CS 3204
Operating Systems

Lecture 22

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Announcements

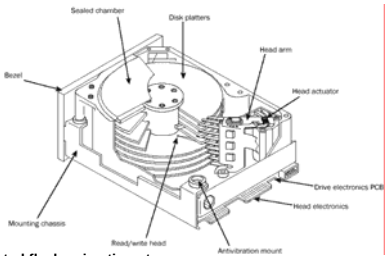
- Project 3 due tomorrow, Nov 8
- Reading assignment:
  - Chapter 10 + TBA
- Project 4 Help Session
  - Th Nov 9 + Mo Nov 13 Room TBA

Disks & Filesystems

What Disks Look Like

Hitachi Deskstar T7K500 SATA

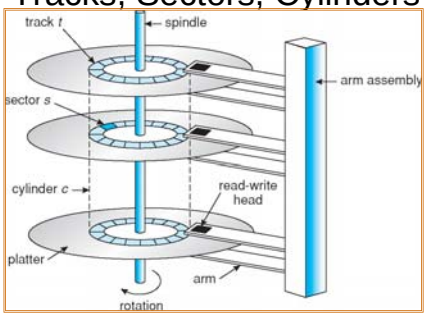
Disk Schematics



See narrated flash animation at
http://cis.poly.edu/cs2214rvs/disk.swf

Source: Micro House PC Hardware Library Volume I: Hard Drives

Tracks, Sectors, Cylinders



Typical Disk Parameters

- 2-30 heads (2 per platter)
- Diameter: 2.5" – 14"
- Capacity: 20MB-500GB
- Sector size: 64 bytes to 8K bytes
  - Most PC disks: 512 byte sectors
- 700-20480 tracks per surface
- 16-1600 sectors per track

What's important about disks from OS perspective

- Disks are big & slow - compared to RAM
- Access to disk requires
  - Seek (move arm to track) – to cross all tracks anywhere from 20-50ms, on average takes 1/3.
  - Rotational delay (wait for sector to appear under track) 7,200rpm is 8.3ms per rotation, on average takes ½: 4.15ms rot delay
  - Transfer time (fast: 512 bytes at 998 Mbit/s is about 3.91us)
- Seek+Rot Delay dominates
- Random Access is expensive
  - and unlikely to get better
- Consequence:
  - avoid seeks
  - seek to short distances
  - amortize seeks by doing bulk transfers

Disk Scheduling

- Can use priority scheme
- Can reduce avg access time by sending requests to disk controller in certain order
  - Or, more commonly, have disk itself reorder requests
- SSTF: shortest seek time first
  - Like SJF in CPU scheduling, guarantees minimum avg seek time, but can lead to starvation
- SCAN: "elevator algorithm"
  - Process requests with increasing track numbers until highest reached, then decreasing etc. – repeat
- Variations:
  - LOOK – don't go all the way to the top without passengers
  - C-SPAN: - only take passengers when going up

Accessing Disks

- Sector is the unit of atomic access
- Writes to sectors should always complete, even if power fails
- Consequence of sector granularity:
  - Writing a single byte requires read-modify-write

```
void set_byte(off_t off, char b) {
    char buffer[512];
    disk_read(disk, off/DISK_SECTOR_SIZE, buffer);
    buffer[off % DISK_SECTOR_SIZE] = b;
    disk_write(disk, off/DISK_SECTOR_SIZE, buffer);
}
```


Disks & Filesystems

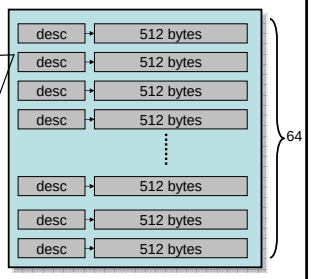
Buffer Cache

Disk Caching – Buffer Cache

- How much memory should be dedicated for it?
  - In older systems (& Pintos), set aside a portion of physical memory
  - In newer systems, integrated into virtual memory system: *e.g.*, page cache in Linux
- How should eviction be handled?
- How should prefetching be done?
- How should concurrent access be mediated (multiple processes may be attempting to write/read to same sector)?
  - How is consistency guaranteed? (All accesses must go through buffer cache!)
- What write-back strategy should be used?

Buffer Cache in Pintos

Cache Block Descriptor
- disk_sector_id, if in use
- dirty bit
- valid bit
- # of readers
- # of writers
- # of pending read/write requests
- lock to protect above variables
- signaling variables to signal availability changes
- usage information for eviction policy
- data (pointer or embedded)



A Buffer Cache Interface

```
// cache.h
struct cache_block;                    // opaque type
// reserve a block in buffer cache dedicated to hold this sector
// possibly evicting some other unused buffer
// either grant exclusive or shared access
struct cache_block * cache_get_block (disk_sector_t sector, bool exclusive);
// release access to cache block
void cache_put_block(struct cache_block *b);
// read cache block from disk, returns pointer to data
void *cache_read_block(struct cache_block *b);
// fill cache block with zeros, returns pointer to data
void *cache_zero_block(struct cache_block *b);
// mark cache block dirty (must be written back)
void cache_mark_block_dirty(struct cache_block *b);
// not shown: initialization, readahead, shutdown
```


Buffer Cache Rationale

Compare to buffer pool assignment in CS2604

```
class BufferPool { // (2) Buffer Passing
public:
  virtual void* getblock(int block) = 0;
  virtual void dirtyblock(int block) = 0;
  virtual int blocksize() = 0;
};
```

Differences:

- Do not combine allocating a buffer (a resource management decision) with loading the data into the buffer from file (which is not always necessary)
- Provide a way for buffer user to say they're done with the buffer
- Provide a way to share buffer between multiple users
- More efficient interface (opaque type instead of block idx saves lookup, constant size buffers)

Buffer Cache Sizing

- Simple approach
  - Set aside part of physical memory for buffer cache/use rest for virtual memory pages as page cache – evict buffer/page from same pool
- Disadvantage: can't use idle memory of other pool - usually use unified cache subject to shared eviction policy
- Windows allows user to limit buffer cache size
- Problem:
  - Bad prediction of buffer caches accesses can result in poor VM performance (and vice versa)

Buffer Cache Replacement

- Similar to VM Page Replacement, differences:
  - Can do exact LRU (because user must call cache_get_block()!)
  - But LRU hurts when long sequential accesses – should use MRU (most recently used) instead.
- Example reference string: ABCDABCDABCD, can cache 3:
  - LRU causes 12 misses, 0 hits, 9 evictions
  - How many misses/hits/evictions with MRU?
- Also: not all blocks are equally important, benefit from some hits more than from others

Buffer Cache Writeback Strategies

- Write-Through:
  - Good for floppy drive, USB stick
  - Poor performance – every write causes disk access
- (Delayed) Write-Back:
  - Makes individual writes faster – just copy & set bit
  - Absorbs multiple writes
  - Allows write-back in batches
- Problem: what if system crashes before you've written data back?
  - Trade-off: performance in no-fault case vs. damage control in fault case
  - If crash occurs, order of write-back can matter

Writeback Strategies (2)

- Must write-back on eviction (naturally)
- Periodically (every 30 seconds or so)
- When user demands:
  - fsync(2) writes back all modified data belonging to one file – database implementations use this
  - sync(1) writes back entire cache
- Some systems guarantee write-back on file close

Buffer Cache Prefetching

- Would like to bring next block to be accessed into cache before it's accessed
  - Exploit "Spatial locality"
- Must be done in parallel
  - use daemon thread and producer/consumer pattern
- Note: next(n) not always equal to n+1
  - although we try for it – via clustering to minimize seek times
- Don't initiate read_ahead if next(n) is unknown or would require another disk access to find out

```
b = cache_get_block(n, _);
cache_read_block(b);
cache_readahead(next(n));
```

```
queue q;
cache_readahead(sector s) {
  q.lock();
  q.add(request(s));
  signal qcond;
  q.unlock();
}
cache_readahead_daemon() {
  while (true) {
    q.lock();
    while (q.empty())
      qcond.wait();
    s = q.pop();
    q.unlock();
    read sector(s);
  }
}
```