0117401: Operating System
计算机原理与设计
Chapter 12: Mass-Storage structure（外存）

陈香兰
xlanchen@ustc.edu.cn
http://staff.ustc.edu.cn/~xlanchen

Computer Application Laboratory, CS, USTC @ Hefei
Embedded System Laboratory, CS, USTC @ Suzhou

May 25, 2016

温馨提示：

为了您和他人的工作学习，
请在课堂上关机或静音。

不要在课堂上接打电话。

提纲

1. Overview of Mass Storage Structure
2. Disk Structure
3. Disk Scheduling（磁盘调度）
4. Disk Management
5. Swap-Space Management
6. RAID（磁盘阵列）Structure
7. 小结和作业

Outline

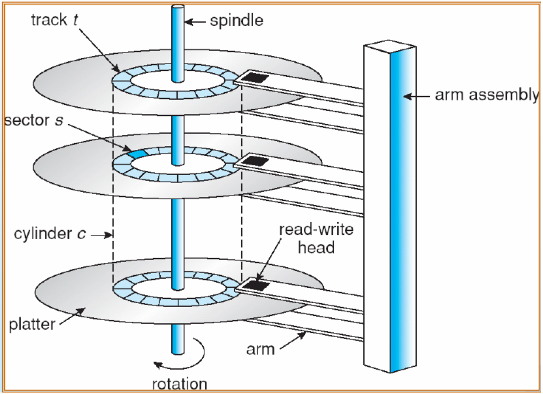
1 Overview of Mass Storage Structure

Overview of Mass Storage Structure

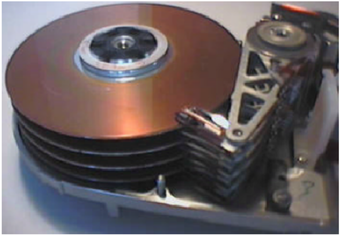
- Magnetic disks (磁盘) provide bulk of secondary storage of modern computers
  - Drives rotate at 60 to 200 times per second
  - Transfer rate (传输速率) is rate at which data flow between drive and computer
  - Positioning time (random-access time) is time to move disk arm to desired cylinder (seek time) and time for desired sector to rotate under the disk head (rotational latency)
  - Head crash results from disk head making contact with the disk surface
    - That's bad
- Disks can be removable

Overview of Mass Storage Structure

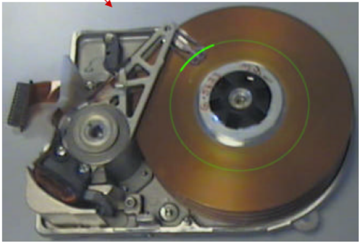
- Drive attached to computer via I/O bus
  - Busses vary, including EIDE, ATA, SATA, USB, Fibre Channel, SCSI
  - Host controller in computer uses bus to talk to disk controller built into drive or storage array



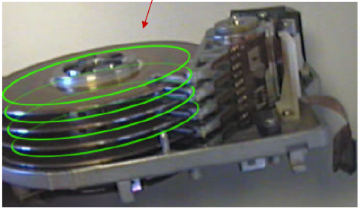
Overview of Mass Storage Structure



sector



cylinder



Overview of Mass Storage Structure

- Magnetic tape (磁带)
  - An early secondary-storage medium
  - Relatively permanent and holds large quantities of data
  - Access time slow
    - Random access ~1000 times slower than disk
  - Mainly used for backup, storage of infrequently-used data, transfer medium between systems
  - Kept in spool and wound or rewound past read-write head
  - Once data under head, transfer rates comparable to disk
  - 20-200GB typical storage
  - Common technologies are 4mm, 8mm, 19mm, LTO-2 and SDLT Oper

Outline

2 Disk Structure

Disk Structure

- Disk drives are addressed as large 1-D arrays of logical blocks,
    - The logical block is the smallest unit of transfer.
    - Usually, 512B
- The 1-D array of logical blocks is mapped into the sectors of the disk sequentially.
    - Cylinder: track: sector
    - Sector 0 is the first sector of the first track on the outermost cylinder.
    - Mapping proceeds in order through that track, then the rest of the tracks in that cylinder, and then through the rest of the cylinders from outermost to innermost.
    - However, in practise, the mapping is difficult, because
        1. Defective sectors
        2. Sectors/track $\neq$ constant
           $\Rightarrow$ zones of cylinder

Outline

3 Disk Scheduling (磁盘调度)

Disk Scheduling (磁盘调度)

- The OS is responsible for using hardware efficiently. For the disk drives, this means having a fast access time and disk bandwidth.
- Access time has two major components
  1. Seek time is the time for the disk to move the heads to the cylinder containing the desired sector.
     - Minimize seek time
     - Seek time ≈ seek distance
  2. Rotational latency is the additional time waiting for the disk to rotate the desired sector to the disk head.
- Disk bandwidth (磁盘带宽) is the total number of bytes transferred, divided by the total time between the first request for service and the completion of the last transfer.

Disk Scheduling (磁盘调度)

- Request queue (请求队列)
  - empty or not
- How?

  Several algorithms exist to schedule the servicing of disk I/O requests.

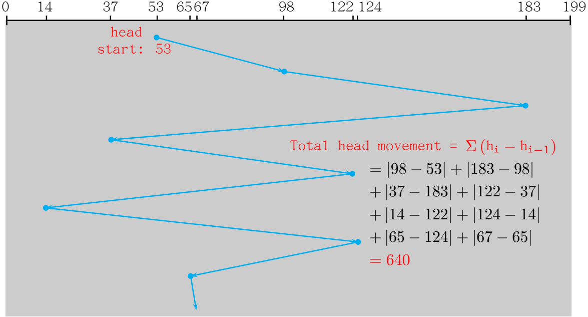
  1. FCFS
  2. SSTF (shortest-seek-time-first)
  3. SCAN (elevator algorithm)
  4. C-SCAN
  5. C-LOOK
- We illustrate them with a request queue (0-199).

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

  Head points to 53 initially

Disk Scheduling (磁盘调度)

1. First Come, First Served (FCFS, 先来先服务)
   - The simplest form of scheduling



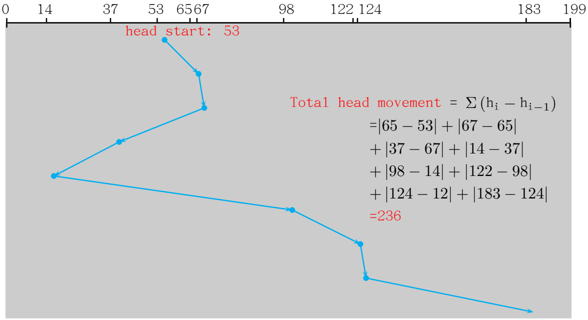
Total head movement = $\Sigma(h_i - h_{i-1})$

$$= |98-53| + |183-98| + |37-183| + |122-37| + |14-122| + |124-14| + |65-124| + |67-65| = 640$$

request queue = 98, 183, 37, 122, 14, 124, 65, 67

Disk Scheduling (磁盘调度)

2. SSTF (shortest-seek-time-first)
   - Selects the request with the **minimum seek time** from the current head position.



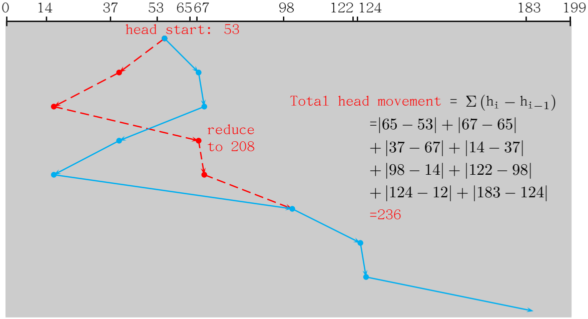
$$\text{Total head movement} = \Sigma(h_i - h_{i-1})$$
$$= |65-53| + |67-65|$$
$$+ |37-67| + |14-37|$$
$$+ |98-14| + |122-98|$$
$$+ |124-12| + |183-124|$$
$$= 236$$

request queue = 98, 183, 37, 122, 14, 124, 65, 67

- SSTF≈SJF : **starvation**

Disk Scheduling (磁盘调度)

2. SSTF (shortest-seek-time-first)
   - Selects the request with the **minimum seek time** from the current head position.



Total head movement = $\Sigma(h_i - h_{i-1})$

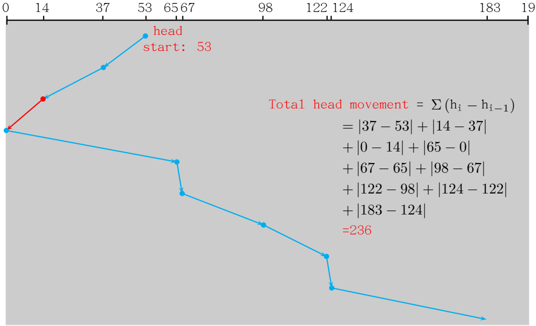
$=|65-53|+|67-65|$
$+|37-67|+|14-37|$
$+|98-14|+|122-98|$
$+|124-12|+|183-124|$
$=236$

request queue = 98, 183, 37, 122, 14, 124, 65, 67

- SSTF≈SJF : **starvation**
- Optimal?

Disk Scheduling（磁盘调度）

3. SCAN (elevator algorithm)
   - The disk arm **starts at one end of the disk, and moves toward the other end**, servicing requests until it gets to the other end of the disk, where the head movement is reversed and servicing continues.



Total head movement $= \Sigma(h_i - h_{i-1})$

$$= |37-53| + |14-37| + |0-14| + |65-0| + |67-65| + |98-67| + |122-98| + |124-122| + |183-124|$$

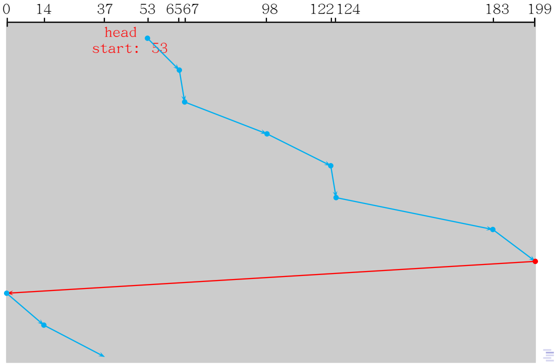
$$=236$$

request queue = 98, 183, 37, 122, 14, 124, 65, 67

- **Waiting time**: Maximum is ?

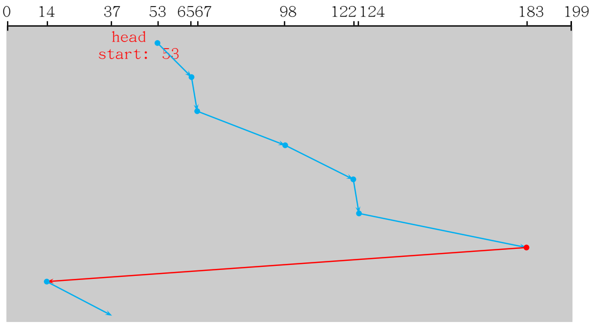
Disk Scheduling (磁盘调度)

4. C-SCAN: Provides a more uniform wait time than SCAN.
   - The head moves from one end of the disk to the other, servicing requests as it goes. When it reaches the other end, however, it immediately returns to the beginning of the disk, without servicing any requests on the return trip.
   - Treats the cylinders as a circular list



Disk Scheduling (磁盘调度)

5. C-LOOK
   - Version of C-SCAN
   - Arm only goes as far as the last request in each direction, then reverses direction immediately, without first going all the way to the end of the disk.



request queue = 98, 183, 37, 122, 14, 124, 65, 67

Selecting a Disk-Scheduling Algorithm

- SSTF is common and has a natural appeal
- SCAN and C-SCAN perform better for systems that place a heavy load on the disk.
- Performance depends on

  the number and types of requests, which can be influenced by

  1. The file-allocation method
  2. The location of directories and index blocks (caching?)

- Either SSTF or LOOK is a reasonable choice for the default algorithm.
- The disk-scheduling algorithm should be written as a separate module of the OS, allowing it to be replaced with a different algorithm if necessary.

Outline

4 Disk Management

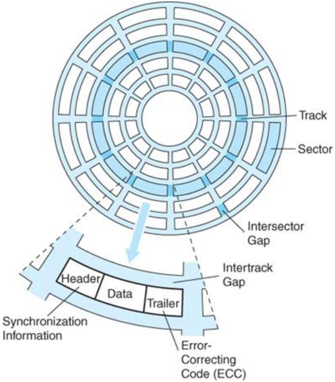
Disk Management

- Disk Formatting
- Boot Block
- Disk Failure

Disk Management

- Disk Formatting

1. Low-level formatting, or physical formatting
   Dividing a disk into sectors that the disk controller can read and write.

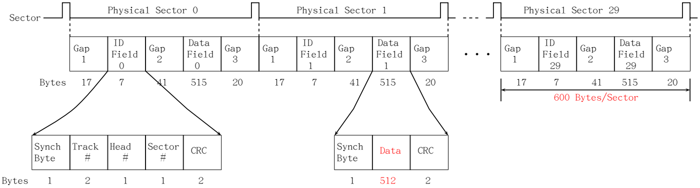


(From: http://tjliu.myweb.hinet.net/COA_CH_7.files/image055.jpg)

Disk Management

- Disk Formatting

  1. **Low-level formatting**, or **physical formatting**
     Dividing a disk into sectors that the disk controller can read and write.



Sector: Physical Sector 0, Physical Sector 1, . . . Physical Sector 29

	Gap 1	ID Field 0	Gap 2	Data Field 0	Gap 3	Gap 1	ID Field 1	Gap 2	Data Field 1	Gap 3	. . .	Gap 1	ID Field 29	Gap 2	Data Field 29	Gap 3
Bytes	17	7	41	515	20	17	7	41	515	20		17	7	41	515	20

600 Bytes/Sector

	Synch Byte	Track #	Head #	Sector #	CRC
Bytes	1	2	1	1	2

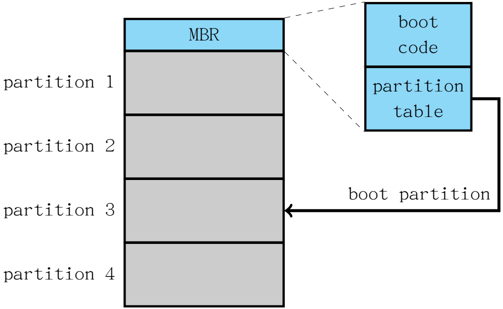
Synch Byte	Data	CRC
1	512	2

Disk Management

- Disk Formatting
  2. To use a disk to hold files, the OS still needs to record its own data structures on the disk.
     - Partition the disk into one or more groups of cylinders.
     - Logical formatting or "making a file system".
  3. To increase efficiency, most file-systems group blocks together into larger chunks, frequently called clusters

Disk Management

- Boot block
  - The (tiny) bootstrap is stored in ROM.
  - Mostly, the only job of bootstrap is to bring in a full bootstrap program from disk (boot disk, or system disk)
  - Master boot record (MBR, 主引导记录)
  - Boot partition (启动分区) & boot sector (启动扇区)



Booting from a Disk in Windows 2000

Disk Management

- Disk failure
  - Complete failure VS. only one or more sectors become defective, Bad blocks
  - The data stored in bad blocks are lost.
  - Methods towards bad blocks
    1. Manually: example, for MS-DOS, write a special value into FAT entry
    2. Sector sparing (备用)
       (1) OS tries to read logical block 87;
       (2) The controller calculates the ECC and finds that sector is bad. It reports this finding to OS.
       (3) When rebooting, a special command is run to tell the SCSI controller to replace the bad sector with a spare;
       (4) After that, whenever logical block 87 is requested, the request is translated into the replacement sector's address by the controller.
       Most disks are formatted to provide a few spare sectors in each cylinder and a spare cylinder as well.
    3. Sector slipping (滑动)

Disk Management

- Disk failure
  - Complete failure VS. only one or more sectors become defective, Bad blocks
  - The data stored in bad blocks are lost.
  - Methods towards bad blocks
    1. Manually: example, for MS-DOS, write a special value into FAT entry
    2. Sector sparing (备用)
    3. Sector slipping (滑动)

       Example:

       (1) Logical block 17 is bad

       (2) Logical blocks 18~202 are used, and 203 is available.

       (3) 202→203, 201→202, ..., 17→18

Outline

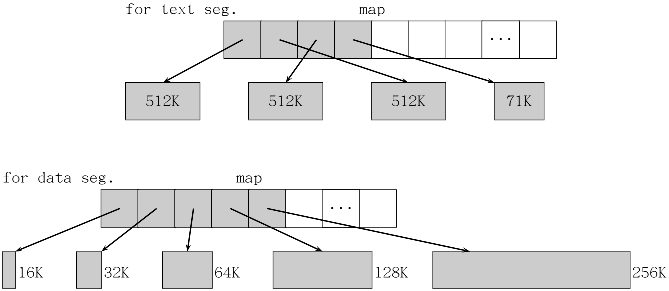
5 Swap-Space Management

Swap-Space Management

- Swapping & paging
  1. Entire processes
  2. Paging√
- Swap-space (对换空间)
  Virtual memory uses disk space as an extension of main memory.
  1. It can be carved out of the normal file system
     - A large file with the file system
  2. Or, more commonly, it can be in a separate disk partition.

Swap-Space Management

- Example1: 4.3BSD
  1. Allocates swap space when process starts;
  2. Holds text segment (the program) and data segment.
  3. Kernel uses swap maps to track swap-space use.

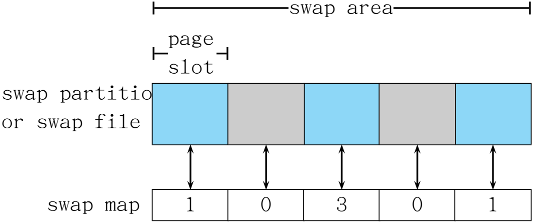


Swap-Space Management

- Example2: Sorlaris
  - Version1:
    For text segment, no use of swap space;
    Only used as a backing store for pages of anonymous memory, including memory allocated for stack, heap, uninitialized data
  - Version2:
    Allocates swap space only when a page is forced out of physical memory, not when the virtual memory page is first created.

Swap-Space Management

- Example3: Linux
  - Similar to Solaris1
  - Allows one or more swap areas with 4KB slots
  - Each swap area is associated with a swap map
    - 0: free; >0: occupied, sharing counts



Outline

6 RAID（磁盘阵列）Structure

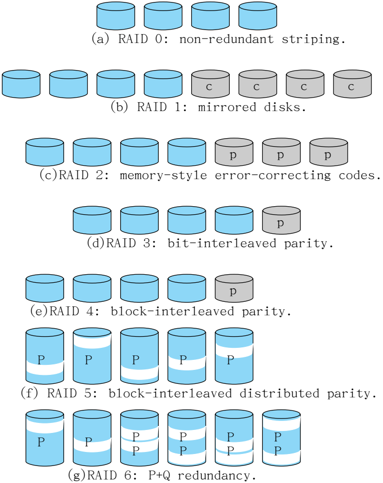
RAID（磁盘阵列）Structure

- Redundant arrays of inexpensive disks (RAIDs, 磁盘阵列) -- Multiple disk drives provides
  - reliability via redundancy
  - higher data-transfer rate
- RAID is arranged into six different levels.

RAID (cont)

- Several improvements in disk-use techniques involve the use of multiple disks working cooperatively.
- Disk striping uses a group of disks as one storage unit.
- RAID schemes improve performance and improve the reliability of the storage system by storing redundant data.
    - Mirroring or shadowing keeps duplicate of each disk.
    - Block interleaved parity uses much less redundancy.

RAID Levels



(a) RAID 0: non-redundant striping.

(b) RAID 1: mirrored disks.

(c)RAID 2: memory-style error-correcting codes.

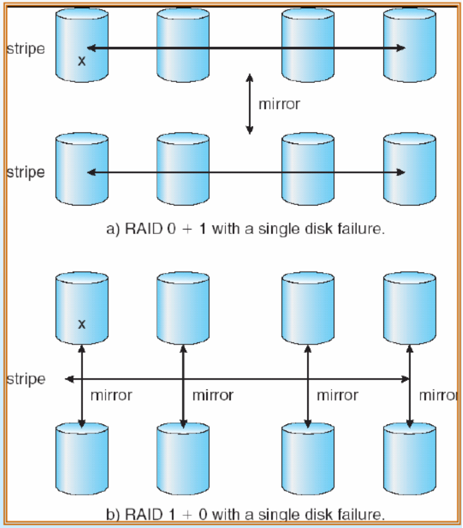
(d)RAID 3: bit-interleaved parity.

(e)RAID 4: block-interleaved parity.

(f) RAID 5: block-interleaved distributed parity.

(g)RAID 6: P+Q redundancy.

RAID (0 + 1) and (1 + 0)



a) RAID 0 + 1 with a single disk failure.

b) RAID 1 + 0 with a single disk failure.

Outline

7 小结和作业

小结

1. Overview of Mass Storage Structure
2. Disk Structure
3. Disk Scheduling（磁盘调度）
4. Disk Management
5. Swap-Space Management
6. RAID（磁盘阵列）Structure
7. 小结和作业

谢谢！