Disks and Disk Scheduling

Steve Muckle

Monday, March 31st 2003

15-412 Spring 2003

Overview

- Project Discussion
- Anatomy of a Hard Drive
- Common Disk Scheduling Algorithms
- Freeblock Scheduling

Project Discussion (3)

- Project 3 is over!
- War stories?
- Sage advice?

- Sign ups for interviews will begin soon
- Watch bboard

Project Discussion (4)

- File System project out today
- Lots of code
- Planning will save you pain and suffering
- Read it tonight (this afternoon even!)

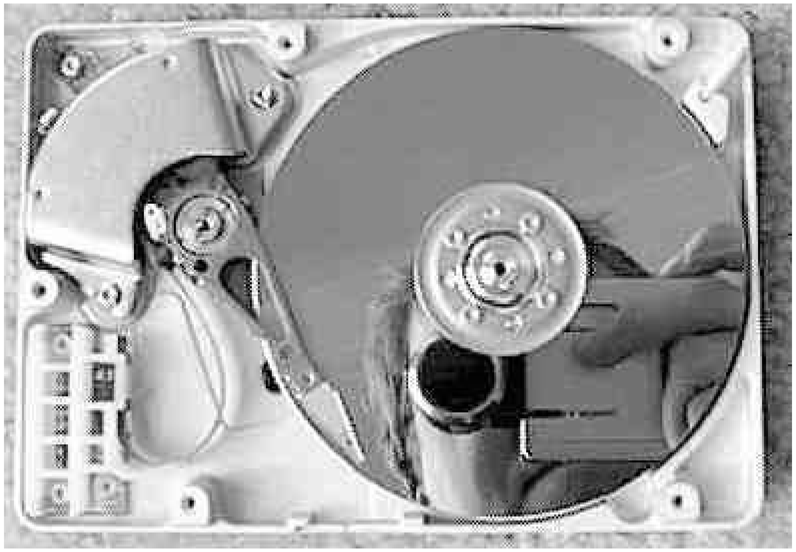
Anatomy of a Hard Drive

- On the outside, a hard drive looks like this

Taken from “How Hard Disks Work”
http://computer.howstuffworks.com/hard-disk2.htm

Anatomy of a Hard Drive

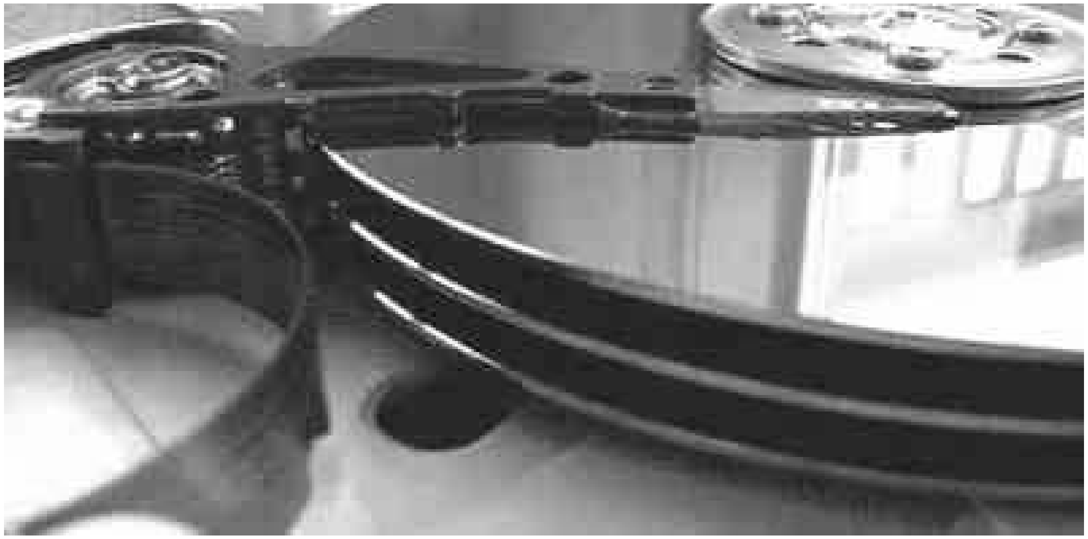
- If we take the cover off, we see that there actually is a “hard disk” inside



Taken from “How Hard Disks Work”
http://computer.howstuffworks.com/hard-disk2.htm

Anatomy of a Hard Drive

- A hard drive usually contains multiple disks, called *platters*
- These spin at thousands of RPM (5400, 7200, etc)



Taken from “How Hard Disks Work”
http://computer.howstuffworks.com/hard-disk2.htm

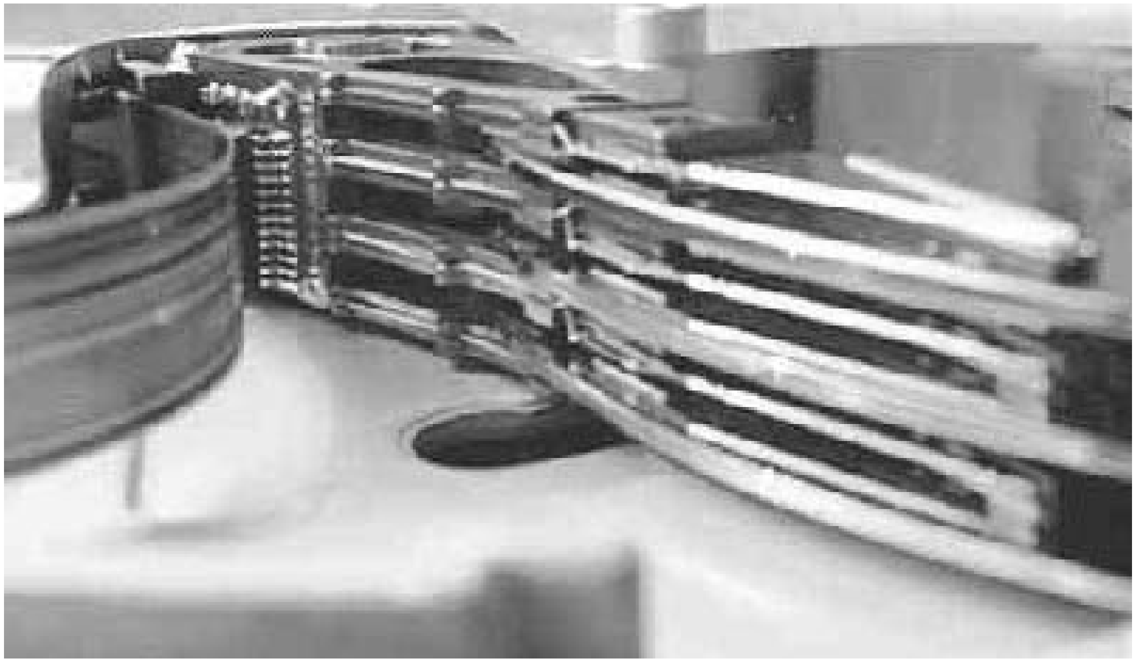
Anatomy of a Hard Drive

- Information is written to and read from the platters by the *read/write heads* on the *disk arm*

Taken from “How Hard Disks Work”
http://computer.howstuffworks.com/hard-disk2.htm

Anatomy of a Hard Drive

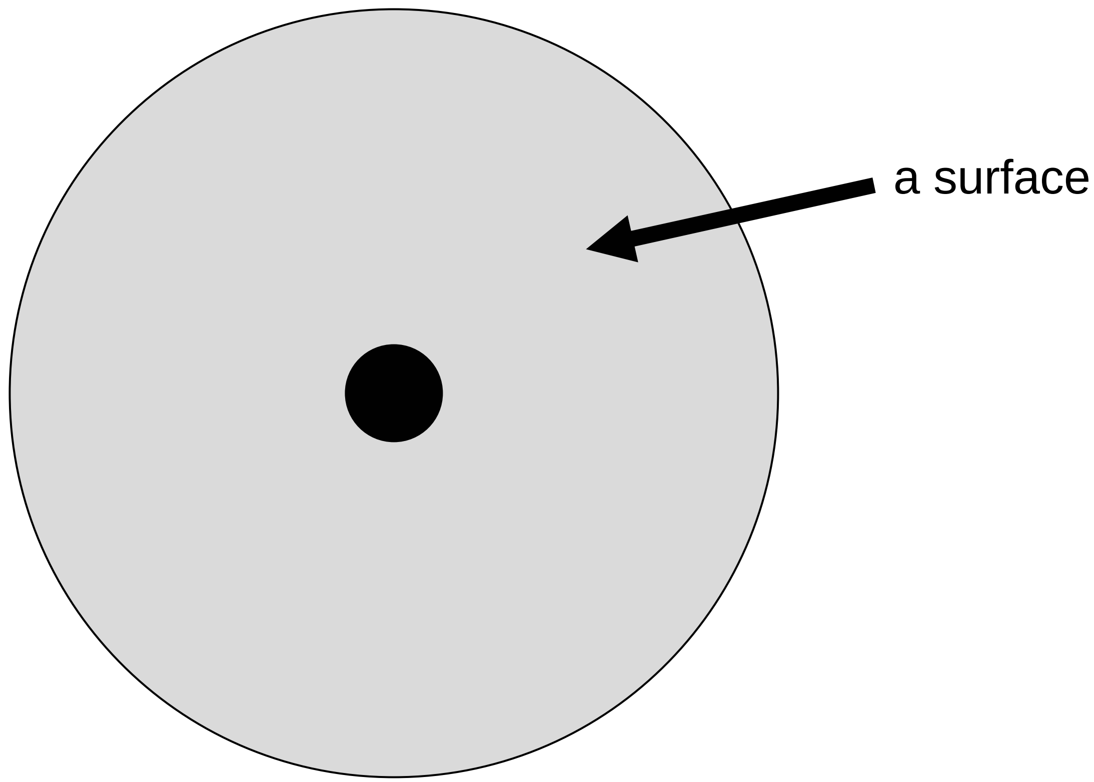
- Both sides of each platter store information
- Each side of a platter is called a *surface*
- Each surface has its own read/write head



Taken from “How Hard Disks Work”
http://computer.howstuffworks.com/hard-disk2.htm

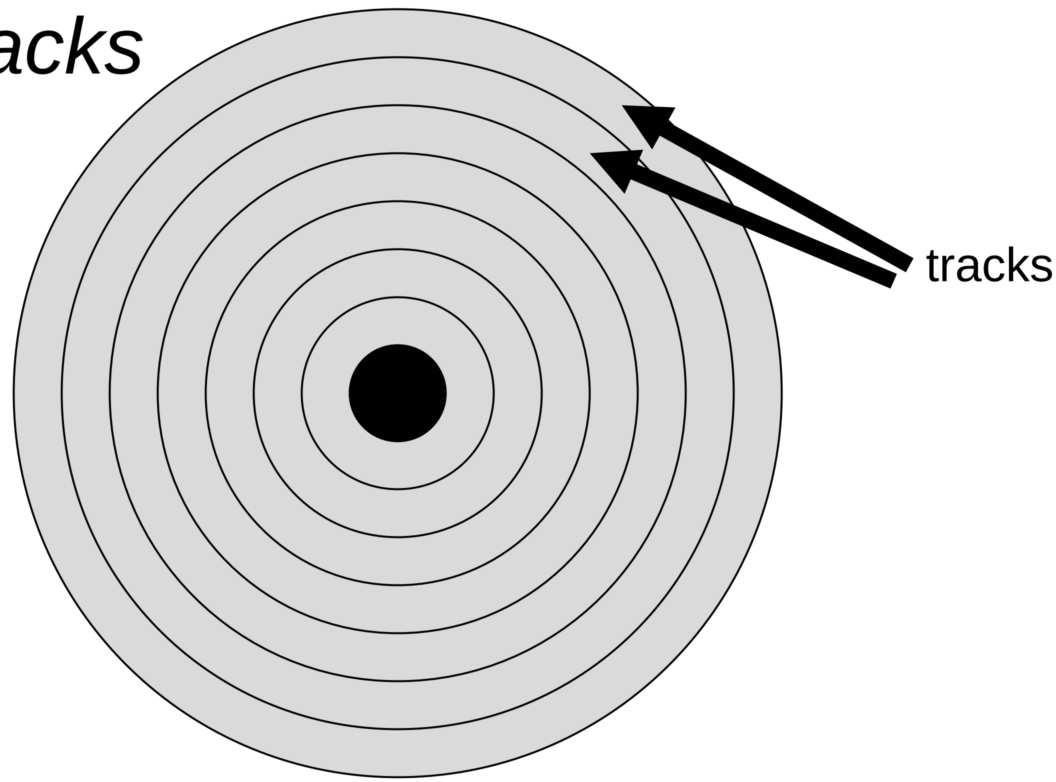
Anatomy of a Hard Drive

- How are the surfaces organized?



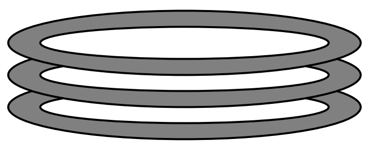
Anatomy of a Hard Drive

- Each surface is divided by concentric circles, creating *tracks*



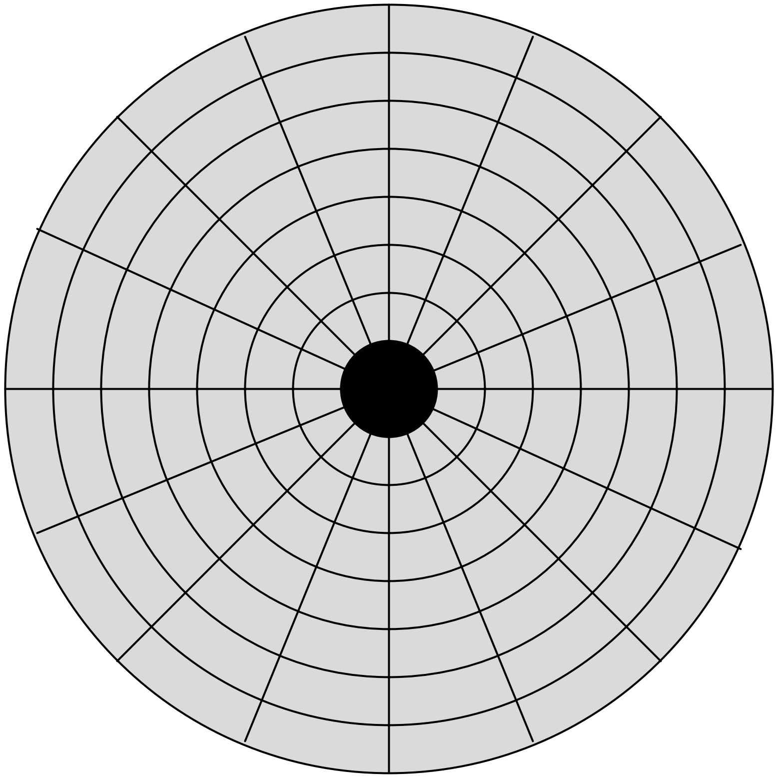
Anatomy of a Hard Drive

- The matching tracks on all surfaces are collectively called a *cylinder*



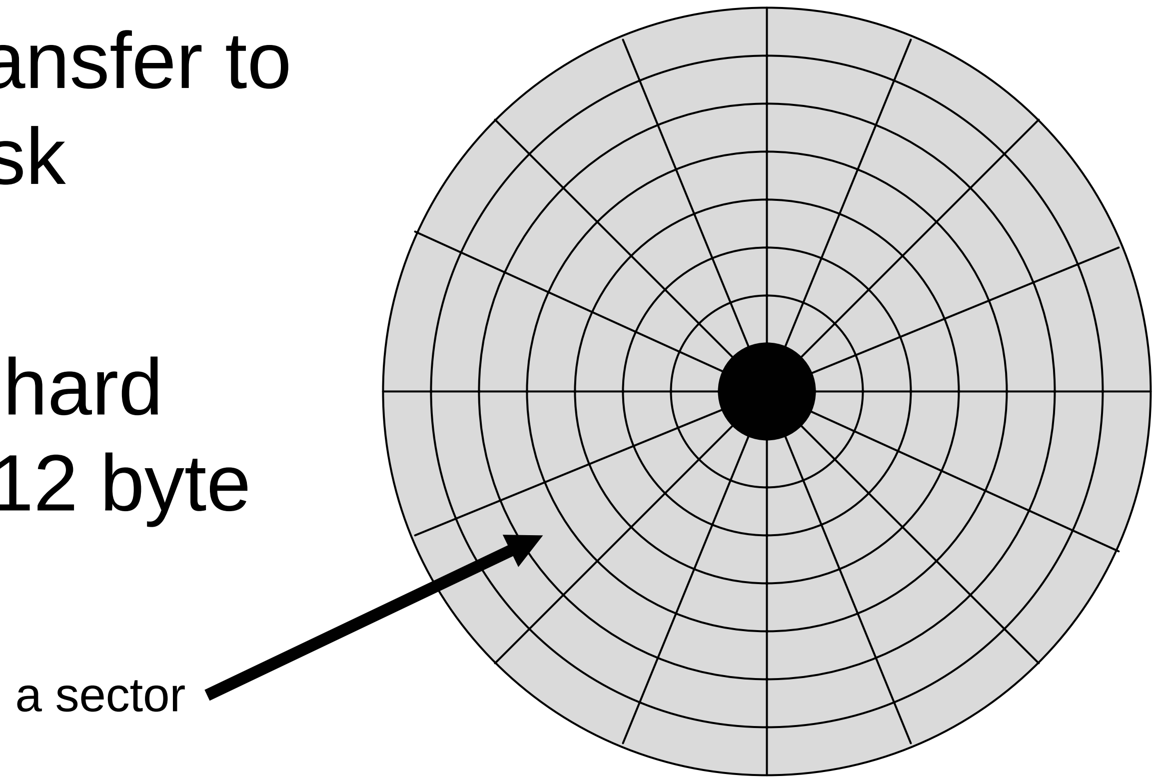
Anatomy of a Hard Drive

- These tracks are further divided into *sectors*



Anatomy of a Hard Drive

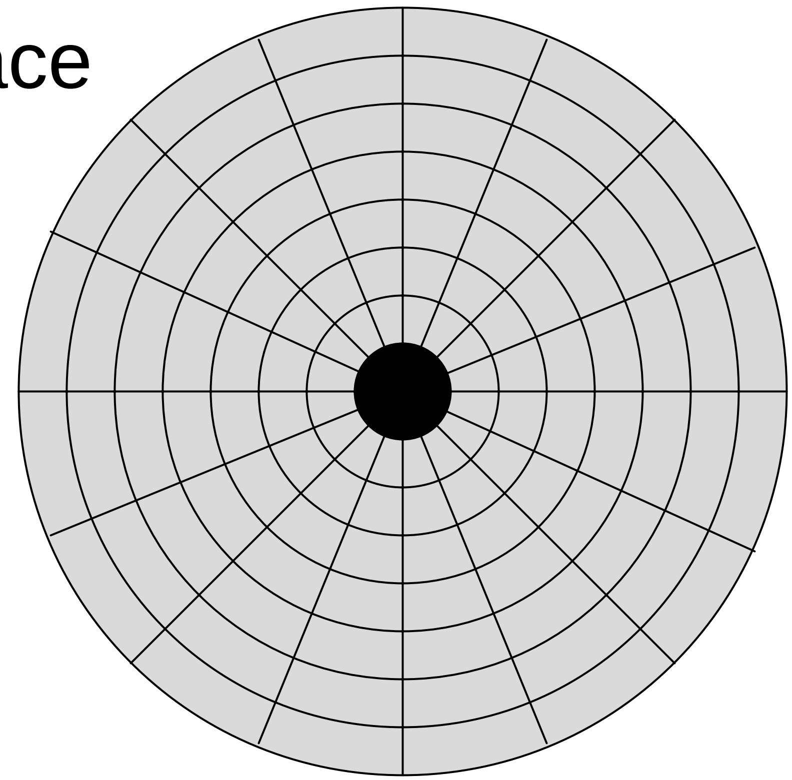
- A sector is the smallest unit of data transfer to or from the disk
- Most modern hard drives have 512 byte sectors



Anatomy of a Hard Drive

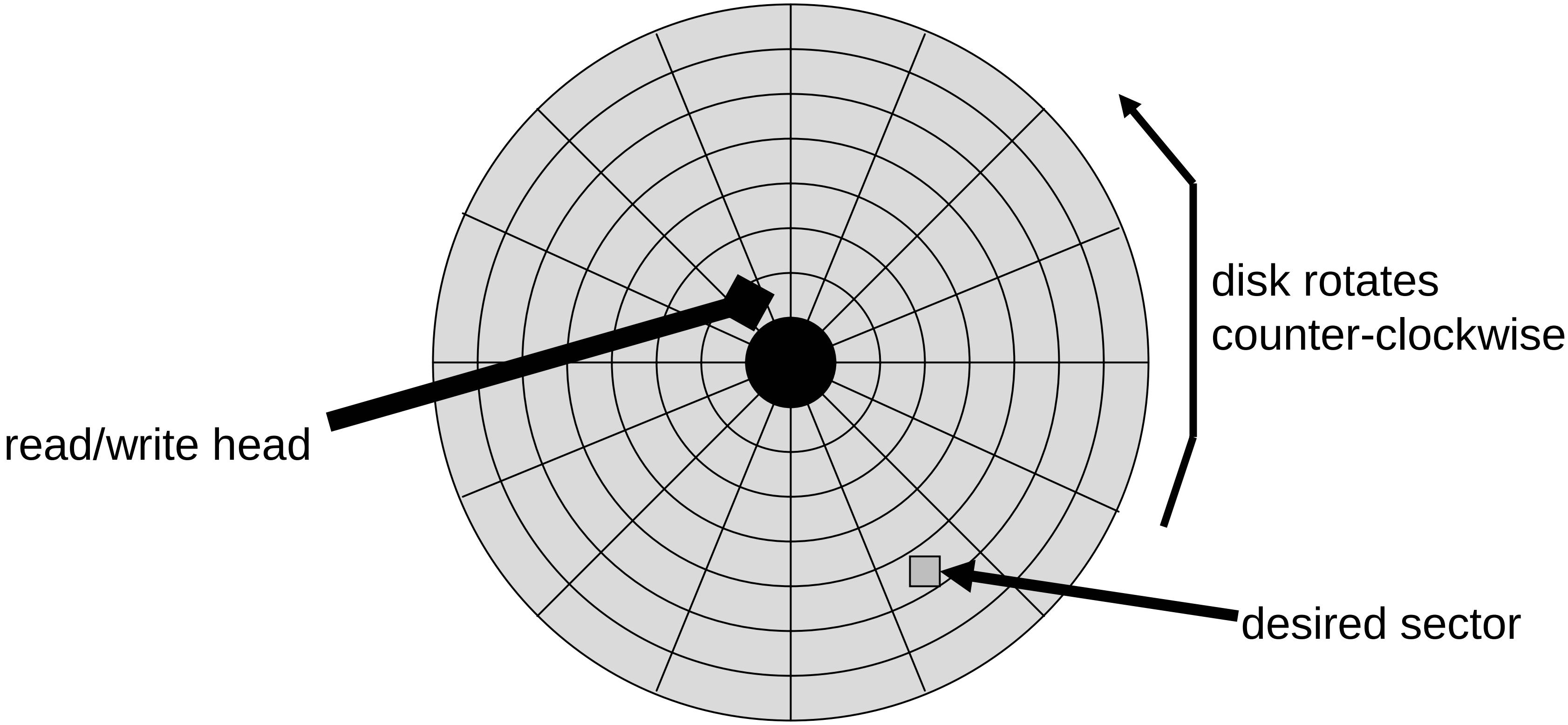
- Does this mean that sectors on the outside of a surface are larger than those on the inside?

- Modern hard drives fix this with *zoned-bit recording*



Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



Anatomy of a Hard Drive

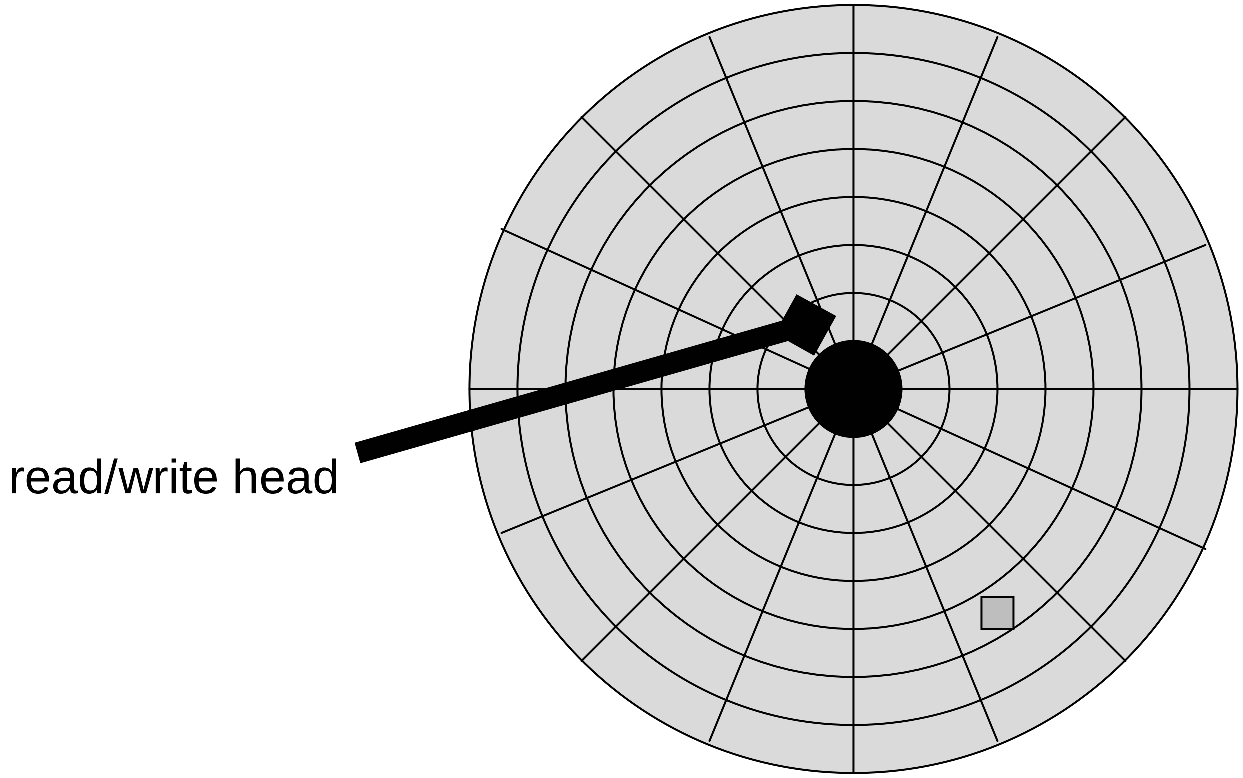
- We need to do two things to transfer a sector

  1. Move the read/write head to the appropriate track (seek)

  2. Wait until the desired sector spins around

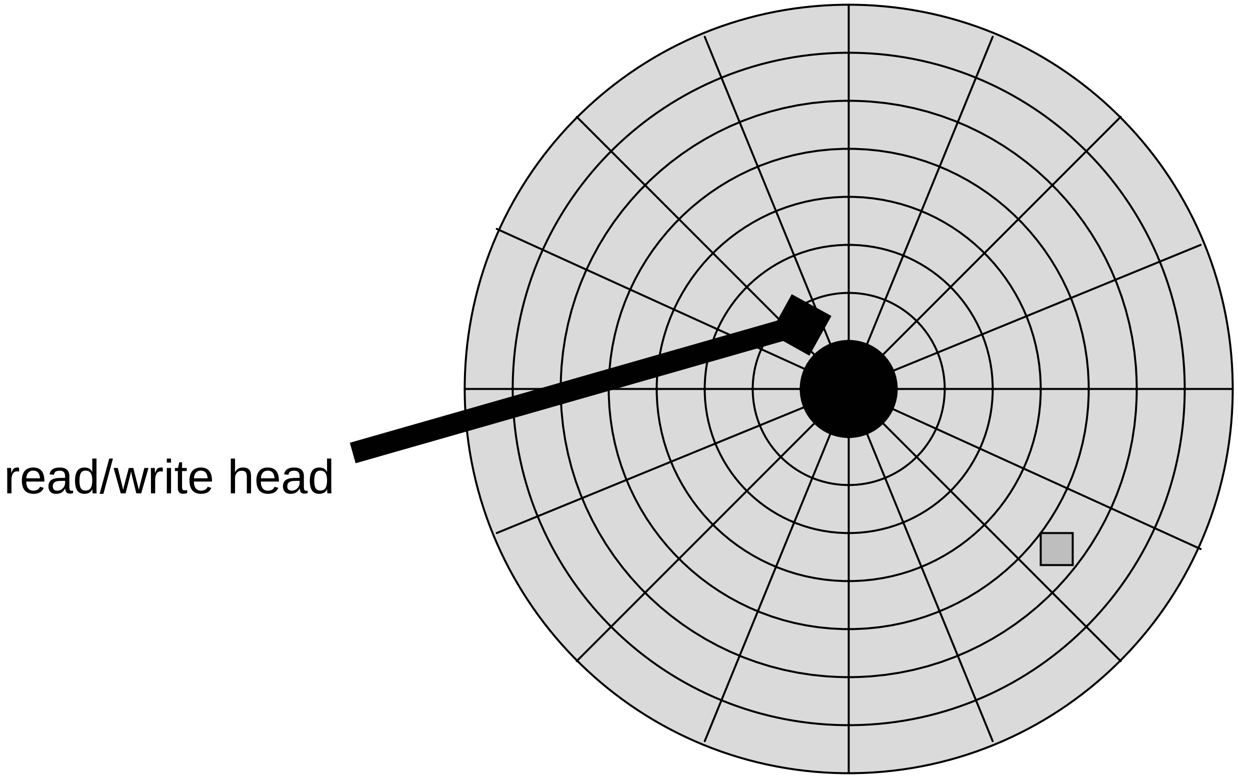
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



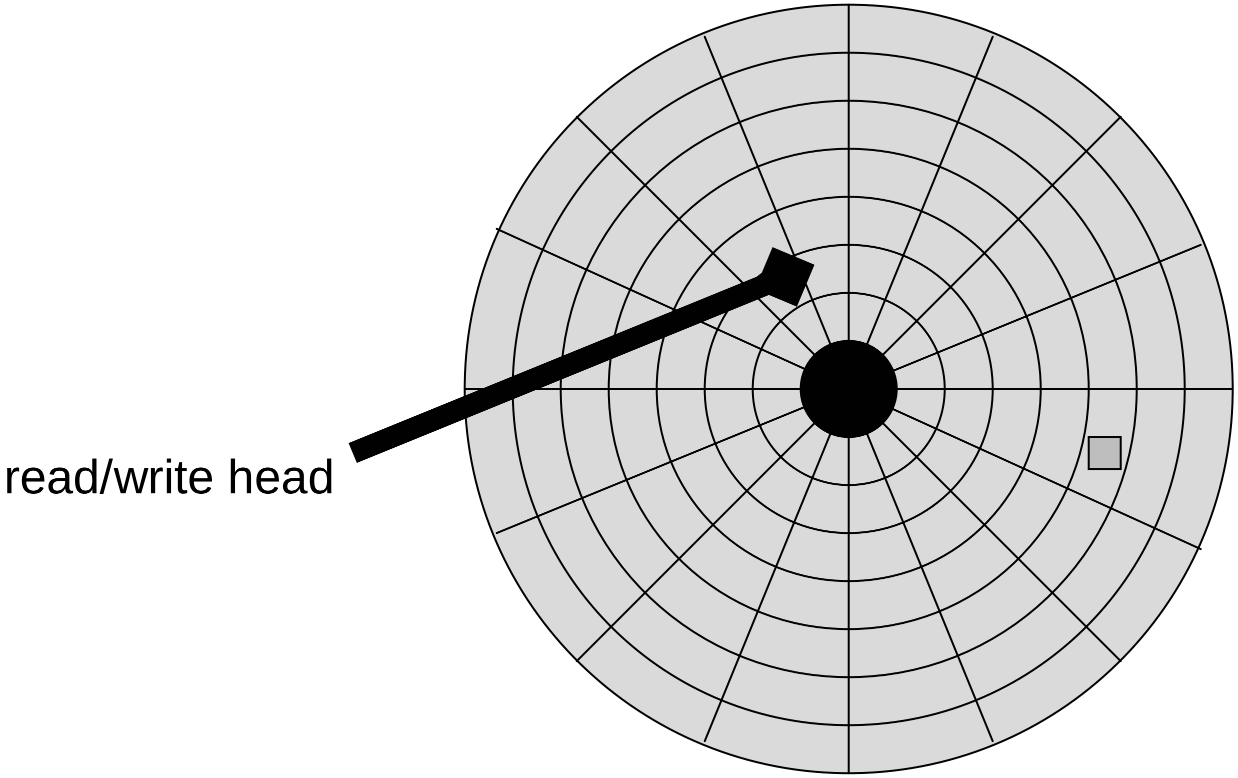
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



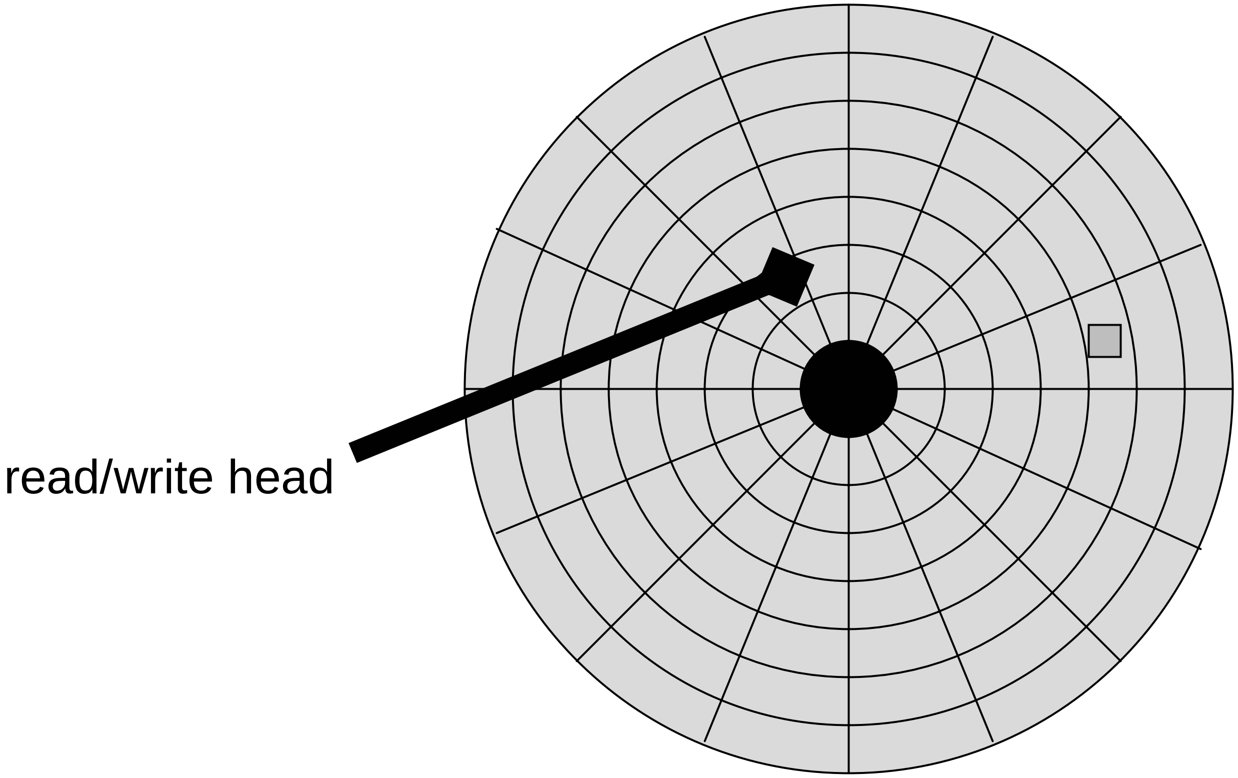
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



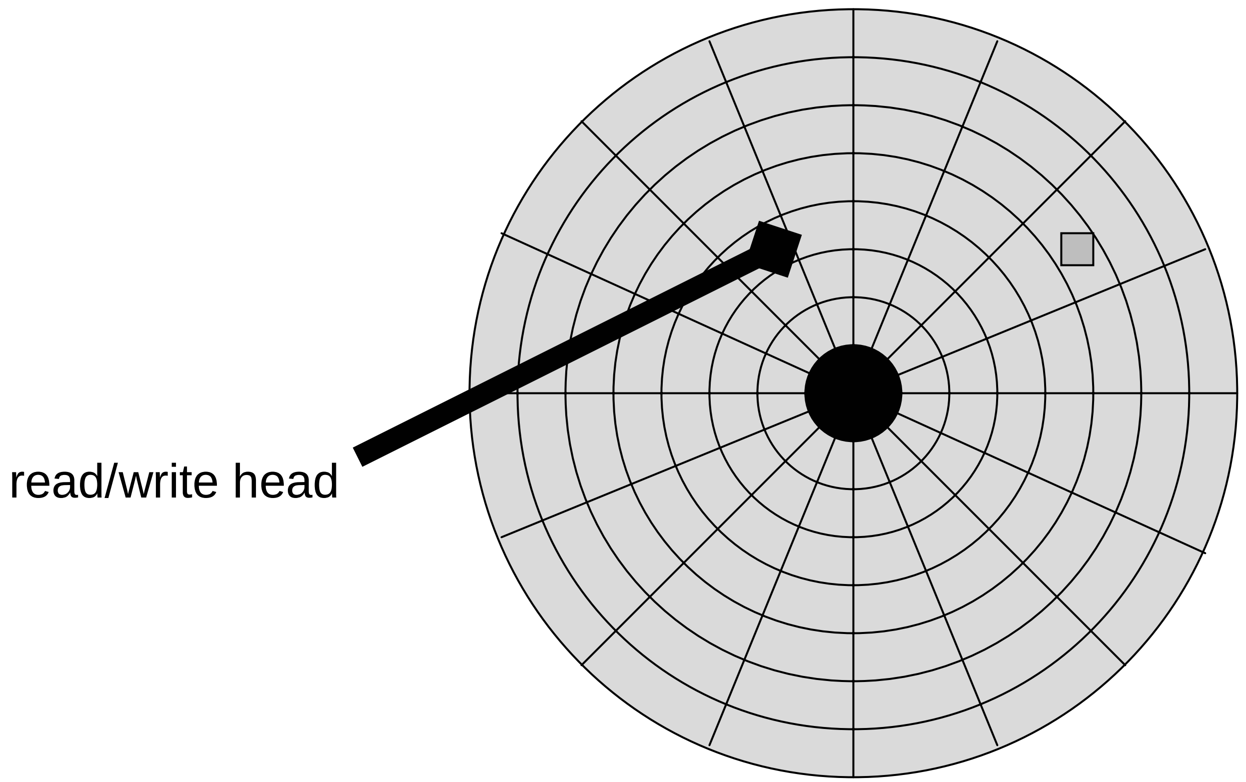
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



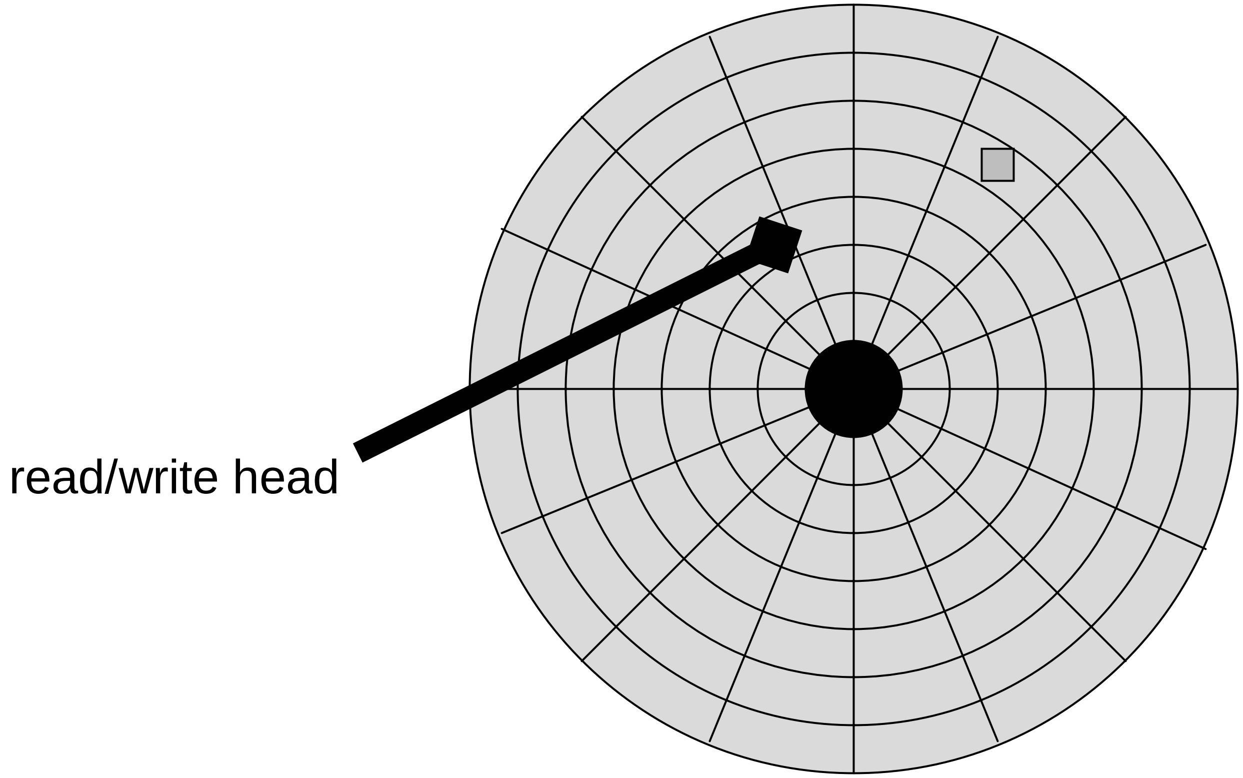
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



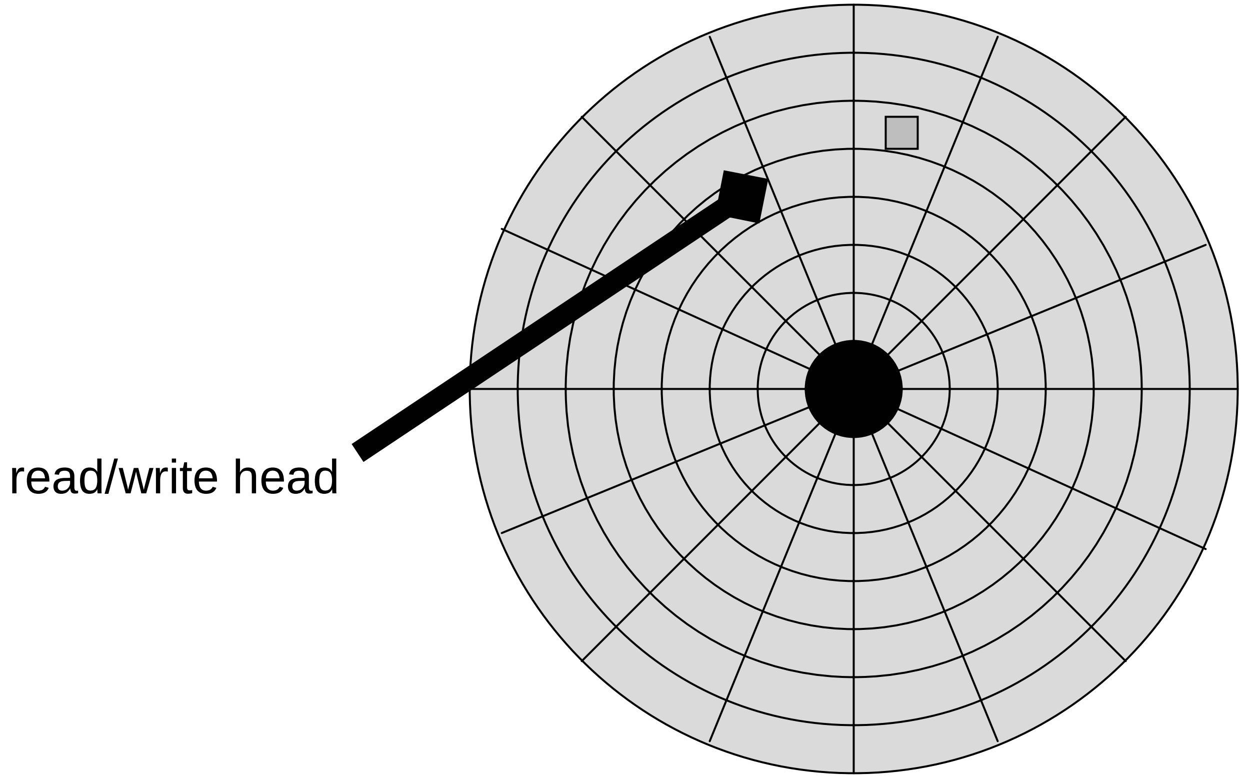
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



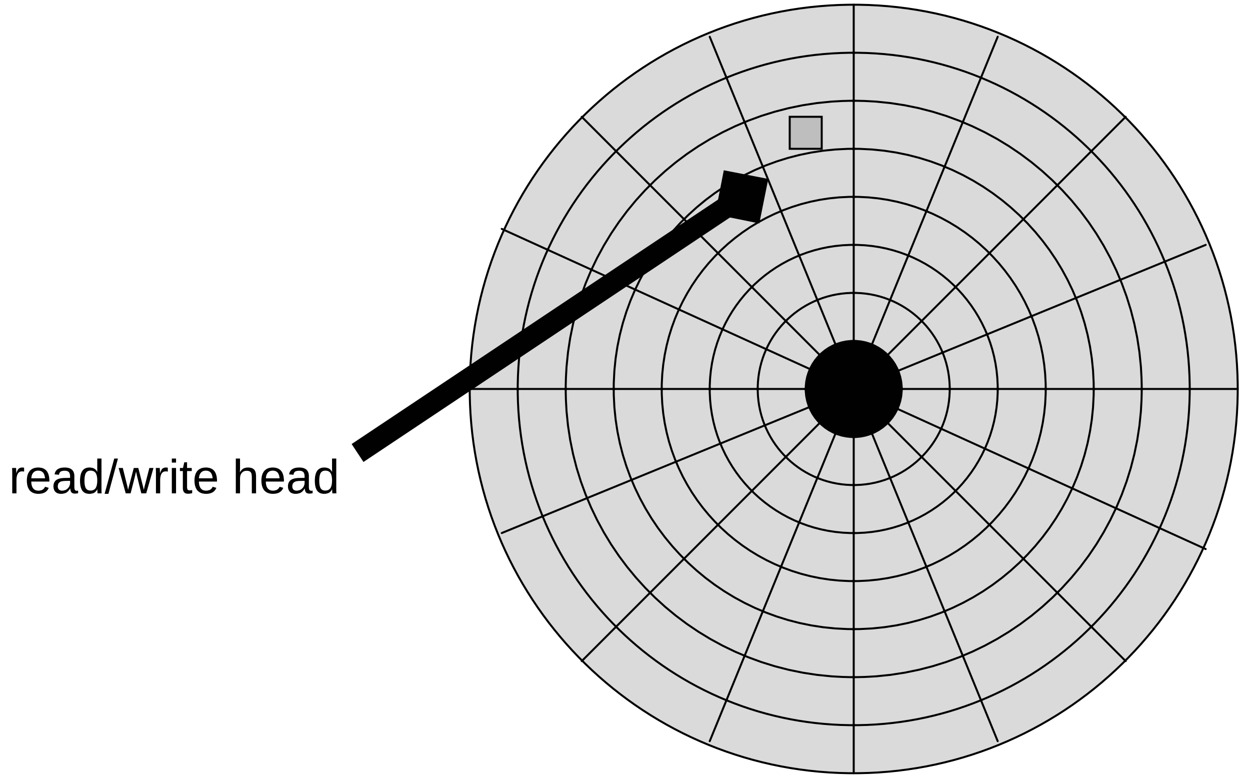
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



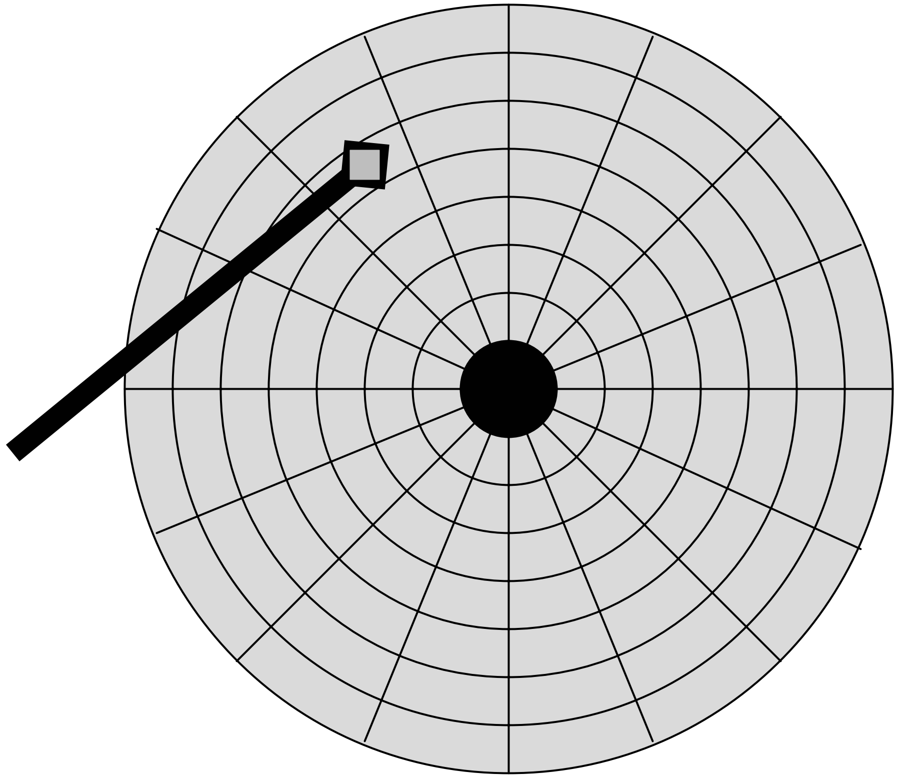
Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



Anatomy of a Hard Drive

- Why don't we read in a sector from the disk



read/write head

Anatomy of a Hard Drive

- On average, we will have to move the read/write head over half the tracks
- The time to do this is the average seek time, and is ~10ms
- We will also have to wait half a rotation
- The time to do this is rotational latency, and on a 5400 rpm drive is ~5.5ms

Anatomy of a Hard Drive

- There are two other things that determine overall disk access time
  - settle time, the time to stabilize the read/write head after a seek
  - command overhead, the time for the disk to process a command and start doing something
- They are both fairly minor compared to seek time and rotational latency

Anatomy of a Hard Drive

- Total drive random access time is on the order of 15 to 20 milliseconds
- Oh man, disks are slow
- What can we, as operating system programmers, do about this?

Disk Scheduling Algorithms

- The goal of a disk scheduling algorithm is to be nice to the disk
- We can help the disk by giving it requests that are located close to each other on the disk
- This minimizes seek time, and possibly rotational latency
- There exist a variety of ways to do this

First Come First Served (FCFS)

- Requests are sent to the disk as they are generated by the OS
- Trivial to implement
- Fair – no request will be starved because of its location on the disk
- Provides an unacceptably high mean response time

…except for project four! ☺

Shortest Seek Time First (SSTF)

- Always send the request with the shortest seek time from current head position
- Generates very fast response time
- Intolerable response time variance, however
- Why?

SCAN

- Send requests in ascending cylinders
- When last cylinder is reached, reverse the scan
- Mean response time is worse than SSTF, but better than FCFS
- Better response time variance than SSTF
- Unfair – why?

LOOK

- Just like SCAN – sweep back and forth through cylinders
- If there are no more requests in our current direction we reverse course
- Improves mean response time, variance
- Still unfair though

CSCAN

- Send requests in ascending (or descending) cylinders
- When the last cylinder is reached, seek all the way back to the beginning
- Long seek is amortized across all accesses
- Variance is improved
- Fair
- Still missing something though…

C-LOOK

- CSCAN + LOOK
- Only scan in one direction, as in CSCAN
- If there are no more requests in current direction reverse course
- Very popular

Shortest Positioning Time First (SPTF)

- Similar to Shortest Seek Time First
- Always select request with shortest total positioning time (rotational latency + seek time)
- More accurate greedy algorithm than SSTF
- Same starvation problems

Weighted Shortest Positioning Time First (WSPTF)

- SPTF, but we age requests to prevent starvation
- Aging policy is very flexible
- Excellent performance
- Why don’t we use this?

Freeblock Scheduling

- Research going on right here at CMU
- Something I am involved in this semester

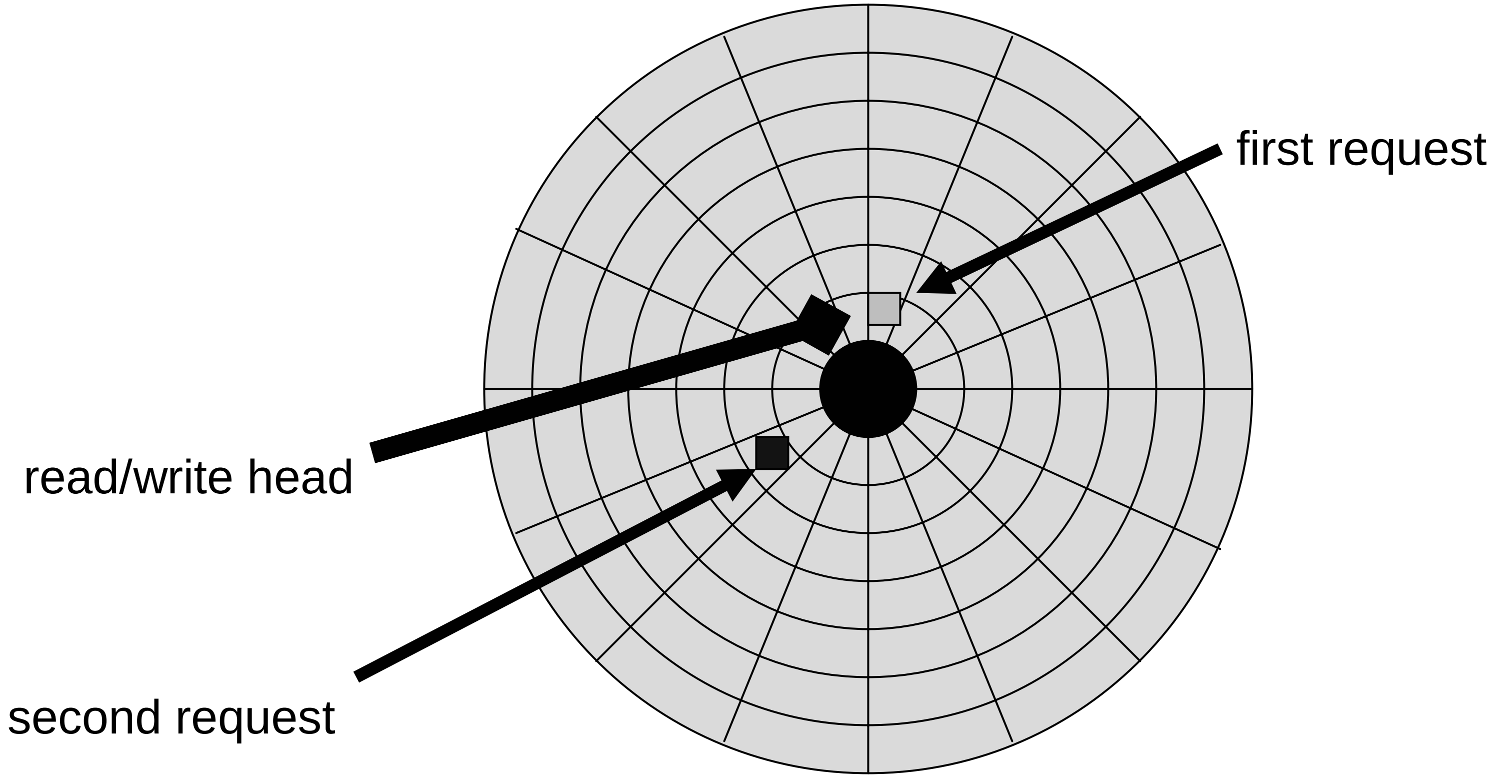
- Who would like some free bandwidth while their disk is busy? ☺

Freeblock Scheduling

- We have settled on a disk scheduling routine (probably C-LOOK)
- We have a queue of disk requests
- Let’s take a closer look at a pair of possible disk requests

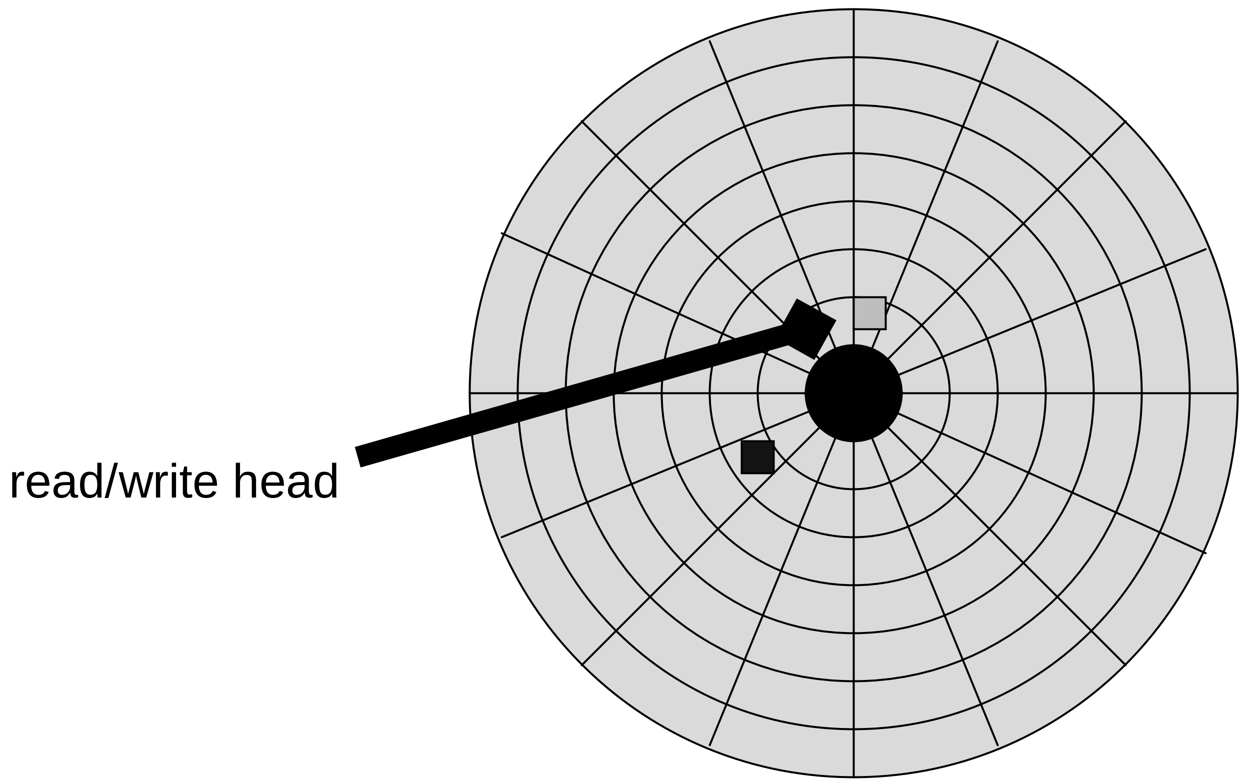
Freeblock Scheduling

- There are two requests at the disk



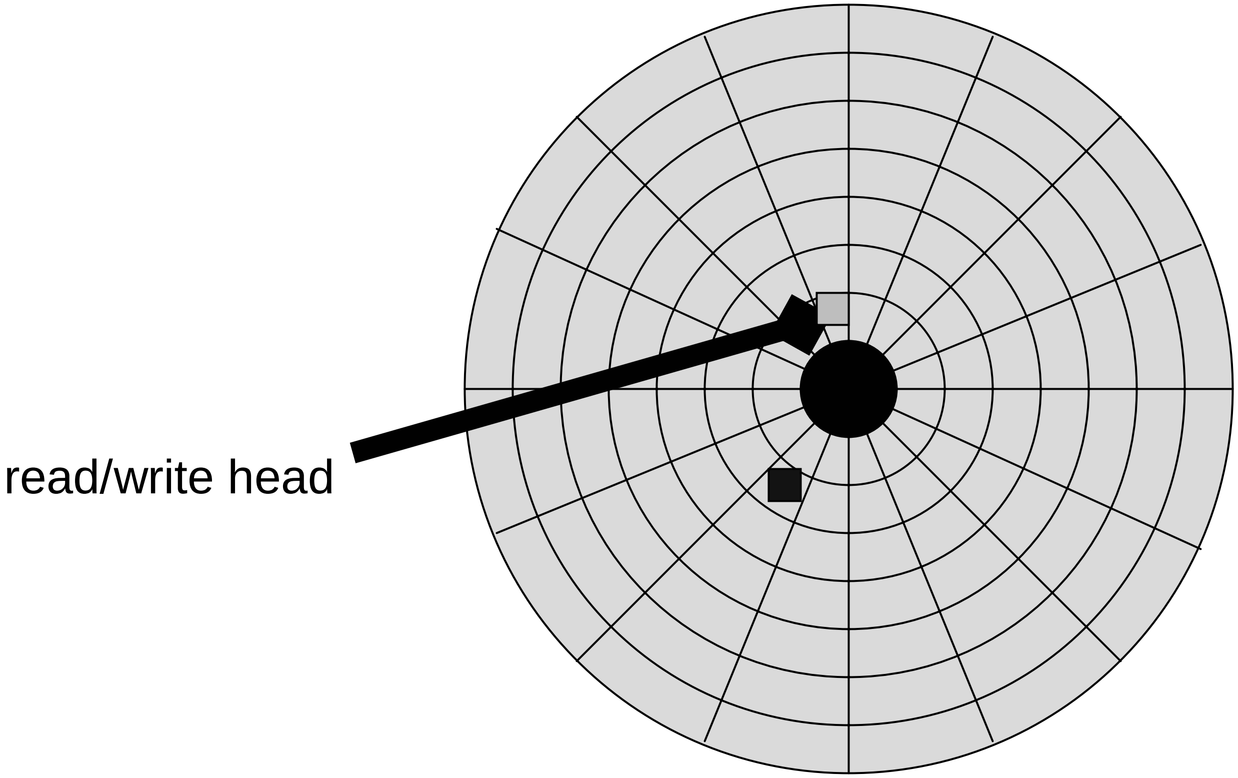
Freeblock Scheduling

- There are two requests at the disk



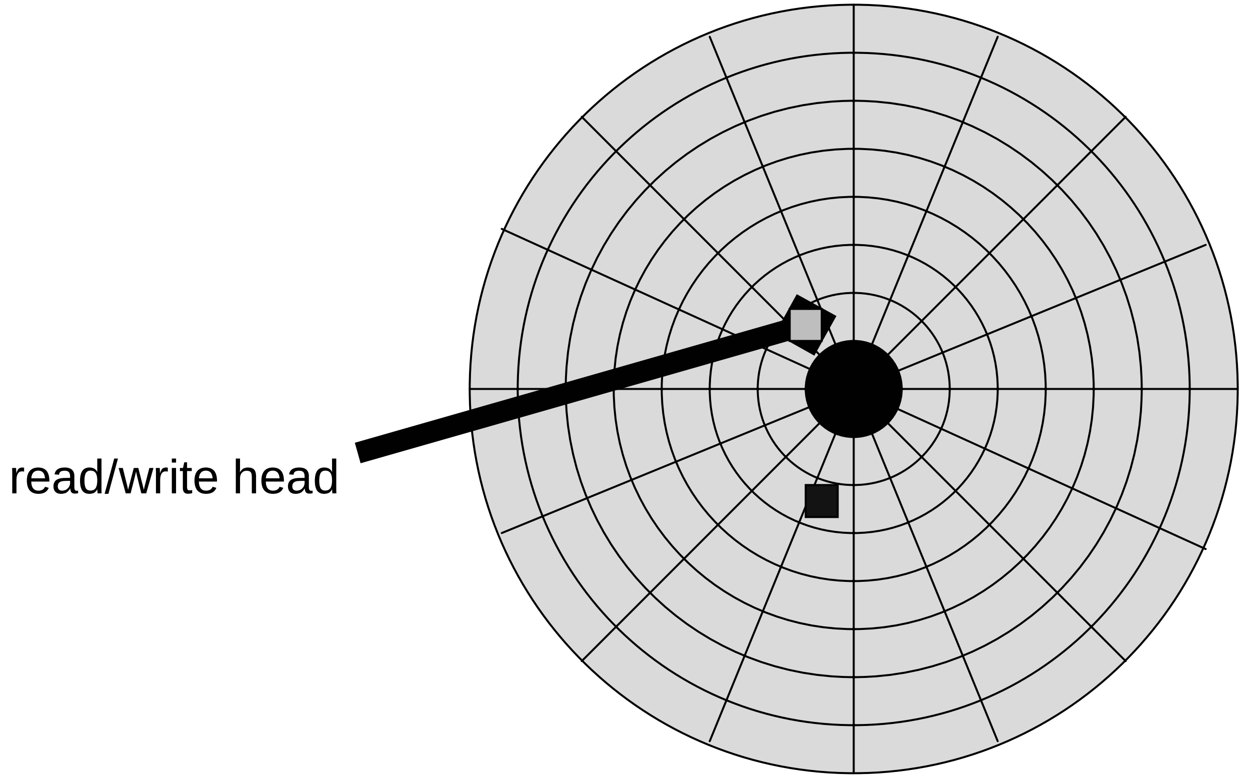
Freeblock Scheduling

- There are two requests at the disk



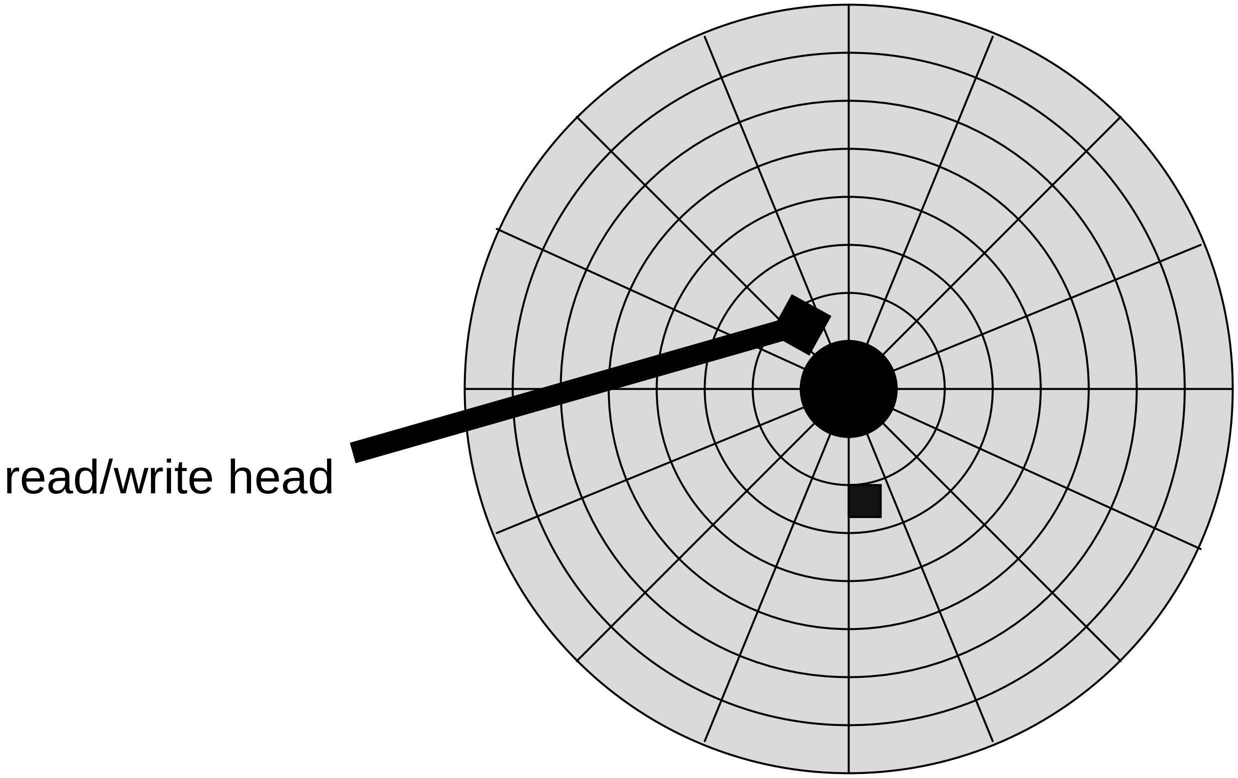
Freeblock Scheduling

- There are two requests at the disk



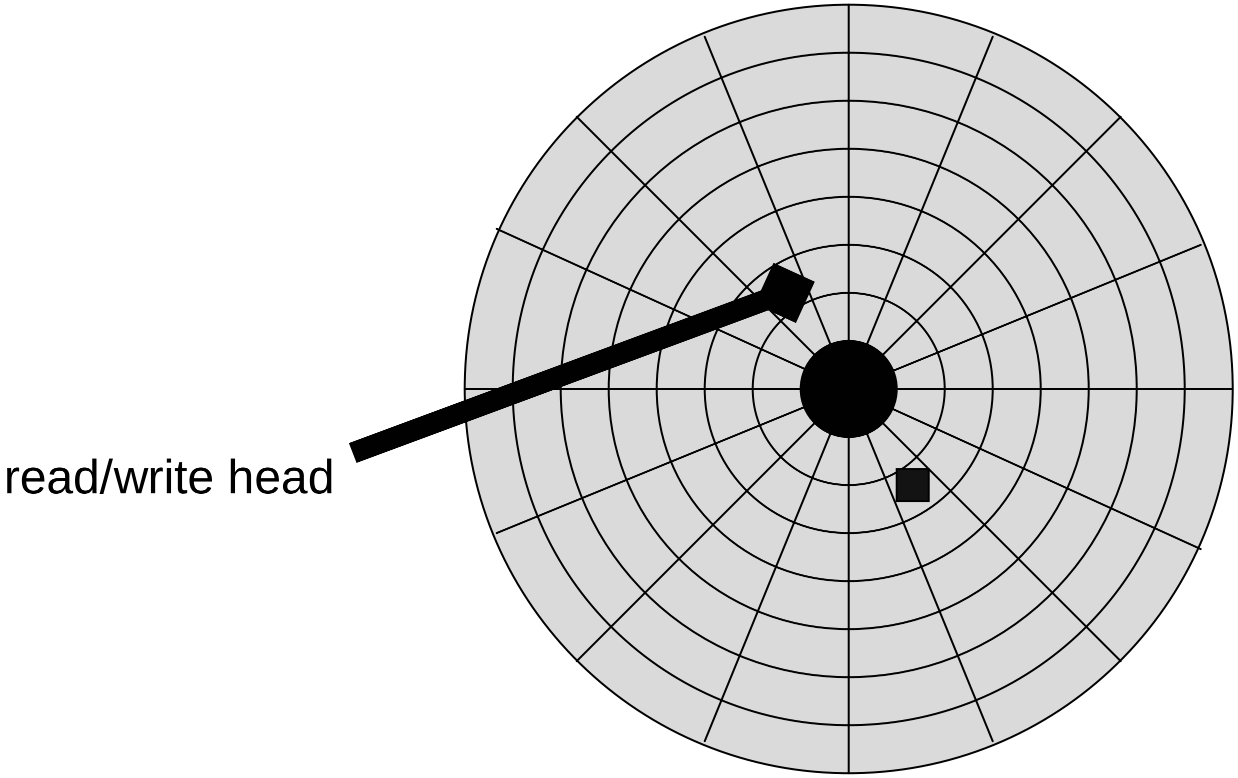
Freeblock Scheduling

- There are two requests at the disk



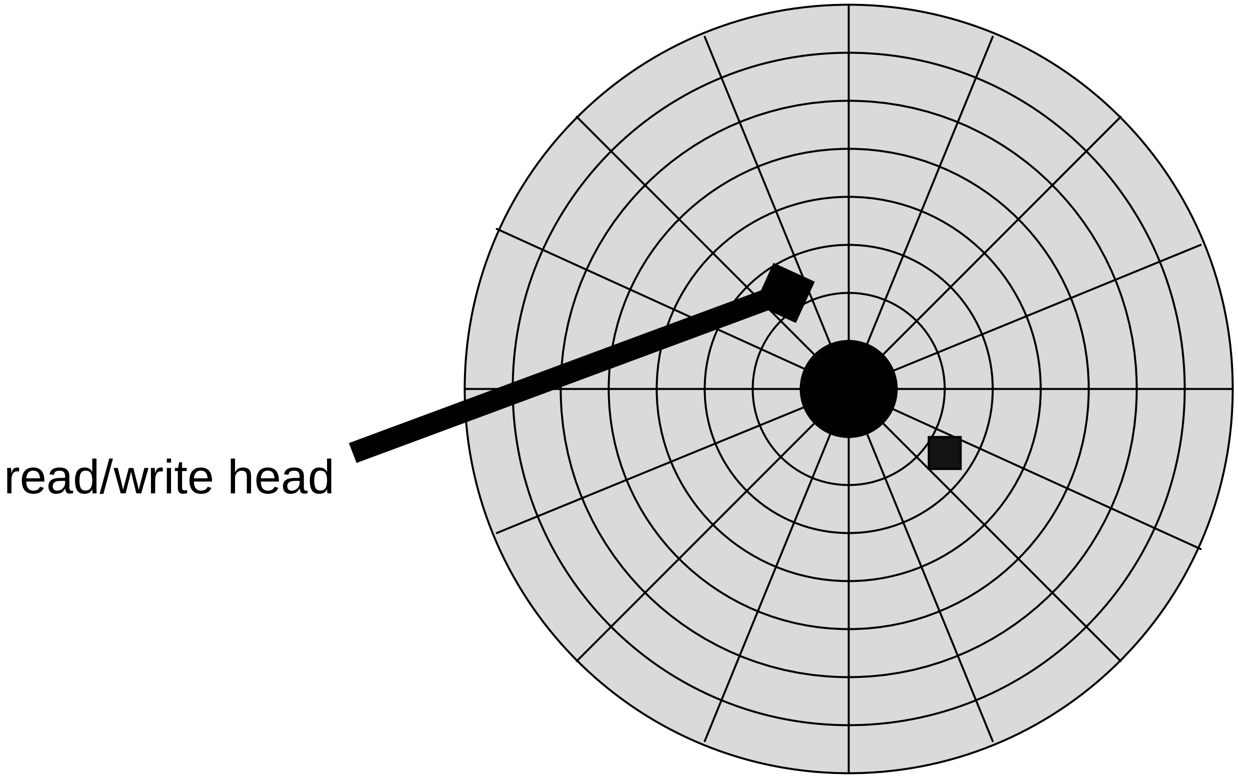
Freeblock Scheduling

- There are two requests at the disk



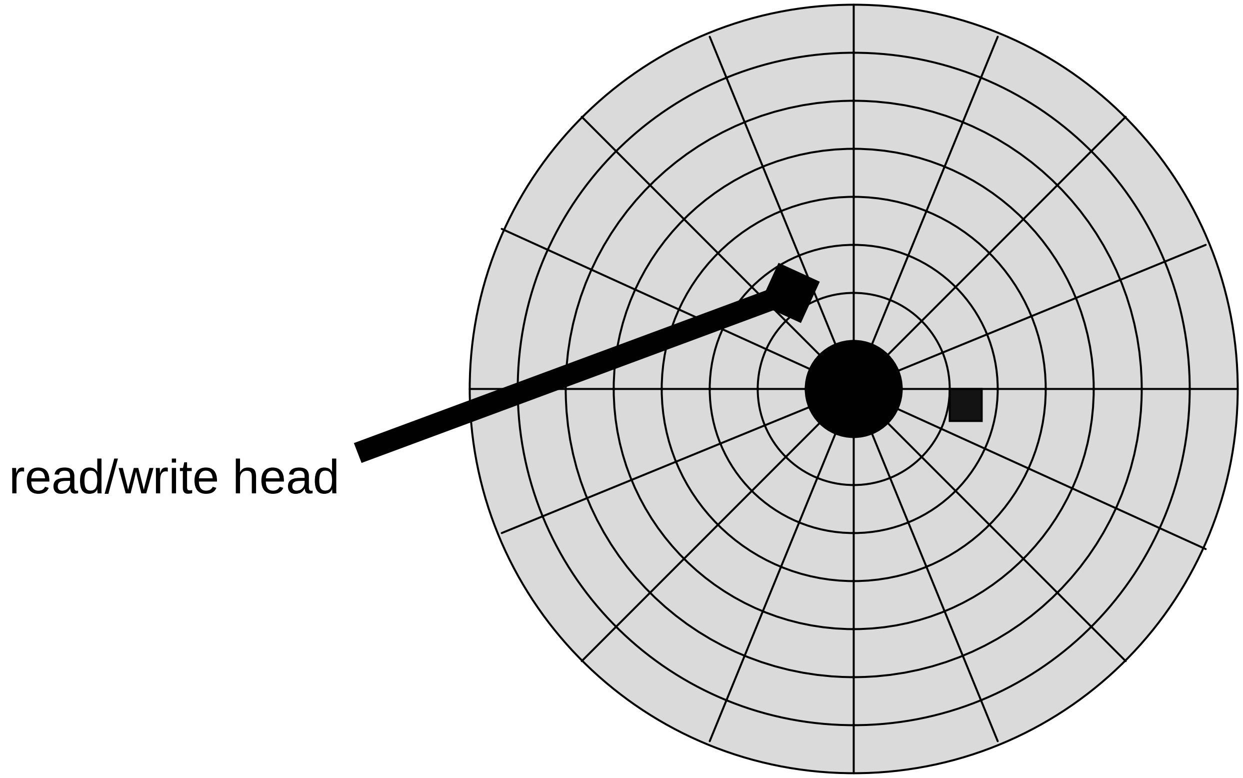
Freeblock Scheduling

- There are two requests at the disk



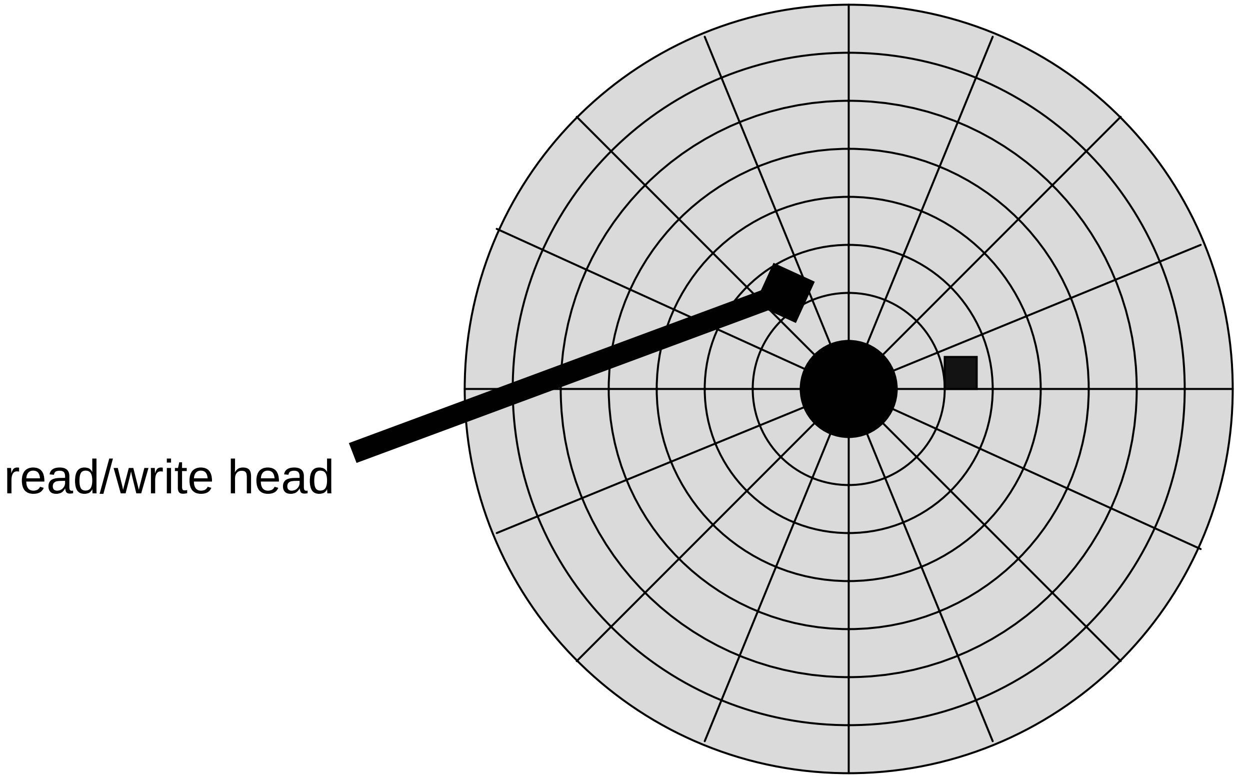
Freeblock Scheduling

- There are two requests at the disk



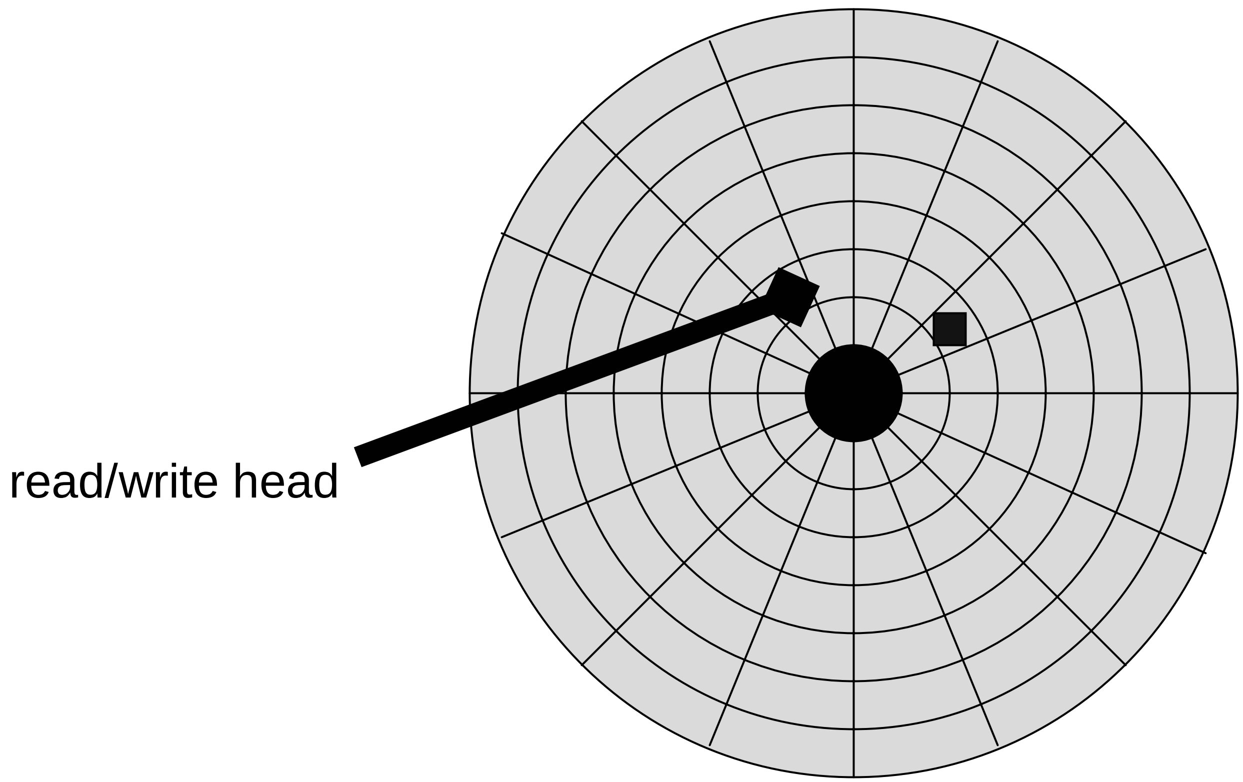
Freeblock Scheduling

- There are two requests at the disk



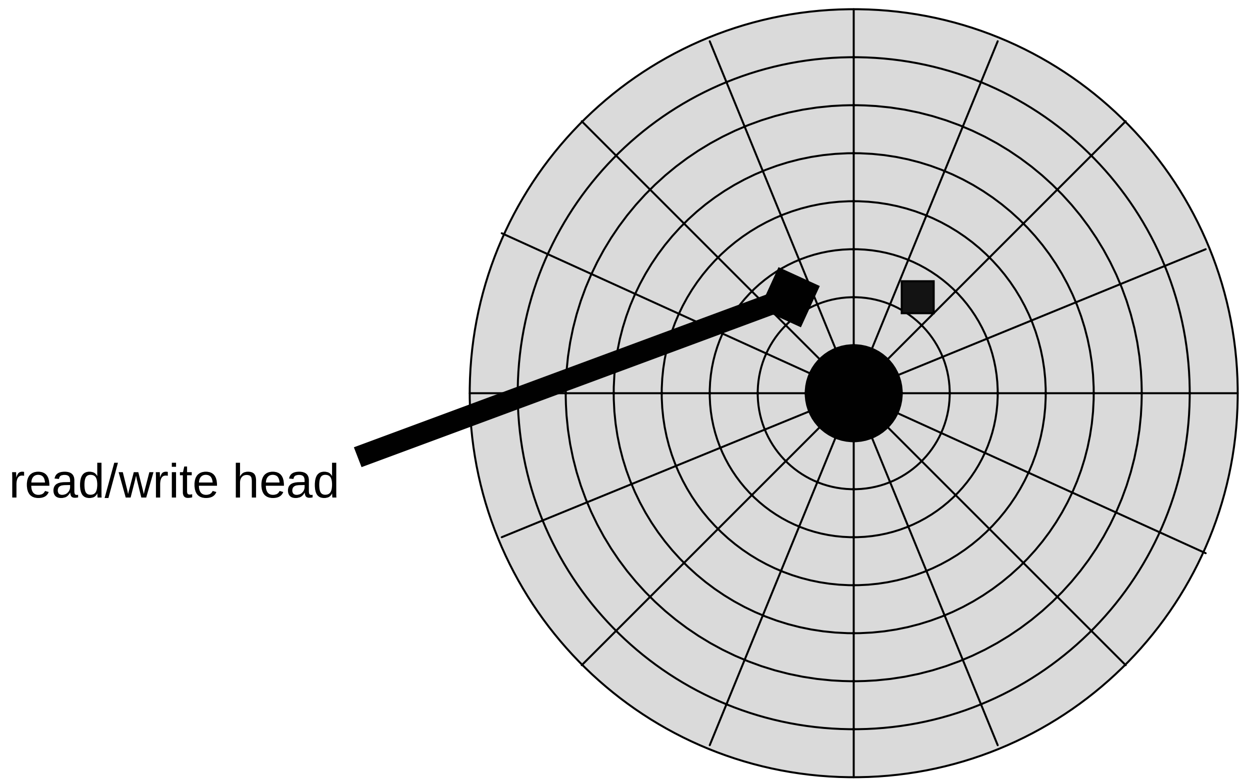
Freeblock Scheduling

- There are two requests at the disk



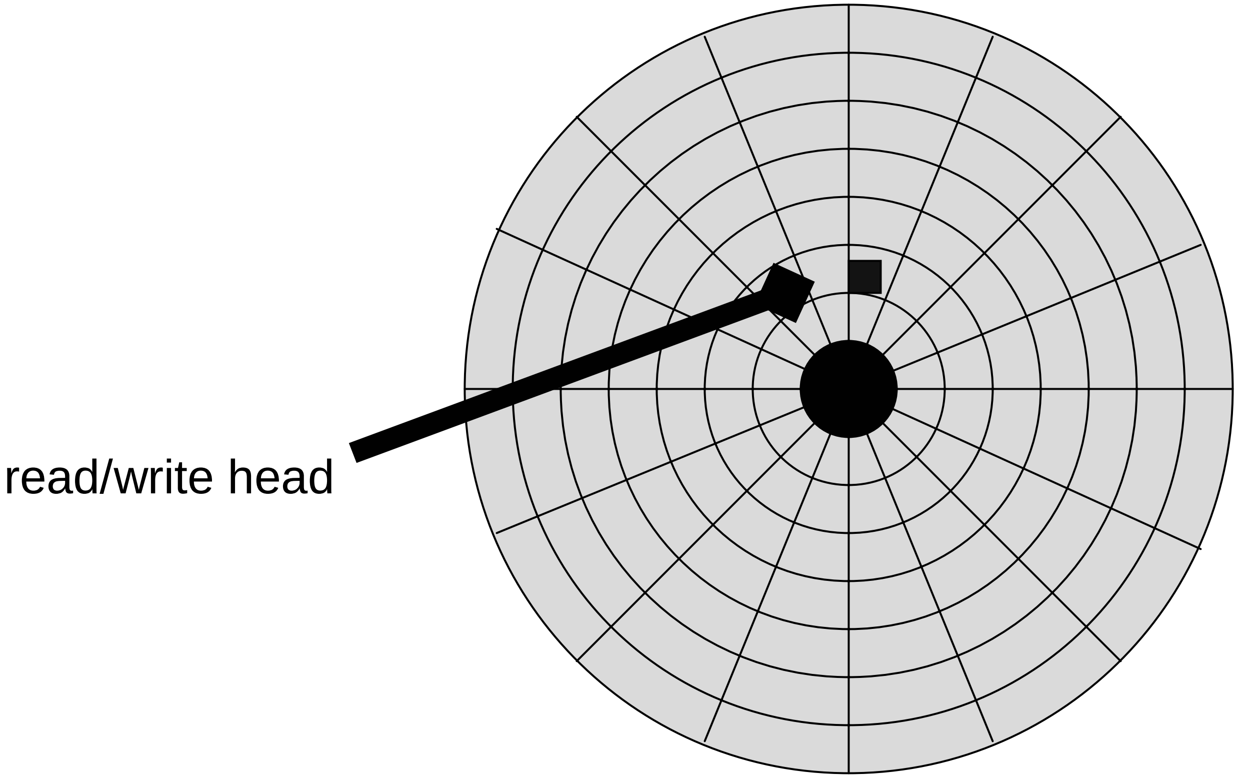
Freeblock Scheduling

- There are two requests at the disk



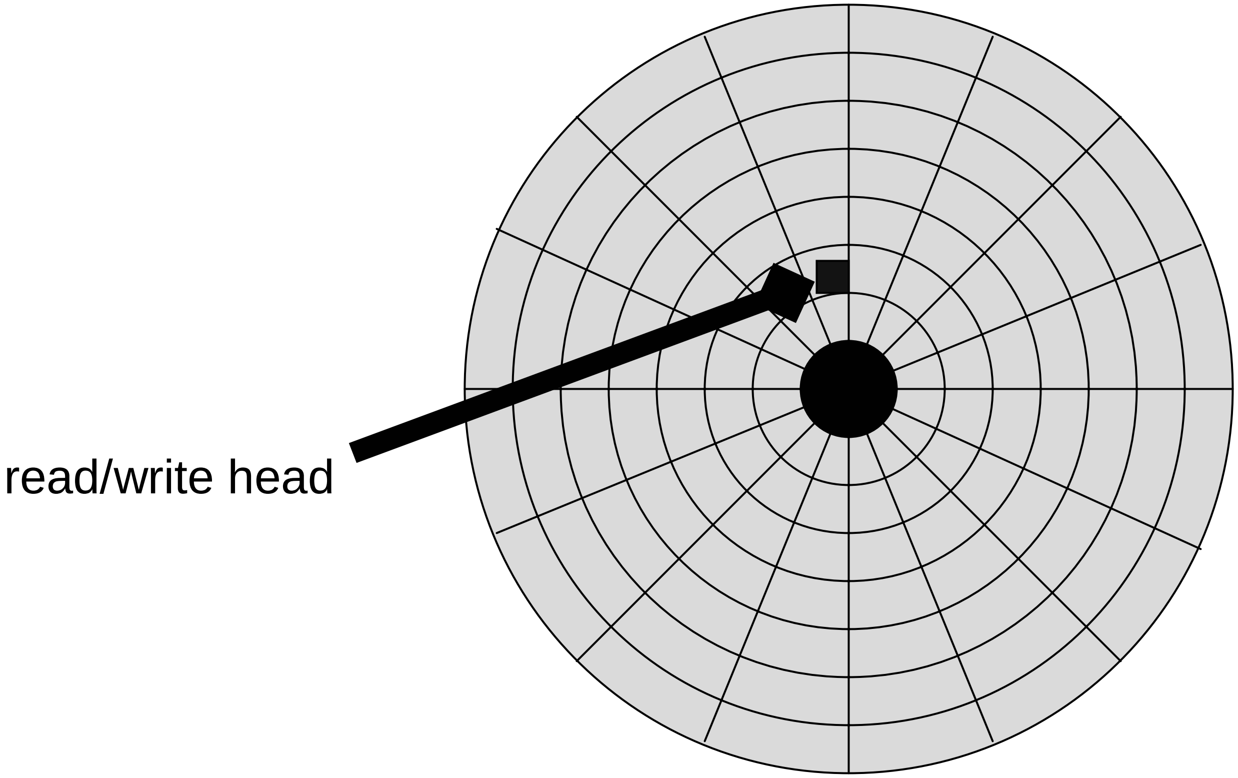
Freeblock Scheduling

- There are two requests at the disk



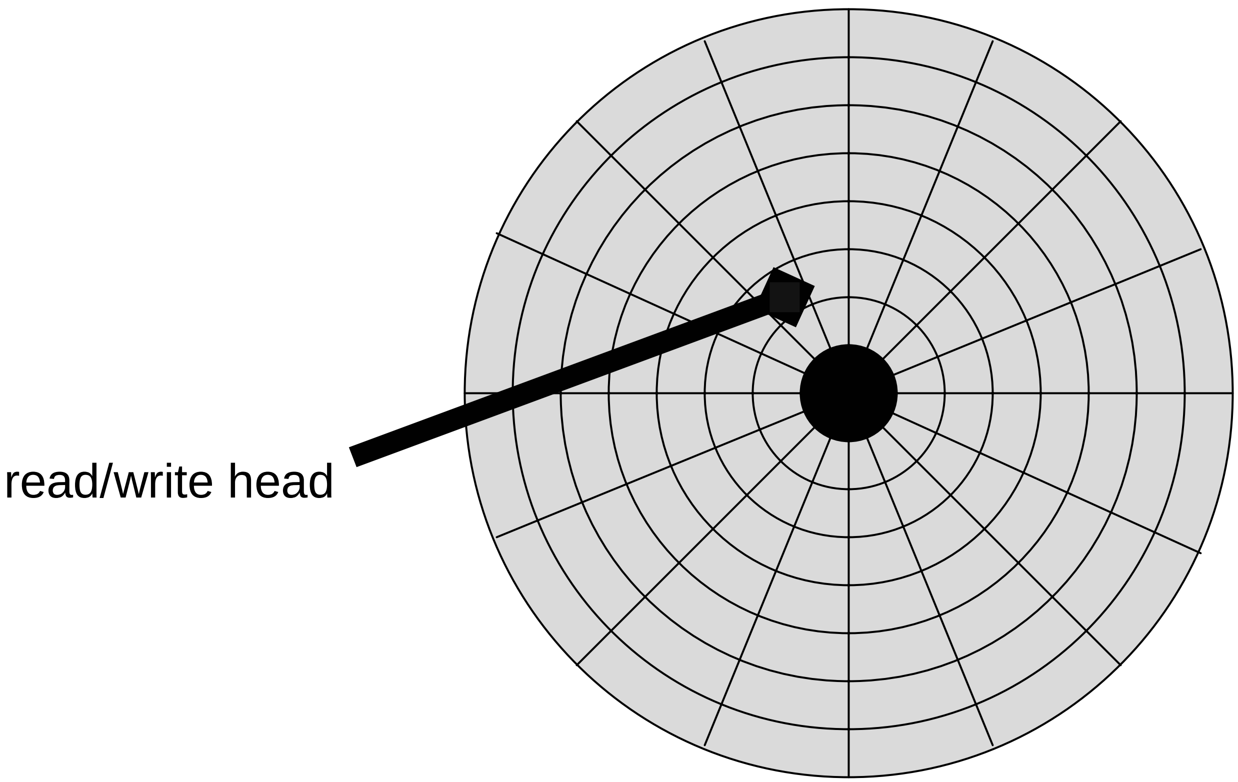
Freeblock Scheduling

- There are two requests at the disk



Freeblock Scheduling

- There are two requests at the disk



Freeblock Scheduling

- As in SPTF scheduling, we must know the EXACT state of the disk
- We need to be able to predict how much rotational latency we have to work with
- Enemies of freeblock scheduling:
  disk prefetching
  internal disk cache hits
  unexpected disk activity (recalibration, etc)
  disk-reordered requests

Freeblock Scheduling

- Results include 3.1MB/sec of free bandwidth
- This free bandwidth is best suited to applications with loose time constraints
- Some sample applications:
  - backup applications
  - disk array scrubbing
  - cache cleaning (perhaps…)

- Read the project 4 handout!