CS323 Operating Systems
Power Management

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Content of this lecture

- Administrative announcements
- Power management
  - Hardware issues
  - OS issues
- File systems
- Summary

Administrative

- Midterm grades available
- MP1 grade available
- Options
  - Drop-class
  - Try harder
    - Understand the material
      - Ask questions if you don't
      - Try the questions on the textbook
      - Exercise with more examples
      - Study group

Midterm Overview

- Graduate students have not been separated from the distribution yet
  - 10: 90-99
  - 8: 80-89
  - 2: 70-79
  - 2: absent
- The hardest question:
  - Using swap to implement mutex

Problem 2 in Midterm

```
typedef int mutex;
Mutex m = 1; // initially mutex is free
Semaphore::P(Mutex *m) {
{
   char temp = 0;

   swap(m, &temp );  // can be omitted
   while ( temp == 0 ) {
      swap(m, &temp );
   }
}

Semaphore::V(mutex *m)
{
   char temp = 1;

   swap(m, &temp ); // or   *m = 1;
}
```

Is the following correct?

```
typedef int mutex;
Mutex m = 1; // initially mutex is free
Semaphore::P(Mutex *m) {
{
   char temp = 0;

  while(temp == 0);
  swap(m, &temp );
}

Semaphore::V(mutex *m)
{
   char temp = 1;

   swap(m, &temp ); // or   *m = 1;
}
```


Admin

- Regrading Period
  - MP1: until this Friday, 3/21 5pm
  - Midterm1: until Friday, 3/21 5pm
    - Pick/up your midterm from TA's office
  - Submit written request to TA
  - After this deadline, no regrading request will be granted!!
- MP3 Released
- Quiz 3 released
- 3/31 & 4/2 lectures
  - Given by TA: Jeff

Review

- Blocking, non-blocking, asynchronous I/O
- Clock and Timer
  - Functionalities
  - Soft timer
  - Watchdog timer
  - Virtual clocks
- Power management

Power Management

- Mobile Device
  - Battery life is short: 2-4 hours for laptop
- Servers
  - High electricity bill
  - Wiring demand
  - Heat dissipation
    - reliability

Approaches to reduce energy consumption

- OS turns off parts of the computer when are not in use (mostly IO devices such as display)
- Application program uses less energy, possibly degrading quality of the user experience

Hardware Issues

- Battery
  - Handheld devices: disposable batteries,
  - Laptops: rechargeable batteries
- Multiple power states for CPU, memory and I/O devices
  - Sleeping
  - Hibernating
  - Off
- Transition between power states:
  - Idle for a certain period of time, transition into lower power state
  - Activated when it is accessed

OS Issues

- Keep track of the states of different devices
- Which device to transition into low-power state?
  - if it shuts down a device and that device is needed again quickly, then there is overhead delay to restart the device;
  - if the device is long on, and it is not needed, then energy is wasted.

Display Energy Management

- The biggest energy consumption
- Reason
  - Require backlit to get a bright sharp image
- Solution:
  - shut down the display if there is no activity for some number of minutes.
  - divide the screen into zones and turn on only zones where the active window resides (work by Flinn and Satyanarayanan)

Hard Disk

- Disk takes substantial energy
  - spinning at high speed, even of there are no accesses.
- Solution:
  - spin the disk down after a certain idle time of activities.
  - When it is needed, it is spun up again
- Spin-up takes
  - Considerable time: 12 sec
  - Energy: 135J
- Disk cache in RAM can save energy
  - If a needed block is in the cache, the idle disk does not have to be restarted.
- Another possibility is to keep application programs informed when disk is down.

Group Discussion

- Spin-up takes
  - Considerable time: 12 sec
  - Energy: 135J
- If the disk energy consumption is 12w (J/s), what is the break point?
  - Or how much time a disk can stay idle?
- Or rent vs. buy
  - Ski boards/shoes $400
  - Ski boards/shoes rental: $30 every time
  - When does it make sense to buy

CPU

- Laptop CPU can be put to sleep, reducing power to almost zero.
- CPU wakes up when interrupt is sensed.
- Important relationship between CPU voltage, clock cycle and power usage

Memory

- Two options to save energy with memory:
  - cache is flushed and then switched off (hibernation)
  - write content of memory to disk and switch off the memory
- When memory is shut off
  - CPU has to shut off or has to execute out of ROM;
  - If CPU is off and interrupt wakes it up, it has to read from ROM to load the memory.
- Tradeoff
  - Switching off memory has high overhead
  - but it might be worth while if the idle times are long.
- Multiple power-mode
  - Active
  - Nap
  - Standby
  - Power-down

Wireless Communication

- If radio receivers always listen for messages, this can be expensive.
- Solution
  - turn off the receiver if it is being idle for some time.
  - Challenge: how to avoid lost incoming messages?
    - use base-stations to buffer incoming messages.
- When to turn off the radio?
  - determined by the application;
  - or by the system
  - Or decided by users

Thermal Management

- Heat dissipation
  - CPUs or devices get hot due to their high speeds
- Solutions:
  - electric fan to blow the hot air out of the chassis
  - Switch device off
- OS needs to monitor the temperature
  - the OS can make a decision to turn on or off the fan.
  - OS performs thermal management
    - If the system gets close to the maximum allowable temperature, the OS may reduce the back-lighting of the screen, slow down the CPU, spin down the disk to reduce the energy, hence decrease the temperature, hence avoiding to turn the fan on.

Battery Management

- Smart batteries can communicate with OS.
  - report on maximum voltage, current voltage, maximum charge, current charge, maximum drain rate, and other parameters.
- Laptops can query for these parameters and visualize them.
- Multiple batteries possible.
  - The OS switches in a graceful manner from one battery to another.

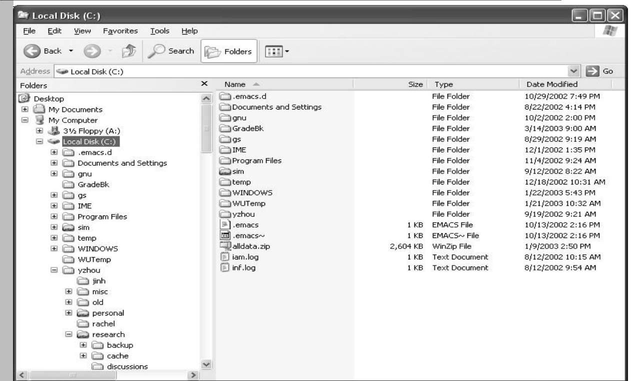
Driver Interface

- Window's ACDI - Advanced Configuration and Power Interface
- OS sends commands asking the device driver to report on device's states (power information)

Input/Output Summary

- I/O Hardware
- I/O software
- Clock/timers
- Power management
- Others (read textbook)
  - Disks (merged into file systems)
  - Character terminals
  - GUI
  - Network terminals

File Systems

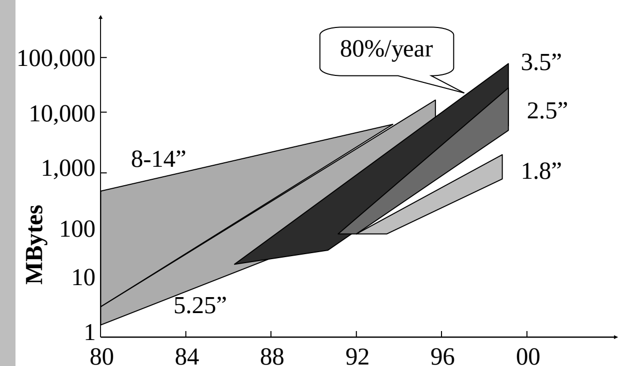


Disks First, Then File Systems



Form factor:	Form factor:	Form factor:
.5-1”× 4”× 5.7”	.4-.7” × 2.7” × 3.9”	.2-.4” × 2.1” × 3.4”
Storage:	Storage:	Storage:
18-73GB	4-27GB	170MB-1GB

Magnetic Disk Capacity

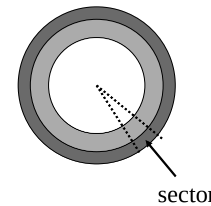


Disk Technology Trends

- Disks are getting smaller for similar capacity
  - Spin faster, less rotational delay, higher bandwidth
  - Less distance for head to travel (faster seeks)
  - Lighter weight (for portables)
- Disk data is getting denser
  - More bits/square inch
  - Tracks are closer together
  - Doubles density every 18 months
- Disks are getting cheaper ($/MB)
  - Factor of ~2 per year since 1991
  - Head close to surface

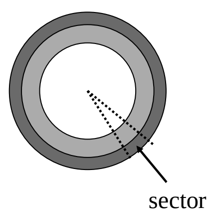
Disk Organization

- Disk surface
  - Circular disk coated with magnetic material
- Tracks
  - Concentric rings around disk surface, bits laid out serially along each track
- Sectors
  - Each track is split into arc of track (min unit of transfer)



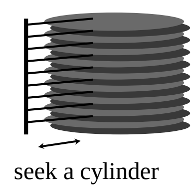
Disk Organization As Fiction

- Fixed arc implies inefficiency
  - short inner sectors, long outer sectors
- Reality
  - More sectors on outer tracks
  - Disks map transparently



More on Disks

- CD's and floppies come individually, but magnetic disks come organized in a disk pack
- Cylinder
  - Certain track of the platter
- Disk arm
  - Seek the right cylinder



Disk Examples (Summarized Specs)

	Seagate Barracuda	IBM Ultrastar 72ZX
Capacity, Interface & Configuration		
Formatted Gbytes	28	73.4
Interface	Ultra ATA/66	Ultra160 SCSI
Platters / Heads	4 / 8	11/22
Bytes per sector	512	512-528
Performance		
Max Internal transfer rate (Mbytes/sec)	40	53
Max external transfer rate (Mbytes/sec)	66.6	160
Avg Transfer rate(Mbytes/sec)	> 15	22.1-37.4
Multisegmented cache (Kbytes)	512	16,384
Average seek, read/write (msec)	8	5.3
Average rotational latency (msec)	4.16	2.99
Spindle speed (RPM)	7,200	10,000

Reminder