Distributed Storage Networks and Computer Forensics
3. Solid State Disks

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Winter Semester 2011/12
Solid State Disks

Motivation
Price Fall of RAM and Disk Storage

Technological impact of magnetic hard disk drives on storage systems, Grochowski, R. D. Halem
IBM SYSTEMS JOURNAL, VOL 42, NO 2, 2003
Price Development of Solid State Disks (SSD)

Speed Development of Solid State Drive (SSD)

Non-Volatile RAM

- EEPROM
  - EPROM
  - non-flash EEPROM
  - Flash memory
- Battery powered RAM
  - SRAM
  - DRAM
Solid State Disks

RAM
Battery Powered RAM

- Combination of DRAM or SRAM with external energy source
  - DRAM = dynamic random access memory
    - memory needs to be refreshed
    - fast, small, energy-consuming
    - DDR-SDRAM (Double Data Rate Synchronous Dynamic Random Access Memory)
  - SRAM = static random access memory
    - memory needs continuous power supply
    - slower, still energy-consuming

- Usage
  - RAM Disks

- Advantages
  - high speed

- Disadvantages
  - direct addressing
  - long lifetime of memory

- Hybrid hard disks
  - more expensive than hard disks
  - lifetime restricted by battery size

- Hybrid flash memory
  - combine large RAM with hard disk as Cache memory
  - when hard disk is shutdown RAM memory is saved to the disk

- RAM is 80 times faster than Flash memory
Solid State Disks

Flash
E*PROM

- PROM (Programmable Read-Only Memory)
  - can be programmed only once
  - „blowing fuses“ using extra high power when programming
- EPROM (Erasable PROM)
  - can be reprogrammed by exposing it to ultraviolet light
- EEPROM (Electrically EPROM)
  - non-volatile memory
  - Categories: Flash and Non-flash memory
    - difference: addressing for erasure
    - Non-flash erases units
    - Flash erases full blocks
Flash Memory

- **Special form of EEPROM**
  - Random access
  - Fast access times
    - faster than hard disk, slower than SRAM
  - Block-wise erasure

- **Invented 1980 at Toshiba**

- **Types**
  - NOR
    - long erase and write times
    - random access
    - last $10^4$-$10^6$ erase cycles
    - used as replacement for ROM
    - Originally CompactFlash was based on NOR-Flash
  - NAND
    - faster erase and write times
    - block-wise read access
    - used as secondary storage
      * solid state disk
    - used as portable memory
      * Memory cards, USB flash drives,

(c) SanDisk
Nor Flash Memory Cell

- A memory cell is a transistor
  - with an insulated floating gate (trapping electrons)

- Reading
  - If floating gate is charged then the threshold voltage is modified

- Programming/Erasure
  - Apply elevated voltage
  - Electrons jump through the insulated layer by quantum tunneling

- Memory wear
  - After some 100,000 cycles the floating gate cannot be erased

http://en.wikipedia.org/wiki/NOR_flash

http://www.lascon.co.uk/dh00300.htm
Solid State Disk Architecture

- NAND Flash
  - address blocks for read and write access
    - block size 16KB-512 KB
  - Erase block sets all bits to 1
  - Successive writes can add 0s to each block

![Solid State Disk Architecture Diagram](http://www.sandisk.com/Assets/File/pdf/industrial/SanDisk_SSD_SATA_5000_2.5_DS_Rev0.2.pdf)

**Figure 1: SanDisk SSD SATA 5000 2.5” Block Diagram**

[http://www.sandisk.com/Assets/File/pdf/industrial/SanDisk_SSD_SATA_5000_2.5_DS_Rev0.2.pdf](http://www.sandisk.com/Assets/File/pdf/industrial/SanDisk_SSD_SATA_5000_2.5_DS_Rev0.2.pdf)
USB flash drive

- NAND flash memory with USB interface
- File system
  - most flash drives FAT or FAT 32

1. USB connector
2. USB mass storage controller device
3. Test points
4. Flash memory chip
5. Crystal oscillator
6. LED
7. Write-protect switch
8. Space for second flash memory chip

http://en.wikipedia.org/wiki/USB_flash_drive
Wear Levelling

- Techniques to prolong the lifetime of flash storage
  - Error-correcting codes
  - Pool of reserve spaces to redirect read/writes after failure
  - Blocks are tracked in a least recently used queue
    - microcontroller
    - minimizes the number of uses of each block
  - Copy-on-write
    - mark memory and copy it if the write actually occurs
- Special purpose file systems supporting it
  - JFFS (Journalling Flash File System Version 2)
  - YAFFS (Yet Another Flash File System)
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