CSE 506: Operating Systems

Disk Scheduling

Key to Disk Performance

- Don't access the disk
  - Whenever possible
- Cache contents in memory
  - Most accesses ***hit*** in the block cache
- ***Prefetch*** blocks into block cache (a.k.a. ***read-ahead***)
  - When OS accesses disk, get next few blocks too
    - Keep them in block cache
  - If access hits on prefetched block
    - Read the next few blocks in the background
  - Avoids ***demand*** access to the disk

Caching + Throughput

- Most reads and writes to disk are asynchronous
  - Dirty data can be buffered and written at OS’s leisure
  - Most reads hit in block cache – read-ahead works
- How to optimally order pending disk I/O requests?
  - Hint: it isn’t first-come, first-served

Another view of disk accesses

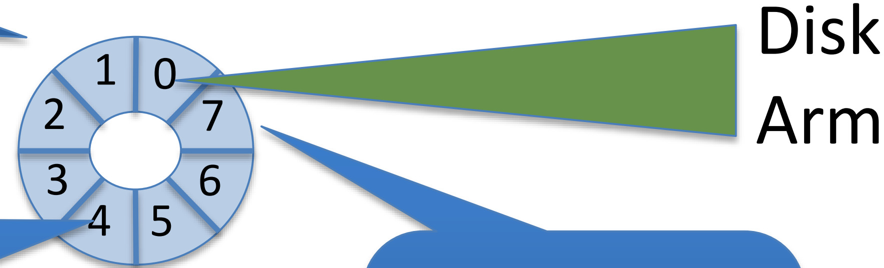
- Between block cache and disk, there is a queue
  - All disk requests wait in this queue
  - Requests are a tuple of (block #, read/write, buffer addr)
- Requests can be reordered
  - To achieve best performance across all requests
- What reordering heuristic to use? If any?
  - Heuristic is called the ***IO Scheduler***

A simple disk model

- Disks are slow
  - Moving parts much slower than circuits
  - Flash storage is faster
    - Still multiple orders of magnitude slower than memory
- Programming interface: simple array of sectors (blocks)
- Physical disk layout:
  - Concentric "cylinders" of blocks on a platter
    - Two tracks, one on each side
  - E.g., sectors 0-9 on innermost track, 10-19 on next track, etc.
  - Disk arm (with heads attached) moves between tracks
  - Platter rotates under disk head to align w/ requested sector

Disk Model

Each block on a sector

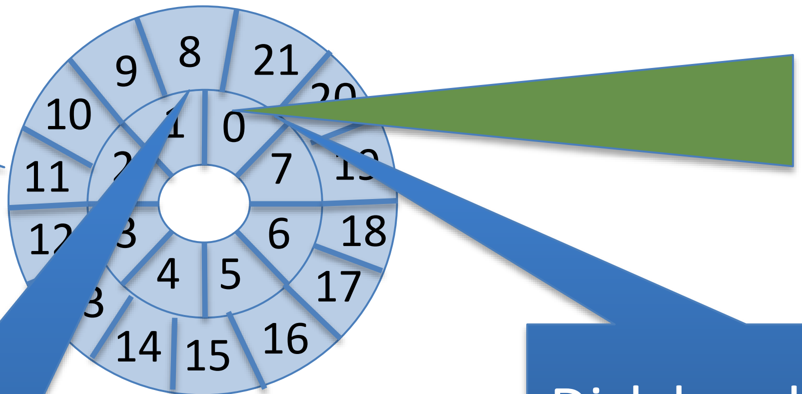


Disk spins at a constant speed. Tracks rotate underneath head.

Disk Head reads at granularity of entire sector

Disk Model

Concentric **tracks**

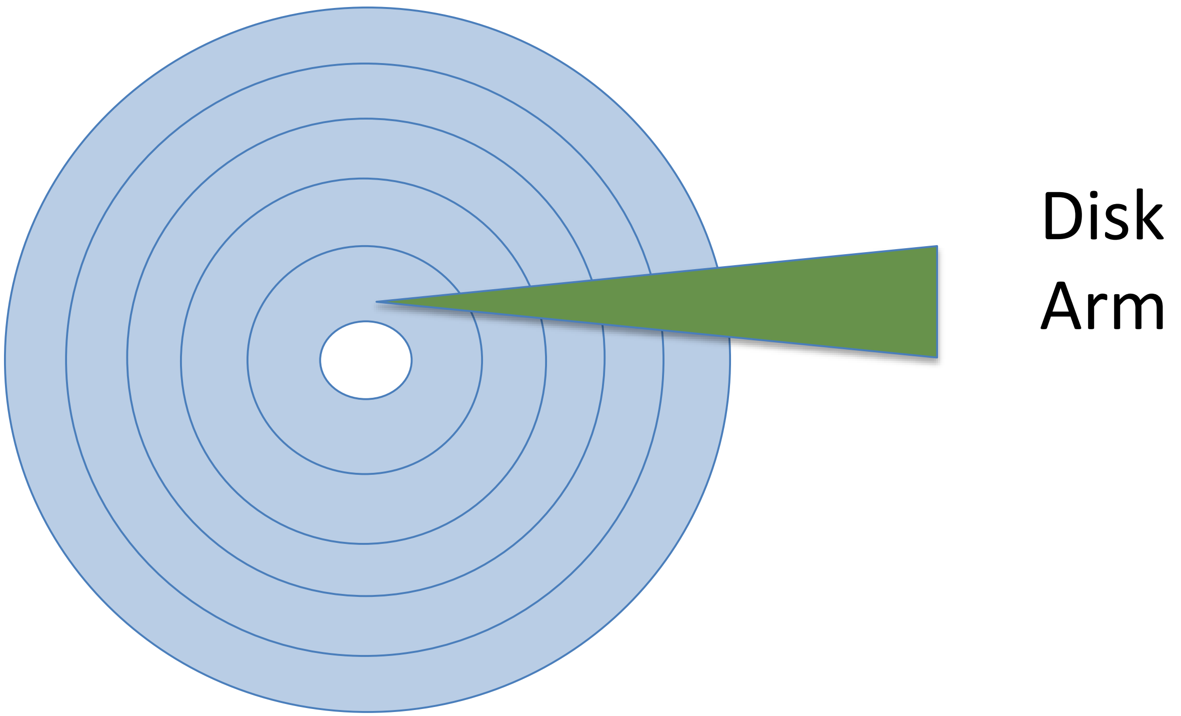


Disk Arm

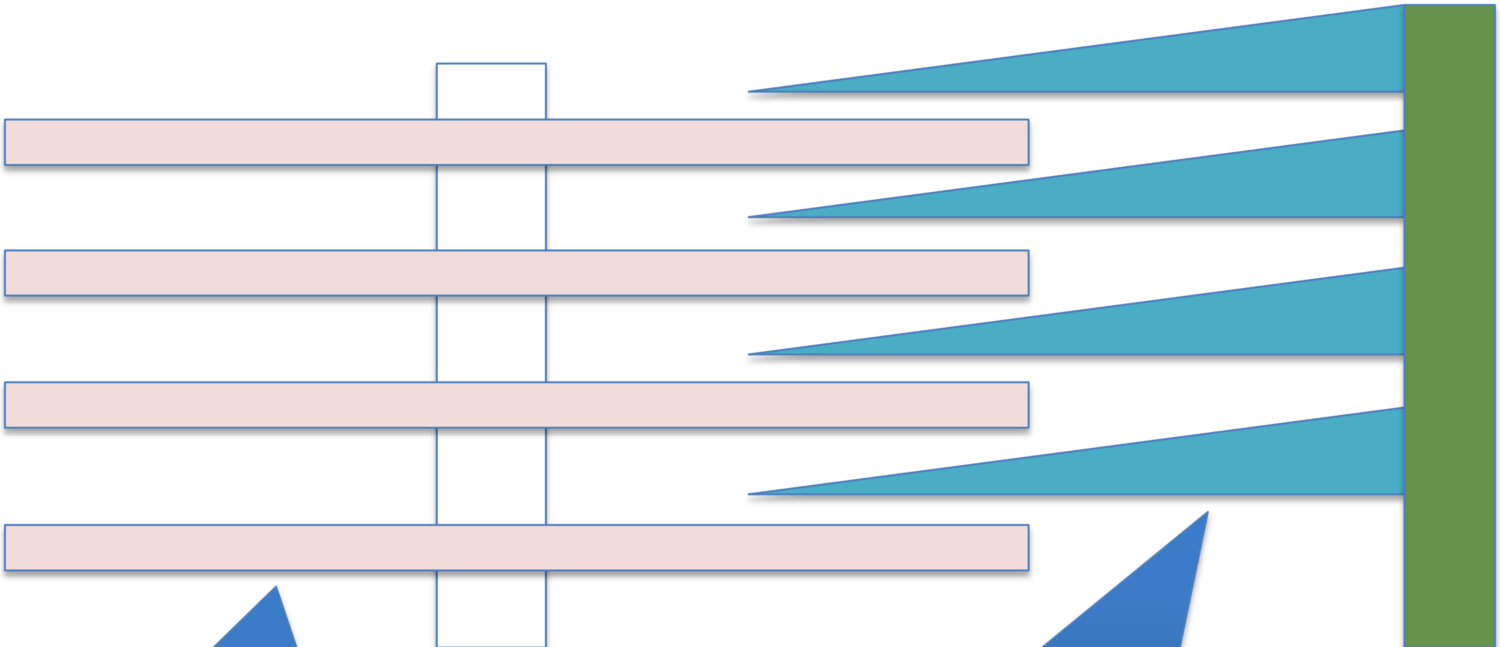
Disk head **seeks** to different tracks

Gap between 7 and 8 accounts for seek time

Many Tracks



Several (~4) Platters



Platters spin together at same speed

Each platter has two heads; All heads seek together on arm

3 key latencies

- I/O delay: Time to read/write a sector
- Rotational delay: Time for track to rotate under head
  - Note: disk rotates continuously at constant speed
- Seek delay: Time to move disk arm to cylinder

Greedy IO Scheduler

- Op. latency is function of arm and cylinder position
- Each request changes these values
- Idea: build a model of the disk
  - Use delay values from measurement or manuals
  - Use math to evaluate latency of each pending request
  - Greedy algorithm: always select lowest latency

Problem with Greedy?

- “Far” requests will starve
- Disk head may just hover around the “middle” tracks

Elevator Algorithms (SCAN)

- Arm moves in continuous “sweeps” in and out
  - Reorder requests within a sweep
    - Closest block in direction of travel is next to be read
    - Request that was just passed has to wait for sweep to return
- Prevents starvation
  - Sectors “inside” or “outside” serviced after bounded time
- Reasonably good throughput
  - Sort requests to minimize seek latency
- Simple to code
  - Programming model hides low-level details

Elevator Algorithms (C-SCAN)

- SCAN is not fair
  - Cylinders in the middle get serviced ~twice as often
    - Likely to be handled when arm travels in either direction
- Only perform ops when moving in one direction
  - Once the end is reached, quickly go to the beginning
- More fair
  - But probably lower average performance

Pluggable Schedulers

- Linux allows the disk scheduler to be replaced
  - Just like the CPU scheduler
- Can choose a different heuristic that favors:
  - Fairness
  - Real-time constraints
  - Performance

Complete Fairness Queue (CFQ)

- Idea: Add a second layer of queues (one per process)
  - Round-robin promote them to the "real" queue
- Goal: Fairly distribute disk bandwidth among tasks
- Problems?
  - Overall throughput likely reduced
  - Ping-pong disk head around

Deadline Scheduler

- Associate expiration times with requests
- Prioritize requests closer to expiration
  - Constrains reordering to ensure forward progress
- Good for real-time applications

Anticipatory Scheduler

- Idea: Try to anticipate locality of requests
- If process P issue bursts of requests for close blocks
  - If a request from P arrives
    - Hold request in queue for a while
    - Hope that more “nearby” requests come in
  - Eventually, schedule all pending requests at once
    - Coalesce adjacent requests

Optimizations at Cross-purposes

- The disk itself does some optimizations
  - Caching
    - Disks have their own caches
    - And do their own read-ahead
  - Reordering requests internally
    - Disk protocols (e.g., SATA) allow many outstanding commands
      - Can't assume that requests are serviced in-order
  - Bad sectors can be remapped to "spares"
    - Problem: disk arm flailing on an old disk