Operating System: Chap12 Mass Storage System

National Tsing-Hua University

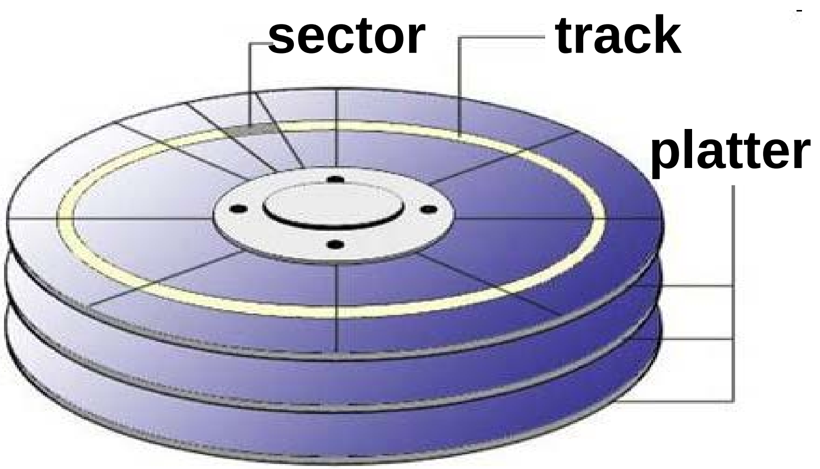
2016, Fall Semester

Overview

- Disk Structure
- Disk Scheduling
- Disk & Swap-Space Management
- RAID

Disk Structure

- Disk drives are addressed as large 1-dim arrays of logical blocks
  - logical block: smallest unit of transfer (**sector**)
- Logical blocks are mapped onto disk sequentially
  - Sector 0: 1st sector of 1st track on the outermost cyl.
  - go from outermost cylinder to innermost one

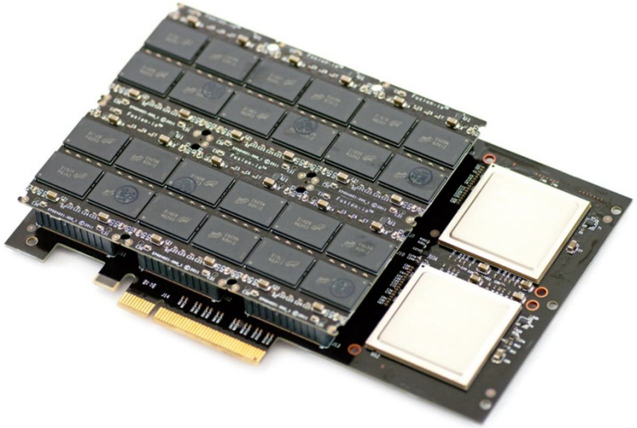


Sectors per Track

- **Constant linear velocity** (CLV)
  - density of bits per track is uniform
  - more sectors on a track in outer cylinders
  - keeping same data rate
    - ➔ increase rotation speed in inner cylinders
  - applications: CD-ROM and DVD-ROM
- **Constant angular velocity** (CAV)
  - keep same rotation speed
  - larger bit density on inner tracks
  - keep same data rate
  - applications: hard disks

Disk IO

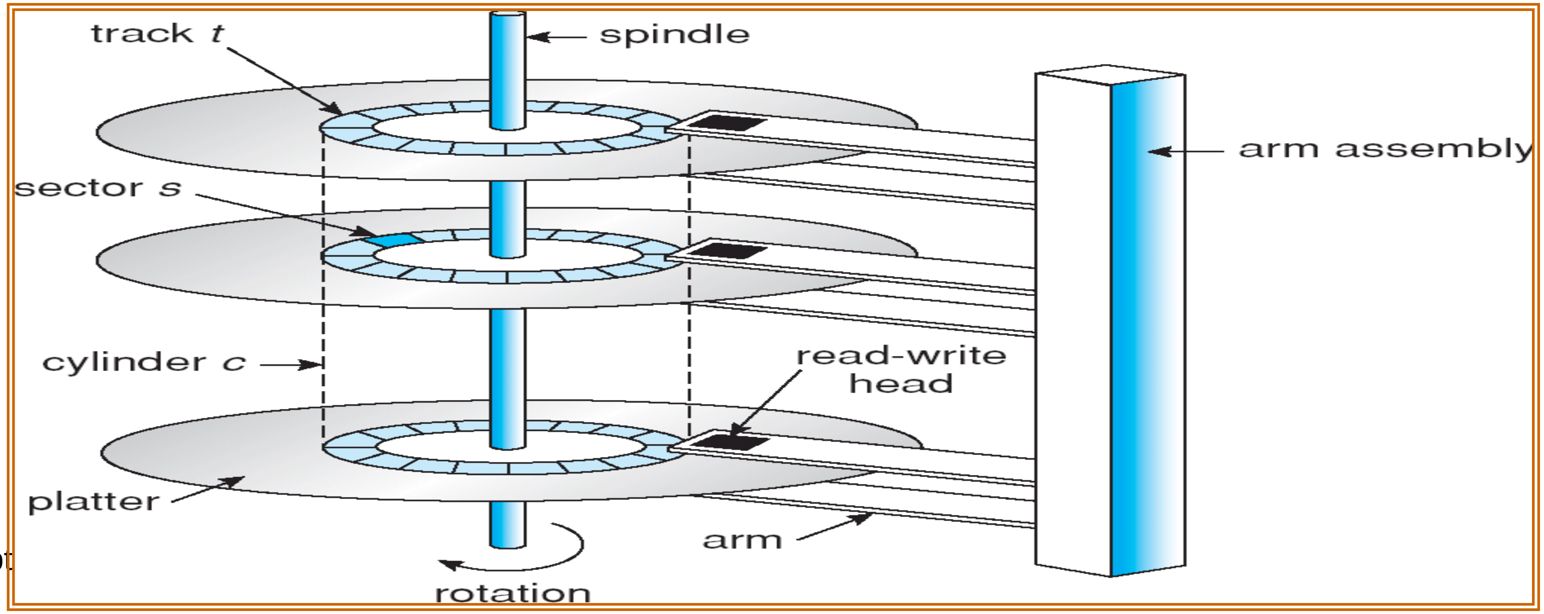
- Disk drive attached to a computer by an I/O bus
  - EIDE, ATA, SATA (Serial ATA), USB, SCSI, etc
  - I/O bus is controlled by controller
    - **Host** controller (computer end)
    - **Disk** controller (built into disk drive)



Disk Scheduling

Introduction

- Disk-access time has 3 major components
  - **seek time**: move disk arm to the desired **cylinder**
  - **rotational latency**: rotate disk head to the desired **sector**
  - **read time**: content **transfer time**
- Disk bandwidth:
  - # of bytes transferred/(complete of last req – start of first req)



Disk Scheduling

- Minimize seek time
  - Seek time ≈ seek distance
- Several algorithms exist to schedule the servicing of disk I/O requests
  - **FCFS** (first-come, first-served)
  - **SSTF** (shortest-seek-time-first)
  - **SCAN**
  - **C-SCAN** (circular SCAN)
  - **LOOK and C-LOOK**

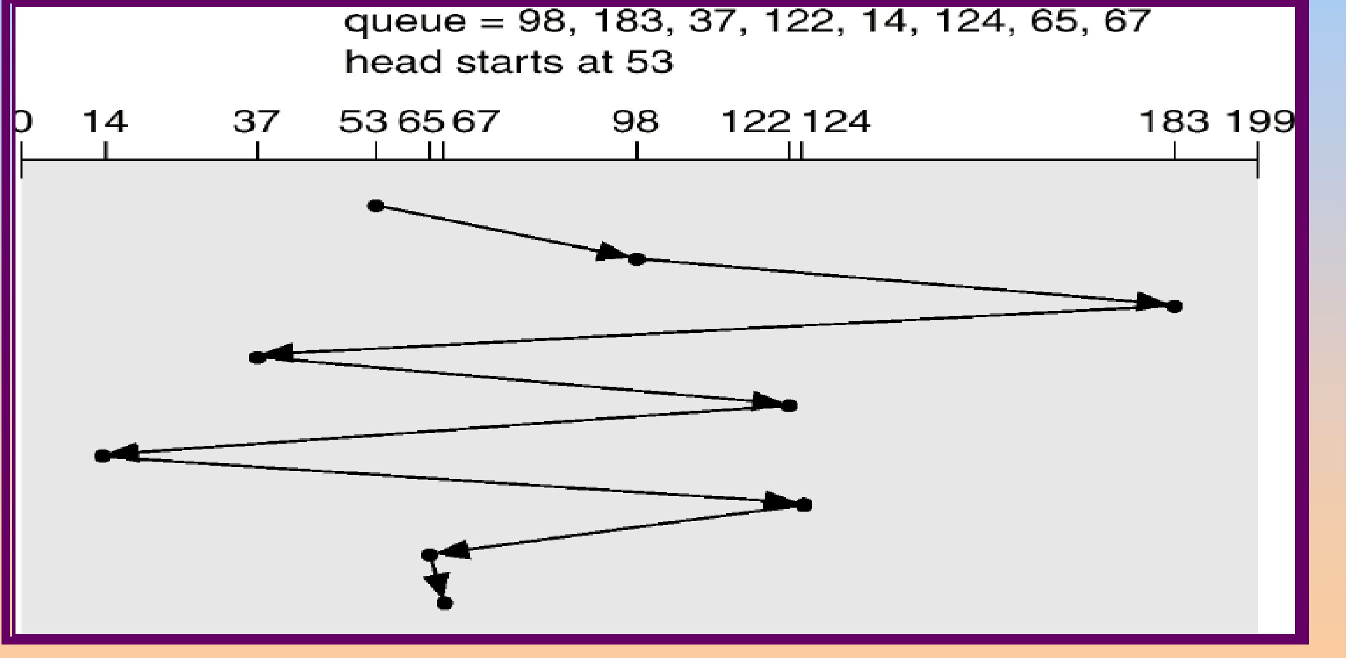
FCFS (First-Come-Frist-Served)

- We illustrate them with a request queue (0-199)

  98, 183, 37, 122, 14, 124, 65, 67

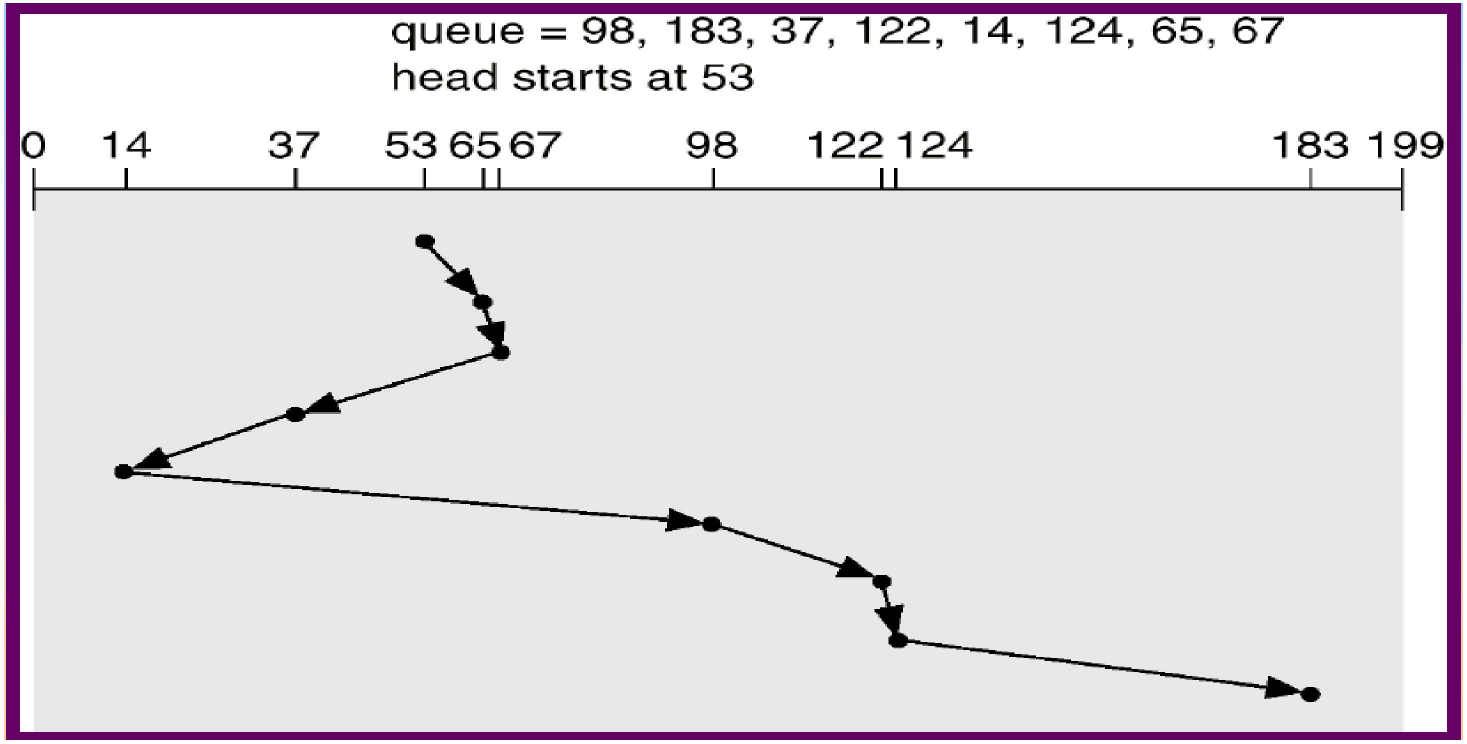
  Head pointer 53

Illustration shows total head movement of 640 cylinders.



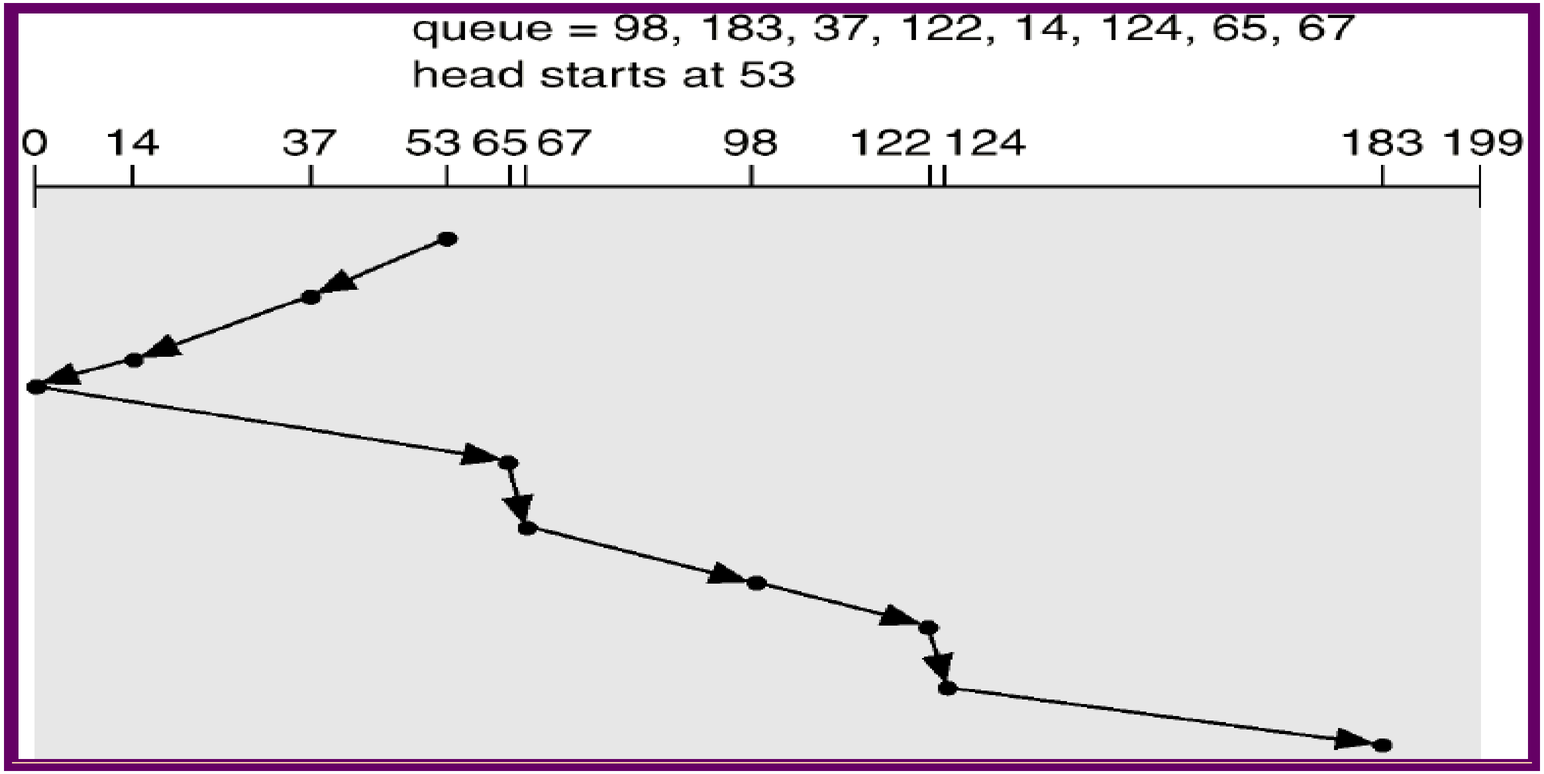
SSTF (Shortest-Seek-Time-First)

- SSTF scheduling is a form of SJF scheduling; may cause starvation of some requests
- total head movement: 236 cylinders



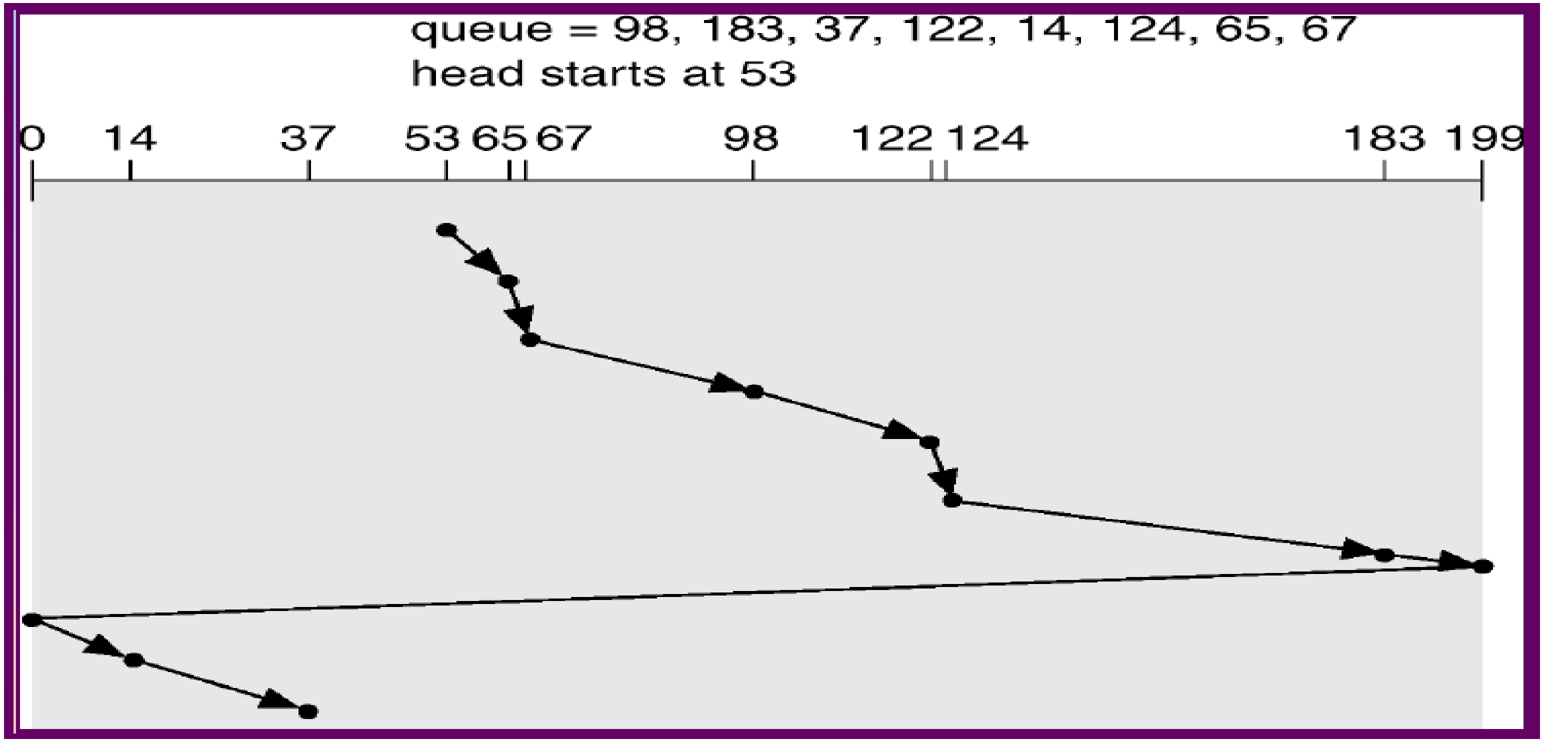
SCAN Scheduling

- disk head move from one end to the other end
- A.k.a. elevator algorithm
- total head movement: 236 cylinders



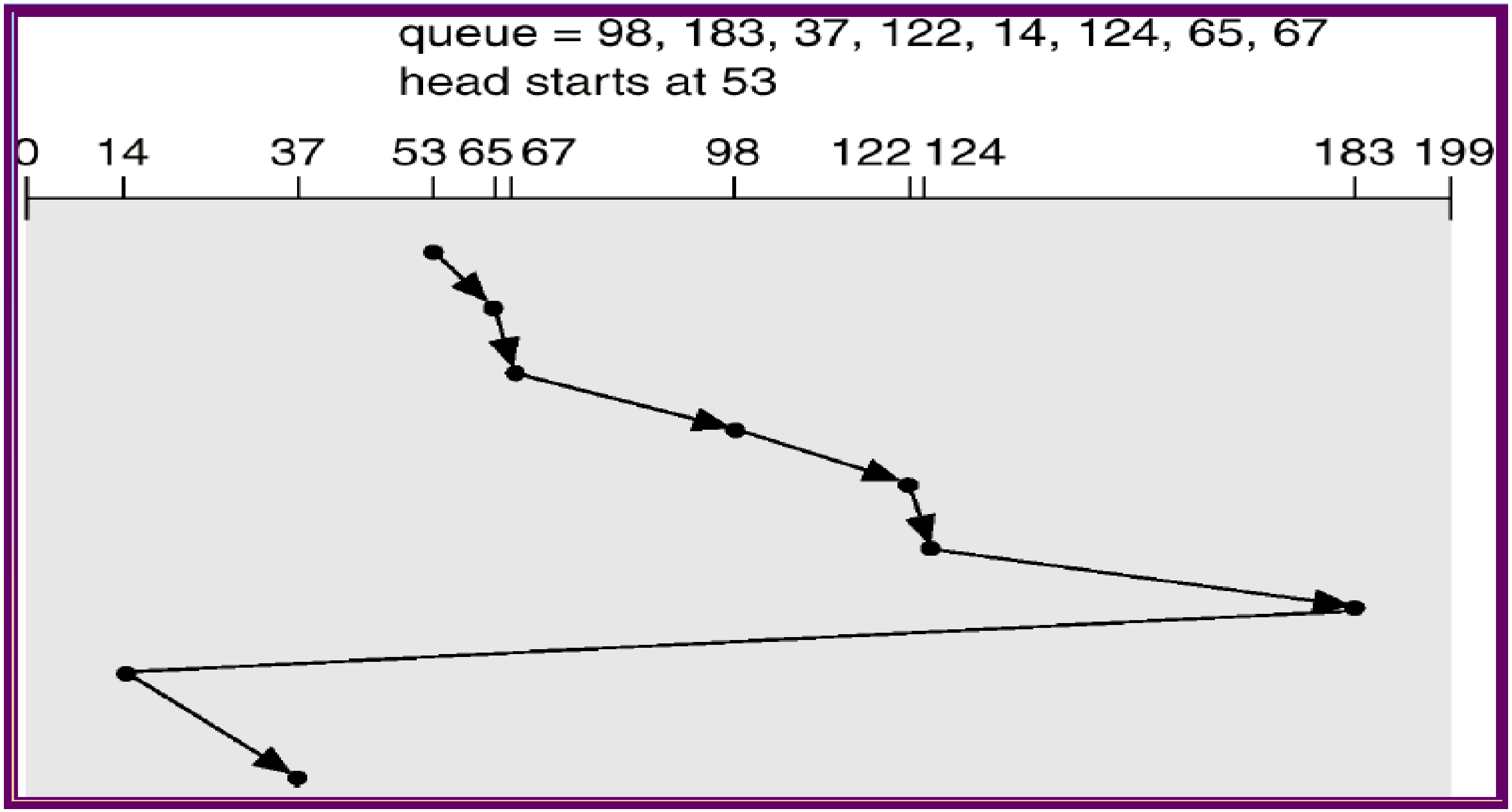
C-SCAN Scheduling

- Disk head move in one direction only
- A variant of SCAN to provide more uniform wait time



C-LOOK Scheduling

- version of C-SCAN
- Disk head moves only to the last request location



Selecting Disk-Scheduling Algorithm

- SSTF
  - common and has a natural appeal, but not optimal
- SCAN
  - perform better for disks with heavy load
  - **No** starvation problem
- C-SCAN
  - More uniform wait time
- Performance is also influenced by the file-allocation method
  - Contiguous: less head movement
  - Indexed & linked: greater head movement

Review Slides (I)

- 3 major components in disk-access time
  - Seek
  - Rotation
  - Read
- Goal of disk-scheduling algorithm?
- Disk-scheduling algorithms
  - FCFS
  - SSTF
  - SCAN
  - C-SCAN
  - C-LOOK

Disk Management

- Formatting
- Booting
- Bad block
- Swap space

Disk Formatting

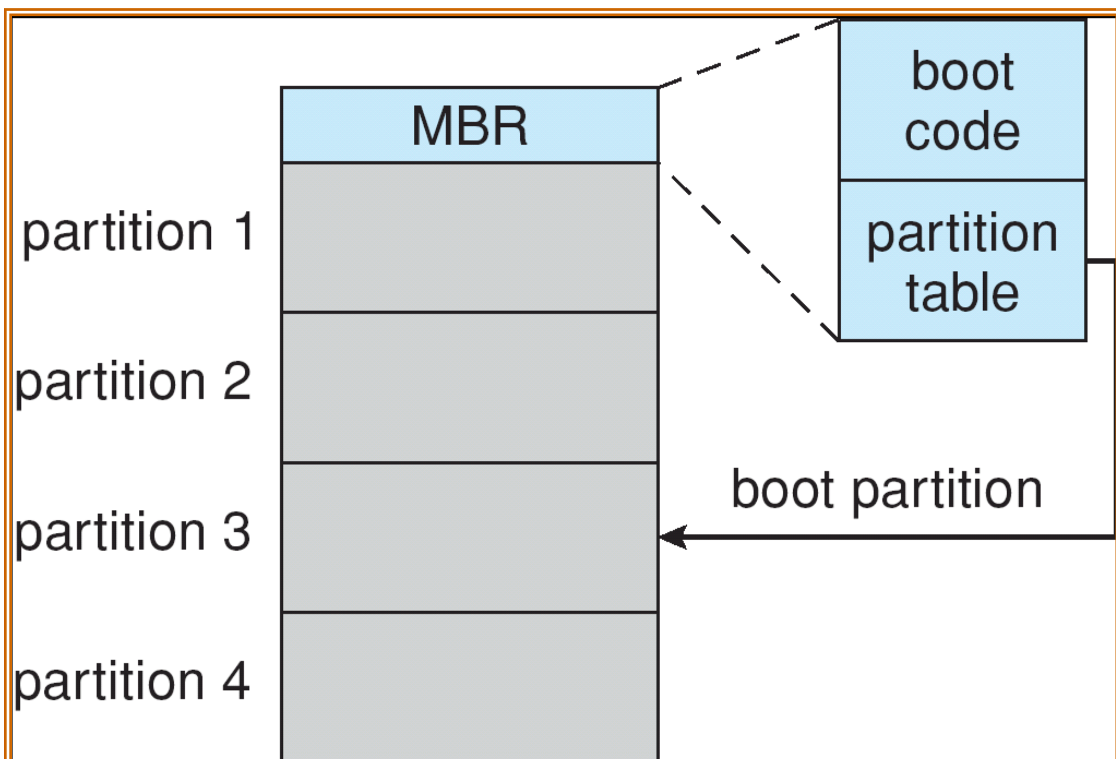
- Low-level formatting (or physical formatting): dividing a disk (magnetic recording material) into sectors that disk controller can read and write
  - each sector = header + data area + trailer
    - header & trailer: sector # and ECC (error-correcting code)
    - ECC is calculated based on all bytes in data area
    - data area size: 512B, 1KB, 4KB
- OS does the next 2 steps to use the disk
  - partition the disk into one or more groups of cylinders
  - logical formatting (i.e. creation of a file system)

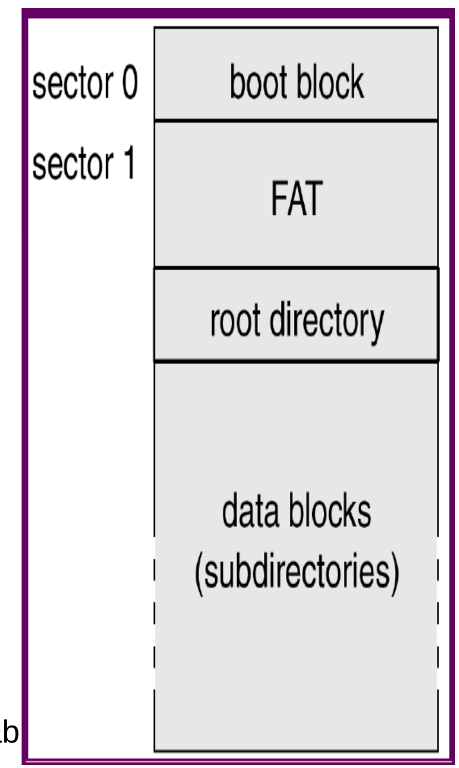
Boot Block

- Bootstrap program
  - Initialize CPU, registers, device controllers, memory, and then starts OS
  - First **bootstrap code** stored in ROM
  - Complete bootstrap in the **boot block** of the boot disk (aka system disk)

Booting from a Disk in Windows 2000

1. Run bootstrap code in ROM
2. Read boot code in MBR(Master boot record)
3. Find boot partition from partition table
4. Read boot sector/block and continue booting





Bad Blocks

- Simple disks like IDE disks
  - Manually use format program to mark the corresponding FAT entry of the bad block
  - Bad blocks are locked away from allocation
- Sophisticated disks like SCSI disks
  - disk controllers maintains the list of bad blocks
  - List is updated over the life of the disk
- **Sector sparing** (forwarding): remap bad block to a spare one
  - Could affect disk-scheduling performance
  - A few spare sectors in each cylinder during formatting
- **Sector slipping**: ships sectors all down one spot

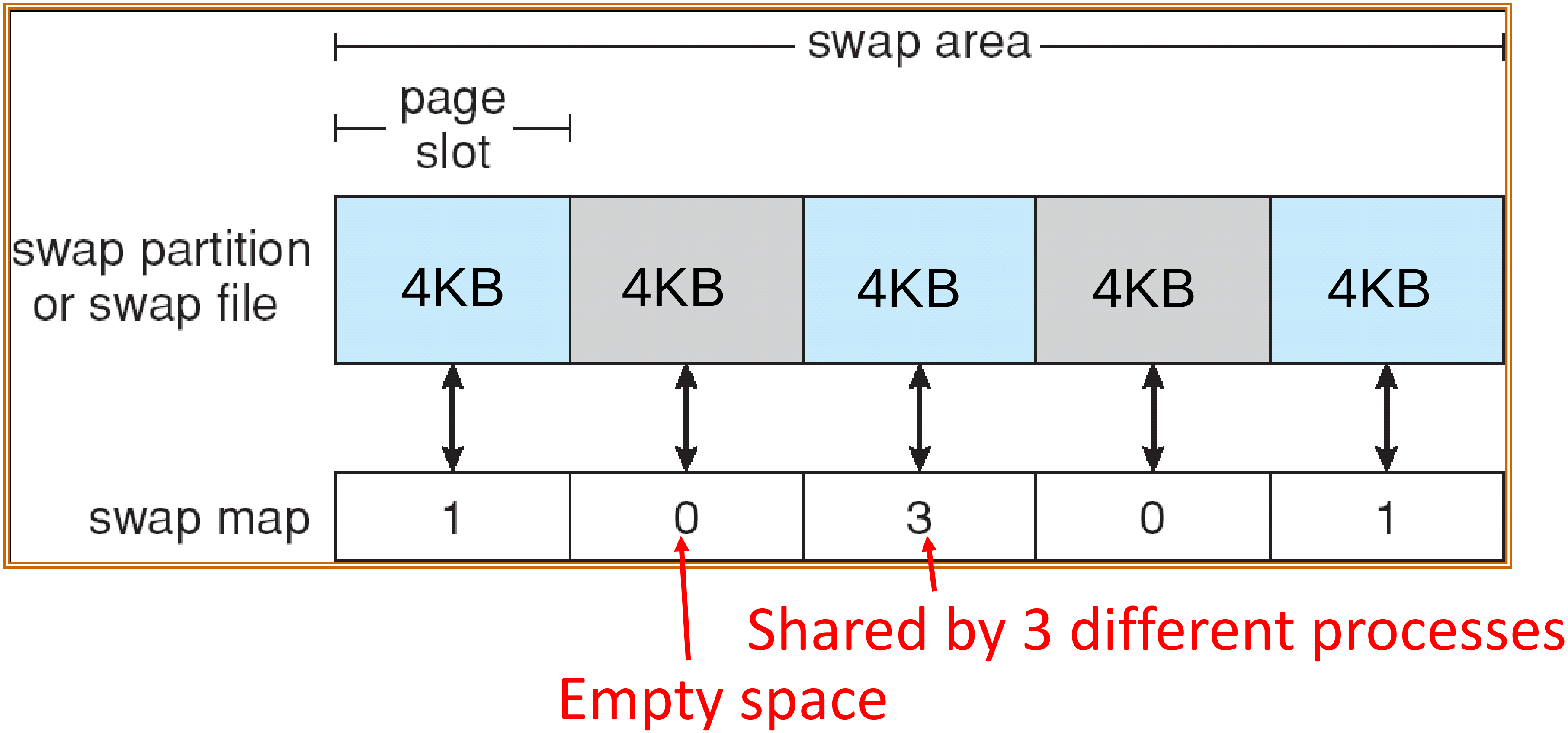
Swap-Space Management

- Swap-space: virtual memory use disk space (swap-space) as an extension of main mem
- UNIX: allows use of multiple swap spaces
- Location
  - part of a normal file system (e.g. NT)
    - Less efficient
  - separate disk partition (raw partition)
    - Size is fixed
  - allows access to both types (e.g. Linux)

Swap Space Allocation

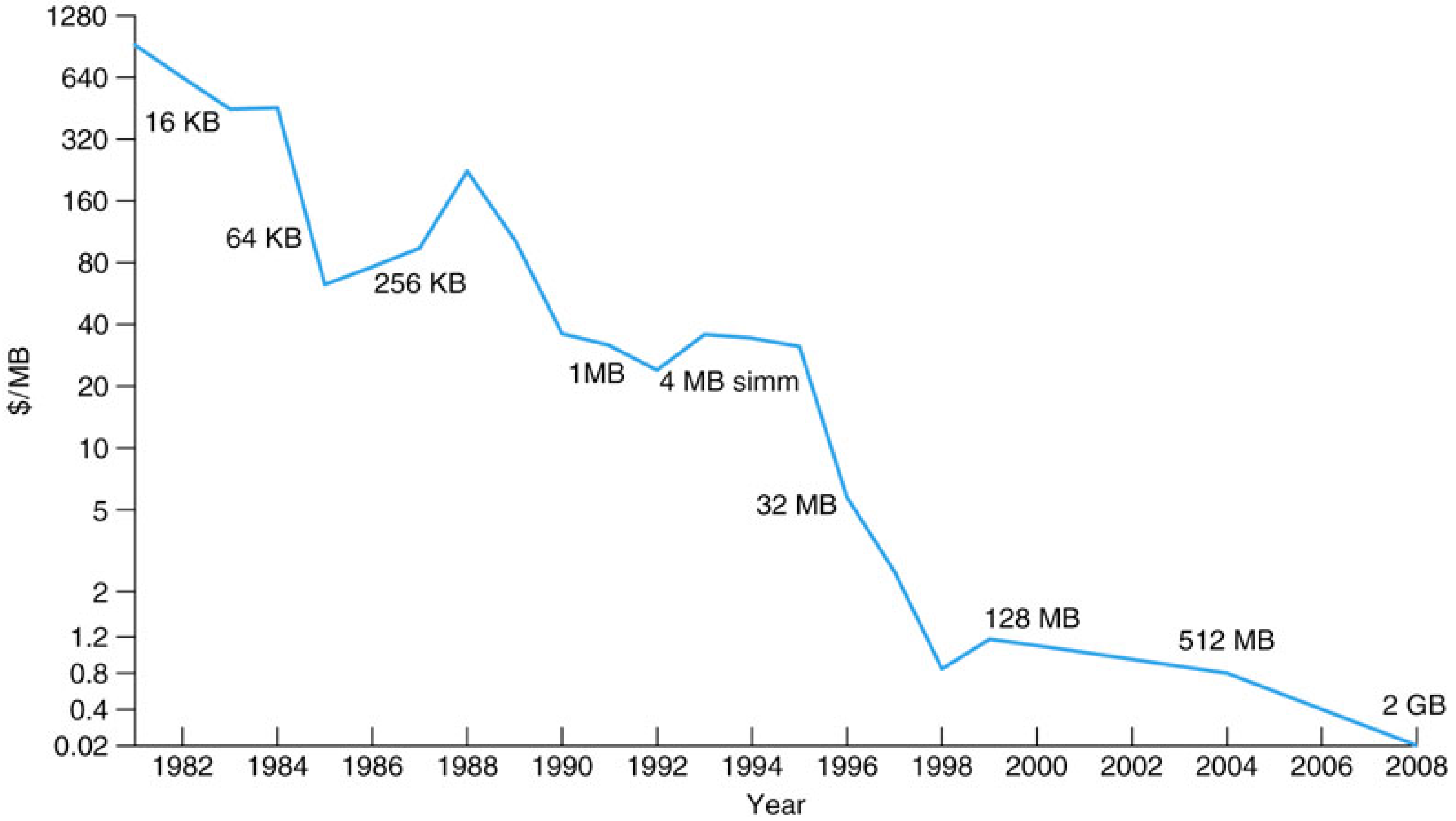
- 1st version: copy entire process between contiguous disk regions and memory
- 2nd version: copy pages to swap space
  - Solaris 1:
    - **text segments** read from file system, thrown away when pageout
    - Only **anonymous memory** (stack, heap, etc) store in swap space
  - Solaris 2:
    - swap-space allocation only when **pageout** rather than **virtual memory creation time**

Data Structures for Swapping (Linux)

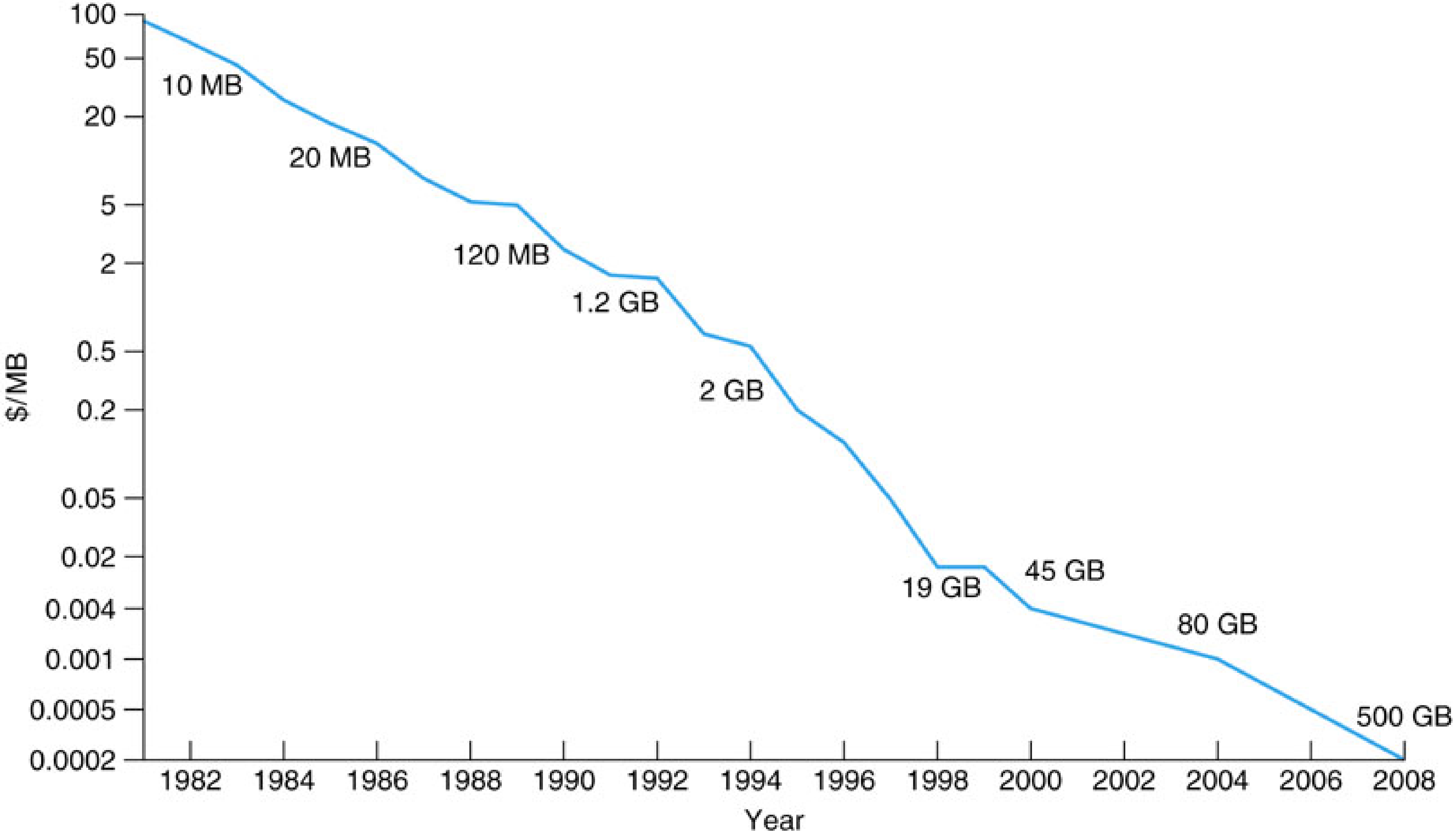


RAID Structure

DRAM Price (1981 – 2008)



Magnetic Hard Disk Price (1981 – 2008)

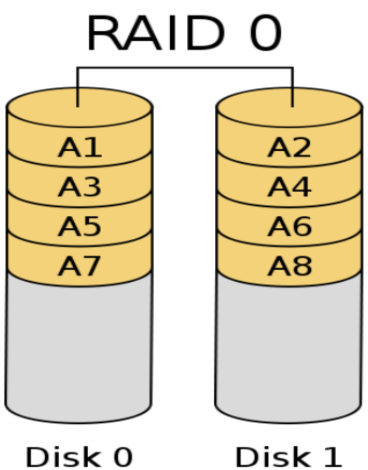


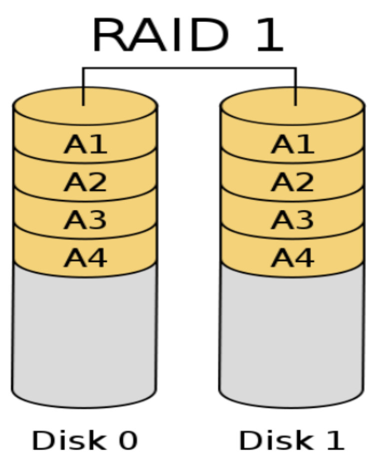
RAID Disks

- **RAID** = **R**edundant **A**rrays of **I**nexpensive **D**isks
  - provide **reliability** via **redundancy**
  - improve **performance** via **parallelism**
- RAID is arranged into different levels
  - Striping
  - Mirror (Replication)
  - Error-correcting code (ECC) & Parity bit

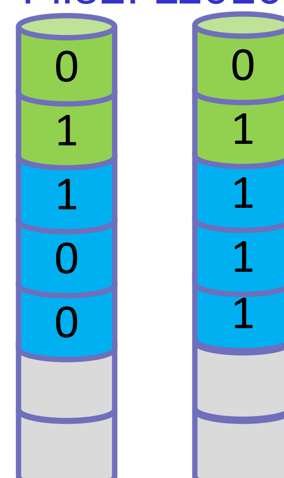
RAID 0 & RAID 1

- RAID 0: non-redundant **striping**
  - Improve **performance** via **parallelism**
  - I/O bandwidth is proportional to the striping count
    - **Both read and write BW increase by N times (N is the number of disks)**
- RAID 1: **Mirrored** disks
  - Provide **reliability** via **redundancy**
    - **Read BW increases by N times**
    - **Write BW remains the same**

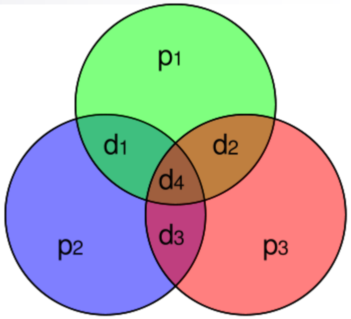


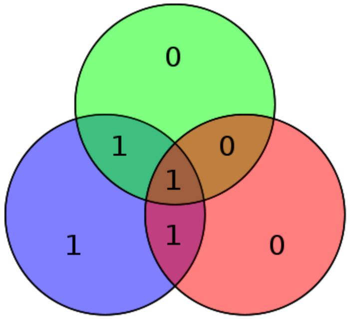


RAID0 Example
File1: 0011
File2: 110101



RAID 2: Hamming code

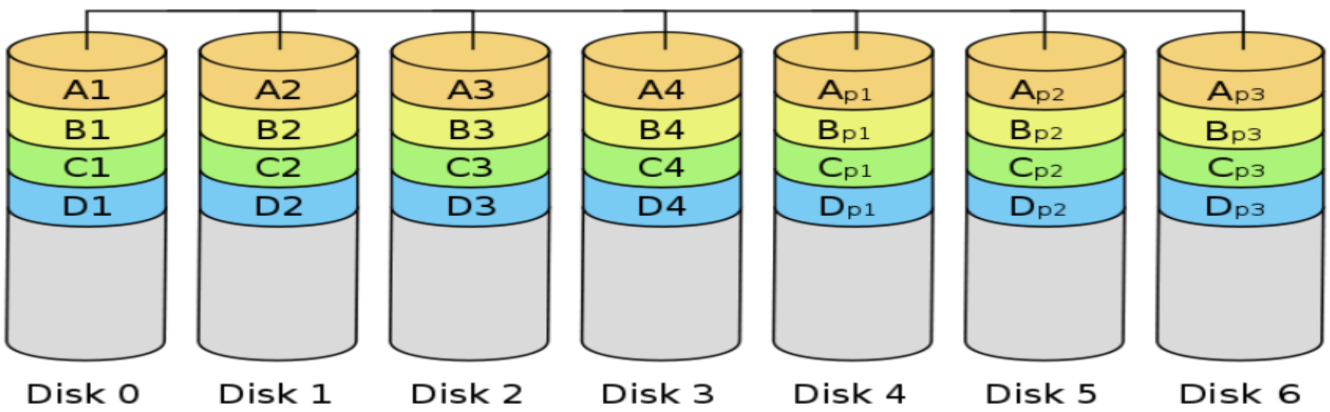




- E.g.: Hamming code(7,4)
  - 4 data bits (on 4 disks) + 3 parity bits (on 3 disks)
  - Each parity bit is linear code of 3 data bits

☺Recover from any single disk failure
  - Can detect up to two disks(i.e. bits) error
  - But can only “correct” one bit error

☺Better space efficient than RAID1 (75% overhead)



Hamming code reference: http://en.wikipedia.org/wiki/Hamming_code

RAID 3 & 4: Parity Bit

- Disk controller can detect whether a sector has been read correctly

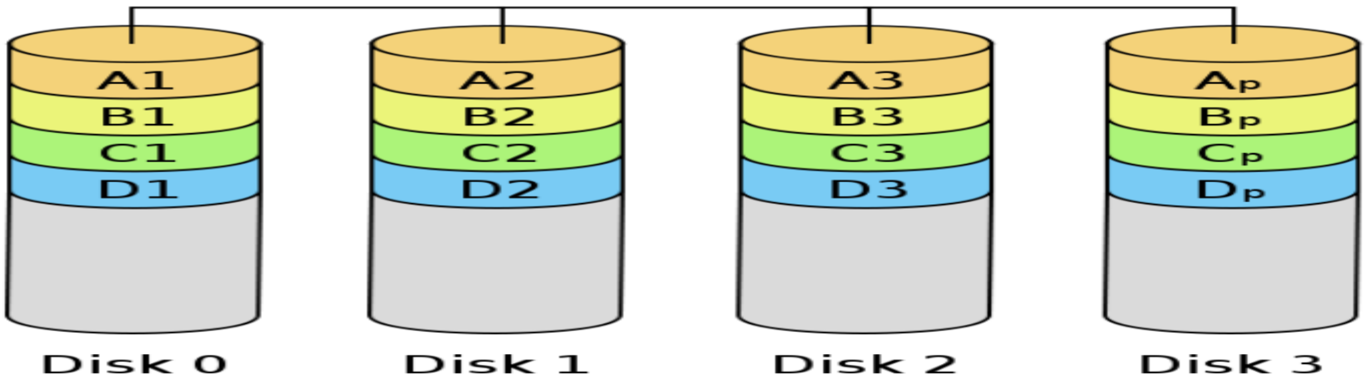
➔ a single parity bit is enough to correct error from a single disk failure

- **RAID 3**: Bit-level striping; **RAID 4**: Block-level striping

☺ Even better space efficiency (33% overhead)

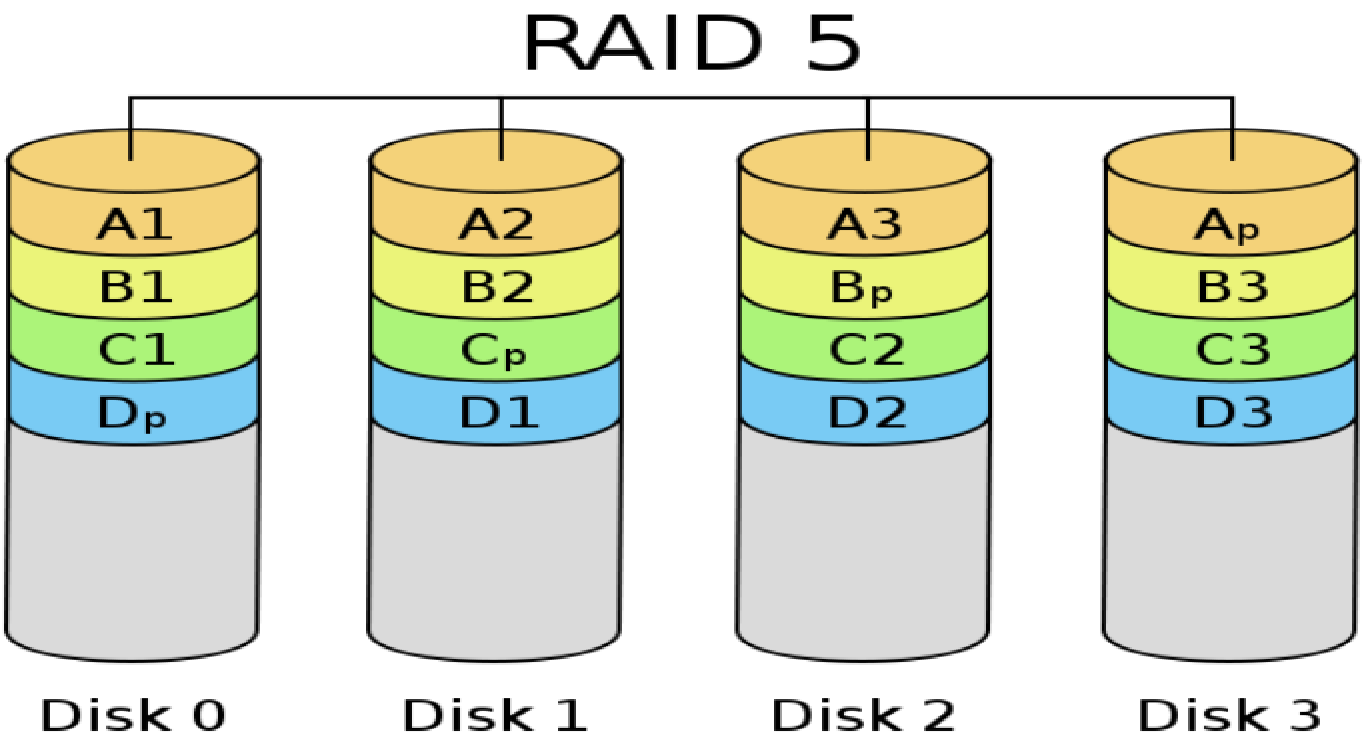
☹ Cost to compute & store parity bit

- RAID4 has higher I/O throughput, because controller does not need to reconstruct block from multiple disks



RAID 5: Distributed Parity

- Spread data & parity across all disks
- Prevent over use of a single disk (e.g. RAID 3,4)

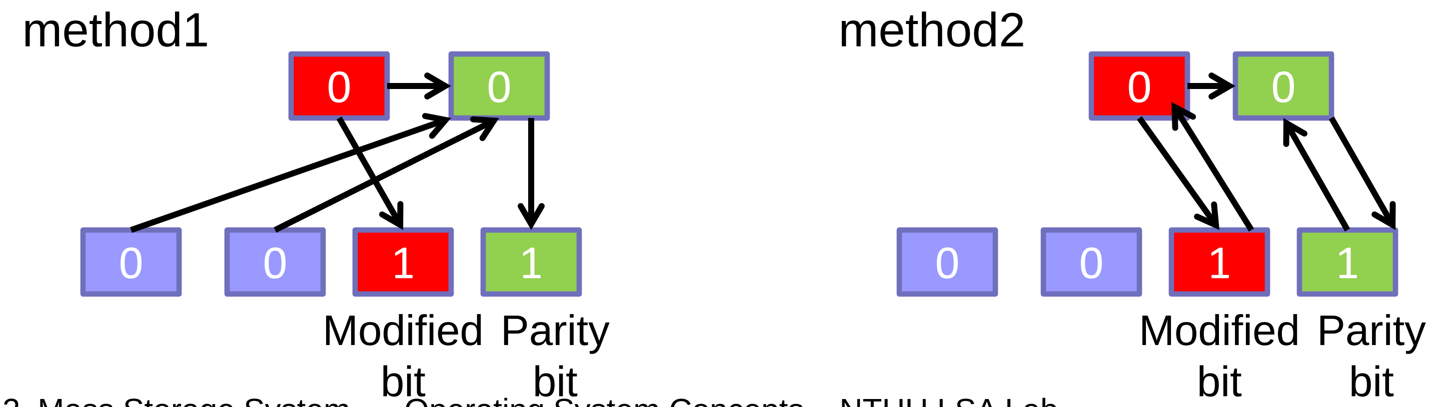


RAID 5: Distributed Parity

- Read BW increases by N times, because all four disks can serve a read request
- Write BW
  - Method1: (1)read out all unmodified (N-2) data bits. (2) re-compute parity bit. (3) write both modified bit and parity bit to disks.

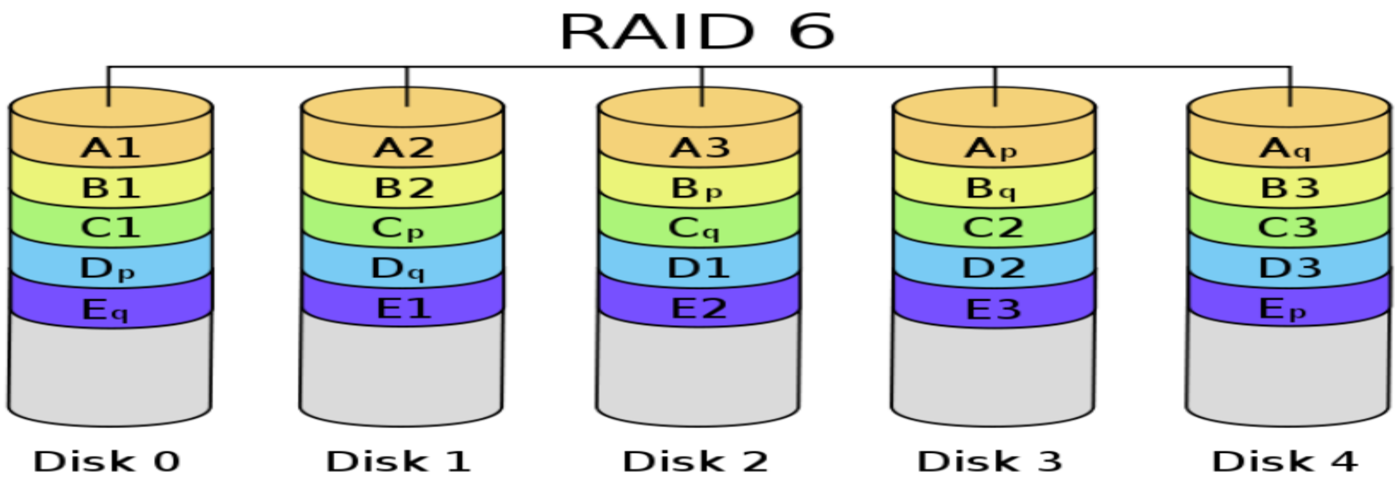
  ➔ write BW = N / ((N-2)+2) = 1 ➔ remains the same
  - Method2: (1)only read the parity bit and modified bit. (2) re-compute parity bit by the difference. (3) write both modified bit and parity bit.

  ➔ write BW = N / (2+2) = N/4 times faster



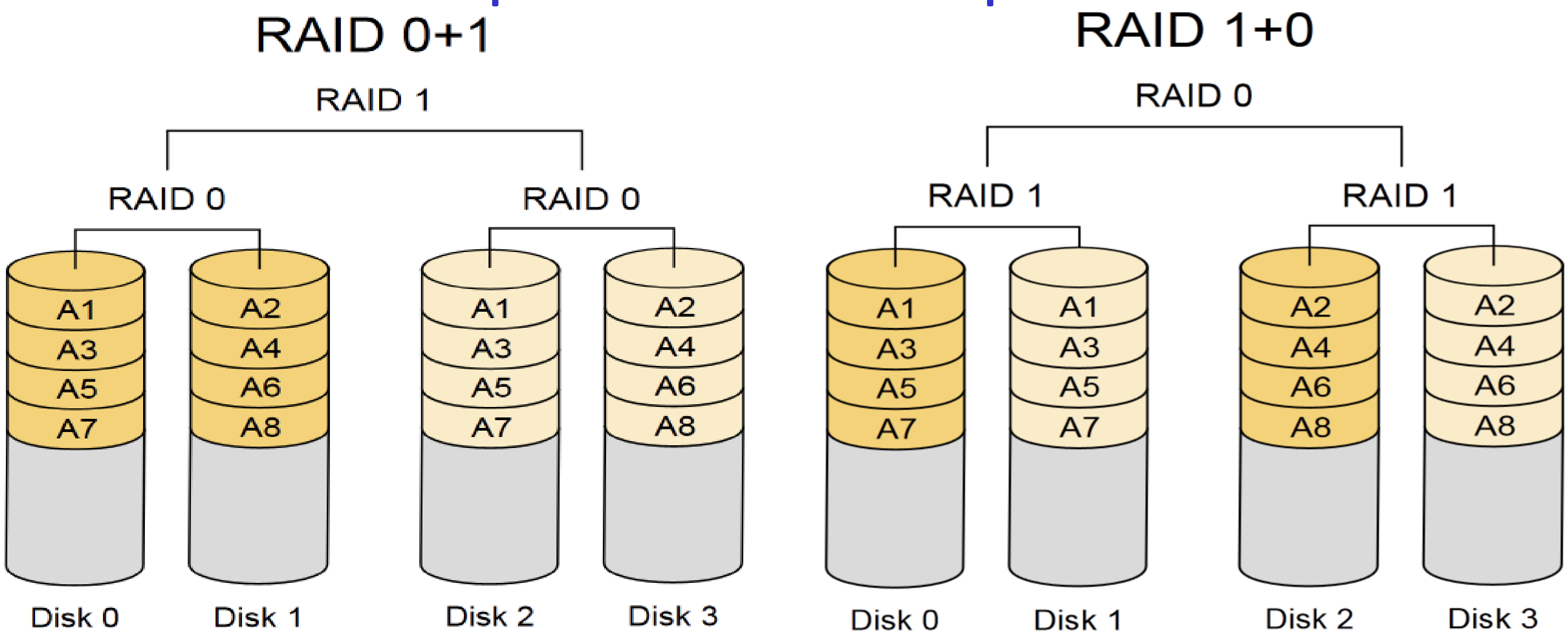
RAID 6: P+Q Dual Parity Redundancy

- Like RAID 5, but stores extra redundant information to guard against **multiple disk failure**
- Use ECE code (i.e. Error Correction Code) instead of single parity bit
- Parity bits are also striped across disks



Hybrid RAID

- RAID 0+1: Stripe then replicate
- RAID 1+0: Replicate then stripe



*First level often control by a controller. Therefore, RAID 10 has better fault tolerance than RAID 01 when multiple disk fails

http://www.thegeekstuff.com/2011/10/raid10-vs-raid01/

Review Slides (II)

- Swap space using FS? Raw partition?
- How to reduce swap space usage?
- RAID disks? Purpose?
- RAID-0~6?
- RAID 0+1, RAID 1+0

Reading Material & HW

- Chapter 12
- Problem Set
  - 12.1
  - 12.3
  - 12.8

Sector Sparing Example

- OS tries to read block 87
- controller finds out 87 is bad block, reports to OS
- next time system rebooted, controller replaces the bad block with a spare
- OS requests block 87 again, controller reads the spare block instead