Operating Systems

Input/Output Devices
(Ch 13)

Introduction

- One OS function is to control devices
  - significant fraction of code (80-90% of Linux)
- Want all devices to be simple to use
  - convenient
  - ex: stdin/stdout, pipe, re-direct
- Want to optimize access to device
  - efficient
  - devices have very different needs

Outline

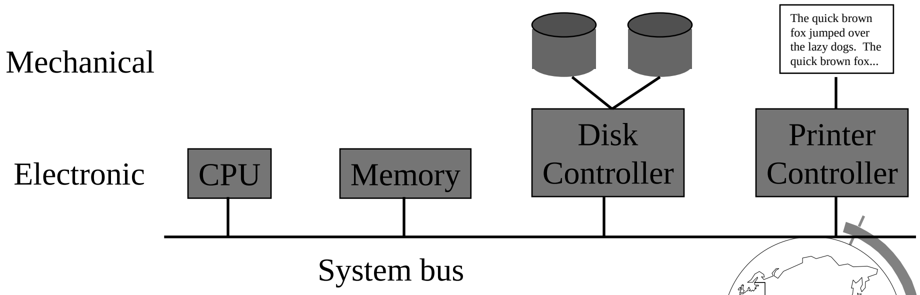
- Introduction (done)
- Hardware ←
- Software
- Specific Devices
  - Hard disk drives
  - Clocks

Hardware

- Device controllers
- Types of I/O devices
- Direct Memory Access (DMA)

Device Controllers

- Mechanical and electronic component



- OS deals with electronic
  - device controller

I/O Device Types

- block - access is independent
  - ex- disk
- character - access is serial
  - ex- printer, network
- other
  - ex- clocks (just generate interrupts)

Direct Memory Access (DMA)

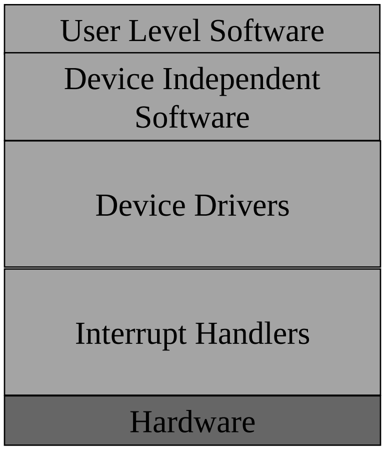
- Very Old
  - Controller reads from device
  - OS polls controller for data
- Old
  - Controller reads from device
  - Controller interrupts OS
  - OS copies data to memory
- DMA
  - Controller reads from device
  - Controller copies data to memory
  - Controller interrupts OS

Outline

- Introduction (done)
- Hardware (done)
- Software ←
- Specific Devices
  - Hard disk drives
  - Clocks

I/O Software Structure

- Layered



(Talk from bottom up)

Interrupt Handlers

<u>CPU</u>

1) Device driver initiates I/O

(CPU executing, checking for interrupts between instructions)

3) Receives interrupt, transfer to handler

4) Handler processes

(*Resume processing)*

<u>I/O Controller</u>

1) Initiates I/O

(I/O device processing request)

2) I/O complete. Generate interrupt.

Interrupt Handler

- Make interrupt handler as small as possible
  - interrupts disabled
  - Split into two pieces
- First part does minimal amount of work
  - defer rest until later in the rest of the device driver
  - Windows: “deferred procedure call” (DPC)
  - Linux: “top-half” handler
- Second part does most of work
- Implementation specific
  - 3rd party vendors

Device Drivers

- Device dependent code
  - includes interrupt handler
- Accept abstract requests
  - ex: “read block n”
- See that they are executed by device hardware
  - registers
  - hardware commands
- After error check
  - pass data to device-independent software

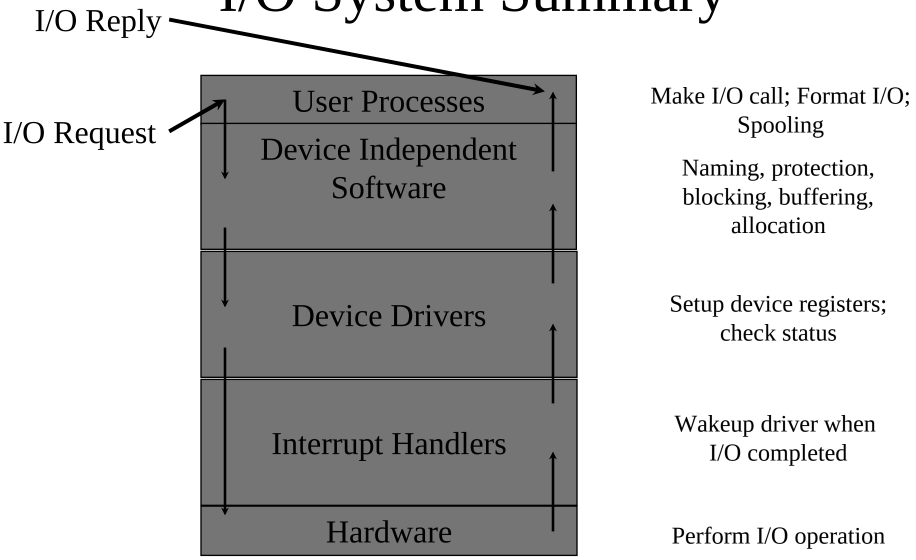
Device-Independent I/O Software

- Much driver code independent of device
- Exact boundary is system-dependent
  - sometimes inside for efficiency
- Perform I/O functions common to all devices
- Examples:
  - naming protection block size
  - buffering storage allocation error reporting

User-Space I/O Software

- Ex: `count = write(fd, buffer, bytes);`
- Put parameters in place for system call
- Can do more: formatting
  - `printf(), gets()`
- Spooling
  - spool directory, daemon
  - ex: printing, USENET

I/O System Summary

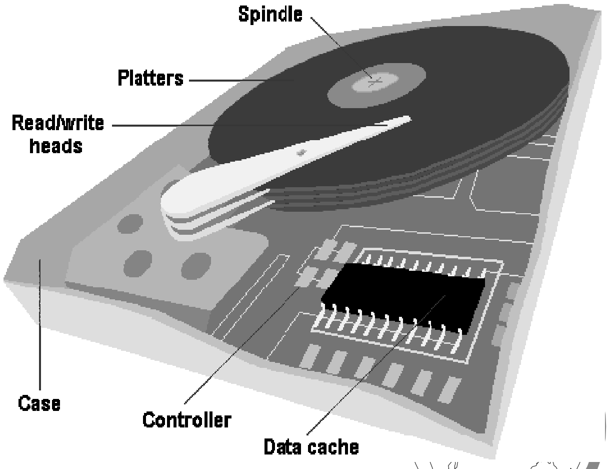

I/O Reply
I/O Request
User Processes
Device Independent Software
Device Drivers
Interrupt Handlers
Hardware
Make I/O call; Format I/O; Spooling
Naming, protection, blocking, buffering, allocation
Setup device registers; check status
Wakeup driver when I/O completed
Perform I/O operation

Outline

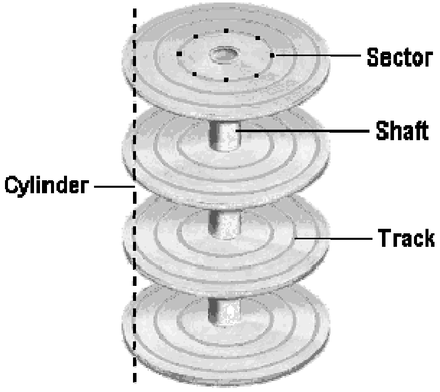
- Introduction (done)
- Hardware (done)
- Software (done)
- Specific Devices ←
  - – Hard disk drives
  - – Clocks

Hard Disk Drives (HDD)

- Controller often on disk
- Cache to speed access



HDD - Zoom



- – Platters
  - + 3000-10,000 RPM (floppy 360 RPM)
- – Tracks
- – Cylinders
- – Sectors

Ex: `hdb: Conner Peripherals 540MB CFS540A, 516MB w/64kB Cache, CHS=1050/16/63`

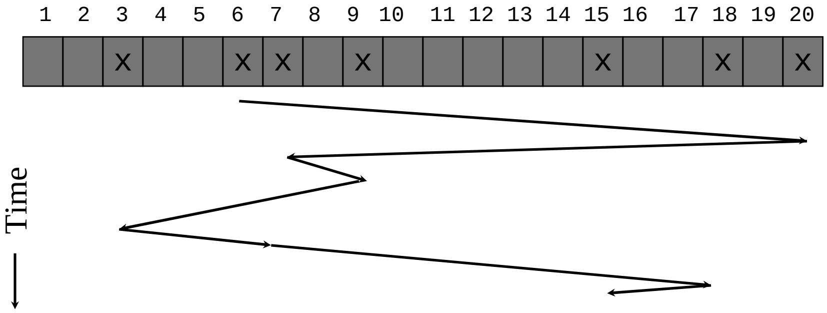
- – 1050 cylinders (tracks), 16 heads (8 platters), 63 sectors per track

- Disk arms all move together
- If multiple drives
  - – overlapping seeks but one read/write at a time

Disk Arm Scheduling

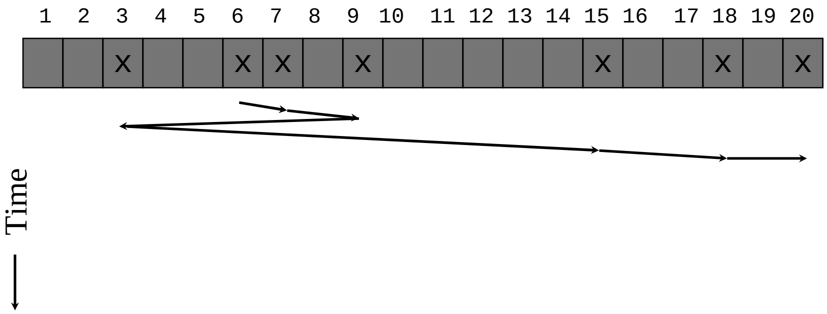
- Read time:
  - – seek time (arm to cylinder)
  - – rotational delay (time for sector under head)
  - – transfer time (take bits off disk)
- Seek time dominates
- How does disk arm scheduling affect seek?

First-Come First-Served (FCFS)



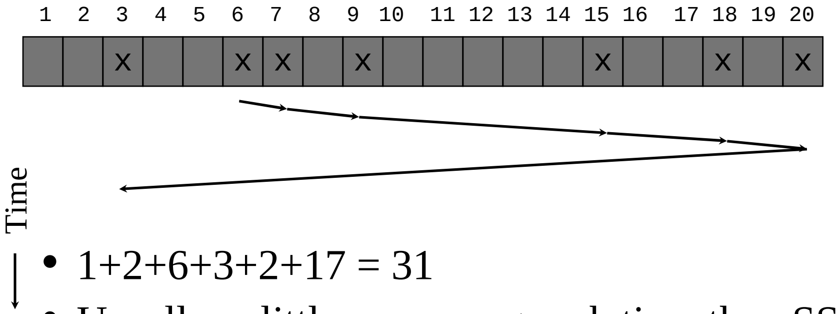
- 14+13+2+6+3+12+3=53
- Service requests in order that they arrive
- Little can be done to optimize
- What if many requests?

Shortest Seek First (SSF)



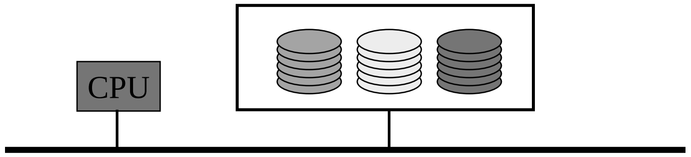
- 1+2+6+9+3+2 = 23
- Suppose many requests?
  - – Stay in middle
  - – Starvation!

Elevator (SCAN)



- 1+2+6+3+2+17 = 31
- Usually, a little worse avg seek time than SSF
  - – But avoids more fair, avoids starvation
- C-SCAN has less variance
- Note, seek getting faster, rotational not
  - – Someday, change algorithms

Redundant Array of Inexpensive Disks (RAID)



- For speed
  - Pull data in parallel
- For fault-tolerance
  - Example: 38 disks, form 32 bit word, 6 check bits
  - Example: 2 disks, have exact copy on one disk

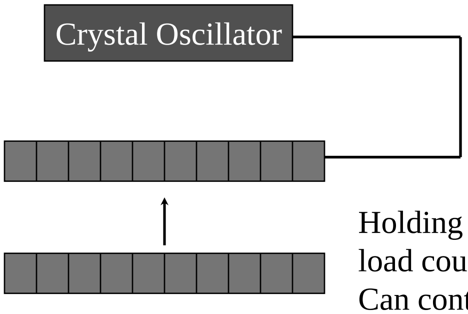
Error Handling

- Common errors:
  - programming error (non-existent sector)
  - transient checksum error (dust on head)
  - permanent checksum error (bad block)
  - seek error (arm went to wrong cylinder)
  - controller error (controller refuses command)

Clock Hardware

- Time of day to time quantum

Pulse from 5 to 300 MHz



Crystal Oscillator

Decrement counter
when == 0
- generate interrupt

Holding register to
load counter
Can control clock ticks

Clock Software Uses

- time of day
  - 64-bit, in seconds, or relative to boot
- interrupt after quantum
- accounting of CPU usage
  - separate timer or pointer to PCB
- `alarm()` system calls
  - separate clock or linked list of alarms with ticks