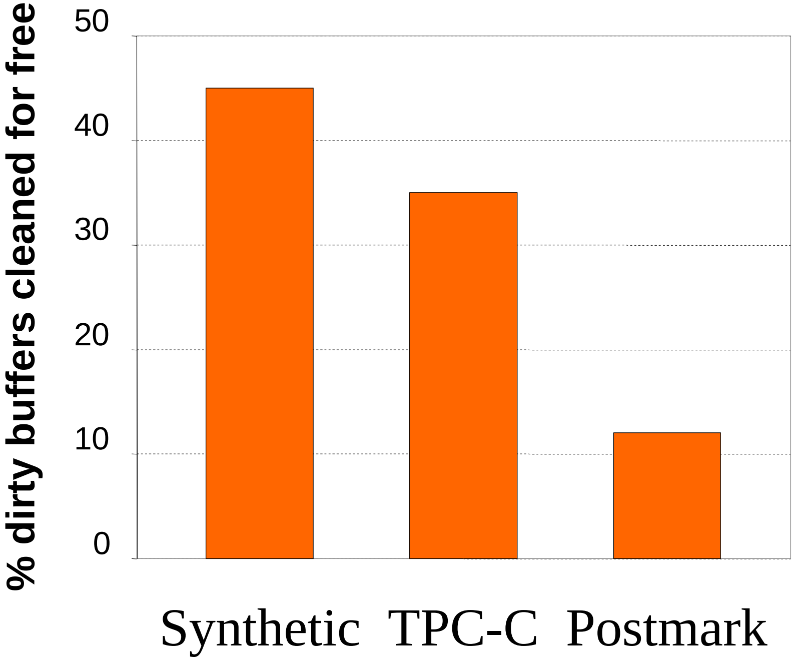
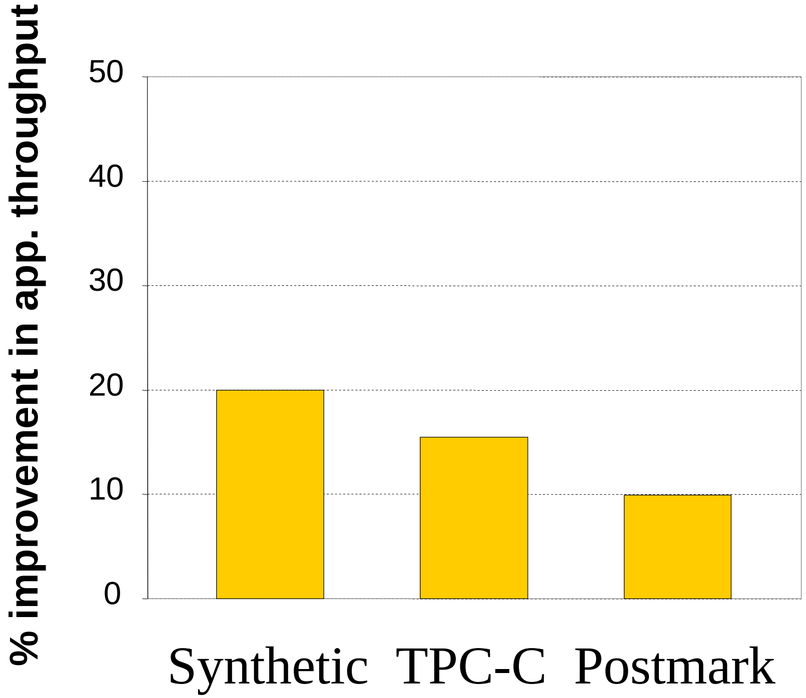
App 3: Cache write-backs

- Must flush dirty buffers
  - for space reclamation
  - for persistence (if memory is not NVRAM)
- Our experiment
  - PIII with 384MB of RAM
  - controlled experiments with synthetic workload
  - benchmarks (same as used before) in FreeBSD
  - syncer daemon wakes up every 1 sec and flushes entries that have been dirty > 30secs
  - goal: write back dirty buffers for free

10-20% improvement in overall perf.





Other maintenance applications

- Virus scanner
- LFS cleaner
- Disk scrubber
- Data mining
- Data migration

Summary I

- Disks are slow
  - but we can squeeze extra bw out of them
- Use freeblock scheduling to extract free bandwidth
- Utilize free bandwidth for background applications
  - they still complete <u>eventually</u>
  - with no impact on foreground workload

Details: preview (extra slides)

- Next few slides will show that:
  - it's hard to do fine grained scheduling at the device driver
  - background apps need new interfaces to express their desires to the background scheduler
  - file consistency issues

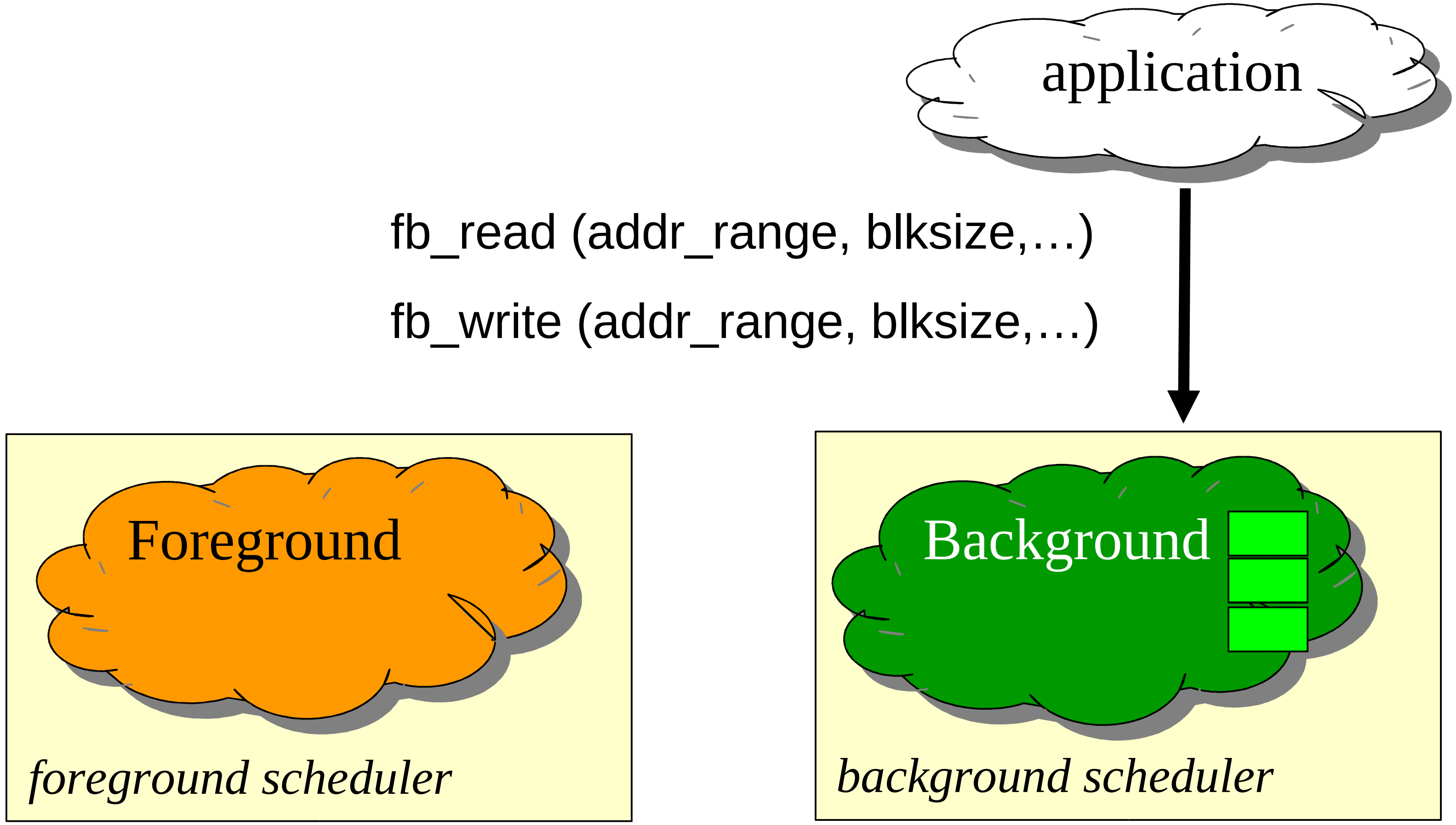
Freeblock scheduling details

- Hard to do at the device driver
  - need to know the position of the disk head
  - however, we have done it!
  - it's more efficient inside the disk drive
    - try to convince your disk vendor to put it in
- Efficient algorithms
  - SPTF for foreground (0.5% of 1GHz PIII)
  - Freeblock scheduling for background (<<5% of 1GHz PIII)
  - Small memory utilization

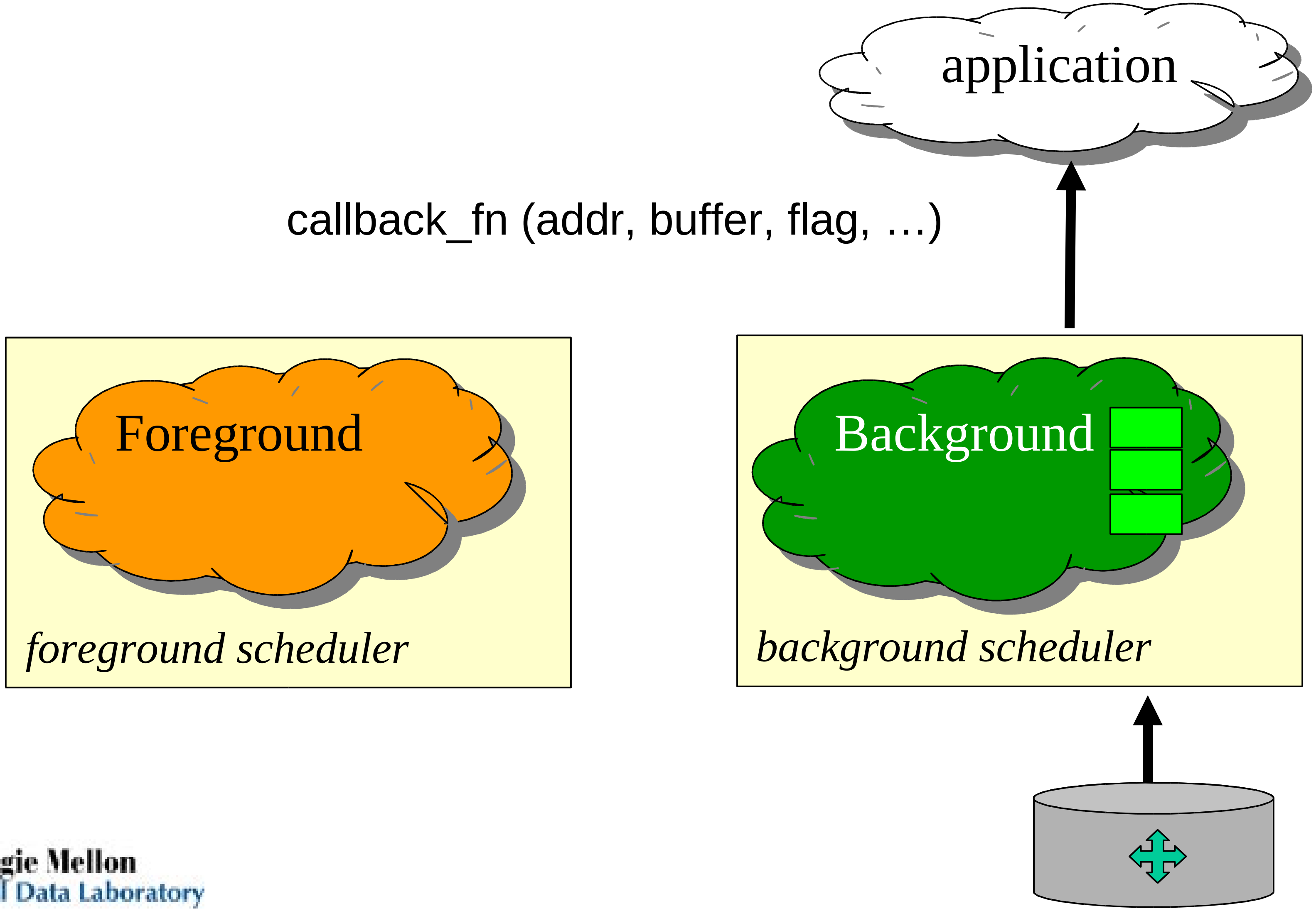
Application programming interface (API) goals

- Work exposed but done opportunistically
  - all disk accesses are asynchronous
- Minimized memory-induced constraints
  - late binding of memory buffers
  - late locking of memory buffers
- “Block size” can be application-specific
- Support for speculative tasks
- Support for rate control

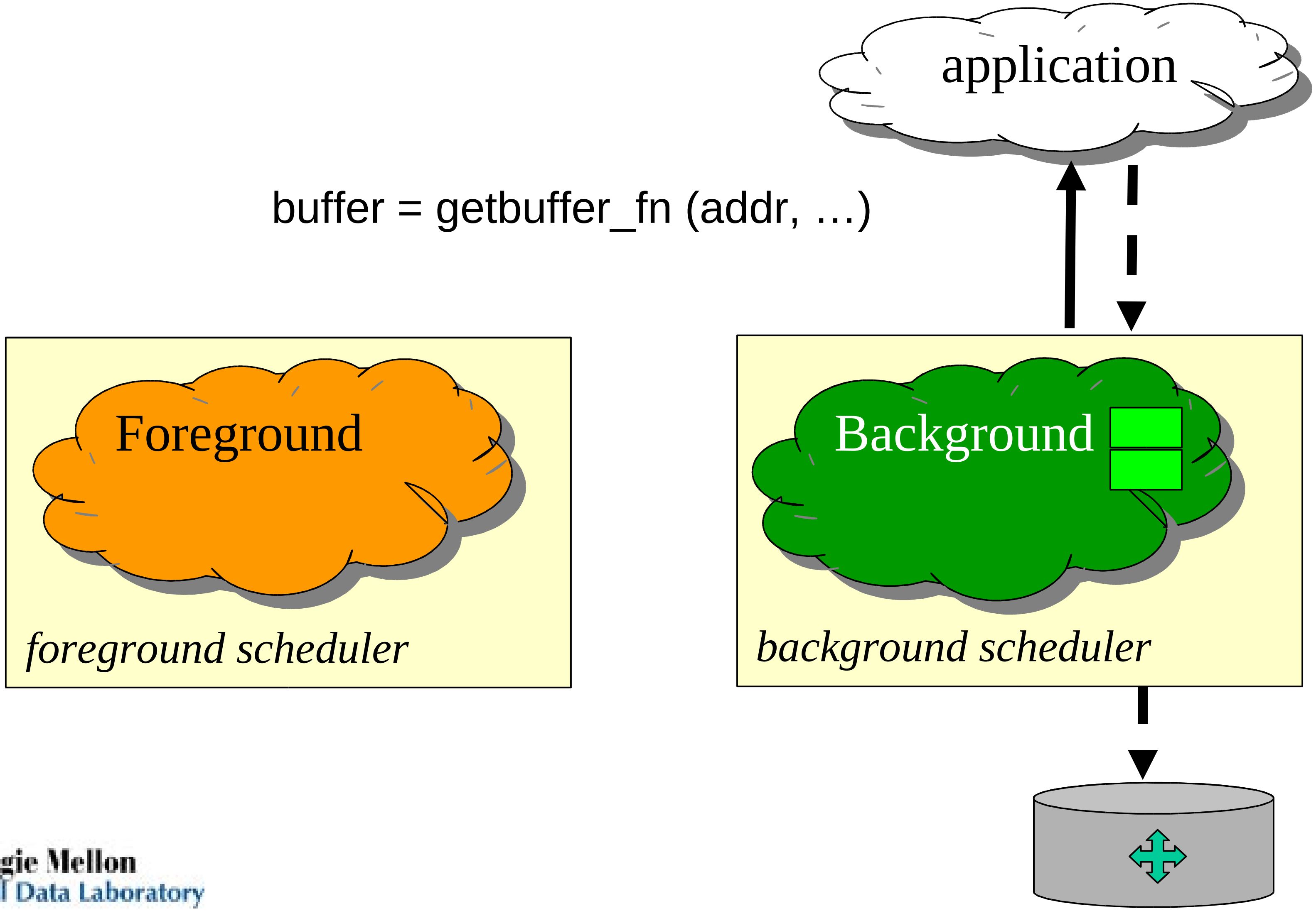
API description: task registration



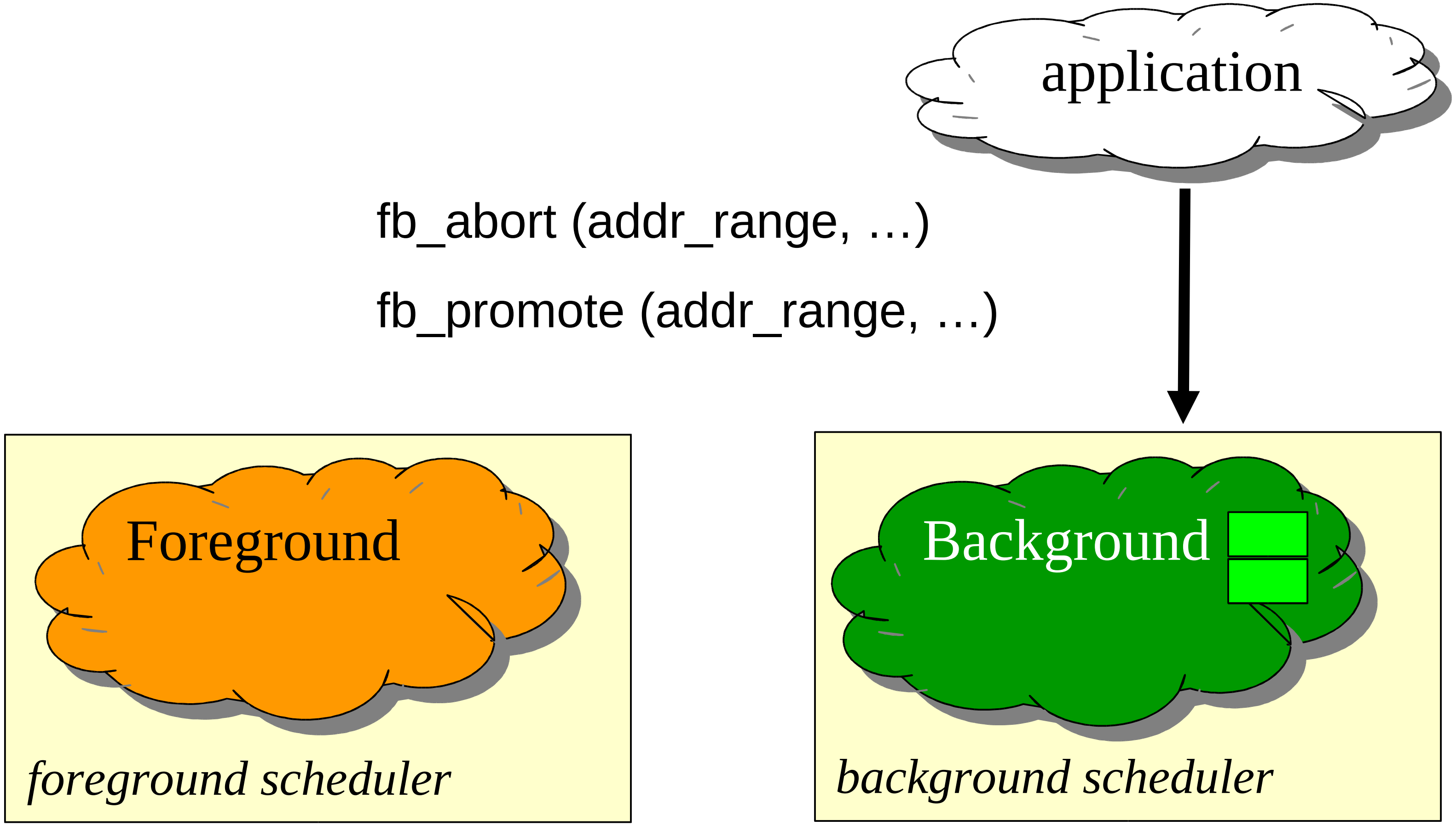
API description: task completion



API description: late locking of buffers



API description: aborting/promoting tasks



Complete API

Function Name	Arguments	Description
fb_open	*priority, callback_fn, getbuffer_fn*	Open a freeblock session (ret: *session_id*)
fb_close	*session_id*	Close a freeblock session
fb_read	*session_id, addr_range, blksize, callback_param*	Register a freeblock read task
fb_write	*session_id, addr_range, blksize, callback_param*	Register a freeblock write task (ret: *task_id*)
fb_abort	*session_id, addr_range*	Abort parts of registered task
fb_promote	*session_id, addr_range*	Promote parts of registered task
fb_suspend	*session_id*	Suspend scheduling of a session's tasks
fb_resume	*session_id*	Resume scheduling of a session's tasks
*(callback_fn)	*session_id, addr, buffer, flags, callback_param*	Report that part of task completed
*(getbuffer_fn)	*session_id, addr, callback_param*	Get memory address for selected write

Designing disk maintenance applications

- APIs talk in terms of logical blocks (LBNs)
- Some applications need structured version
  - as presented by file system or database

- Example consistency issues
  - application wants to read file “foo”
  - registers task for inode’s blocks
  - by time blocks read, file may not exist anymore!

Designing disk maintenance applications

- Application does not care about structure
  - scrubbing, data migration, array reconstruction
- Coordinate with file system/database
  - cache write-backs, LFS cleaner, index generation
- Utilize snapshots
  - backup, background *fsck*

Summary II

- Utilize free bandwidth for background applications
    - they still complete eventually
    - with no impact on foreground workload
- Scheduling is fine-grained
- Need new APIs

Q & A

- See http://www.pdl.cmu.edu/Freeblock/ for more details on freeblocks

- Talk to me if interested in summer internships or research with the PDL