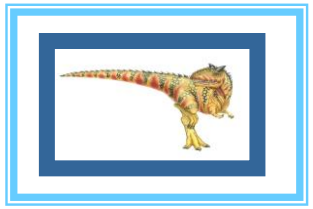
Chapter 12: Mass-Storage Systems

大容量存储系统



Chapter 12: Mass-Storage Systems

- 12.1 Overview of Mass Storage Structure
- 12.2 Disk Structure
- 12.3 Disk Attachment
- 12.4 Disk Scheduling
- 12.5 Disk Management
- 12.6 Swap-Space Management
- 12.7 RAID Structure
- 12.8 Stable-Storage Implementation
- 12.9 Tertiary Storage Devices
- 12.10 Summary

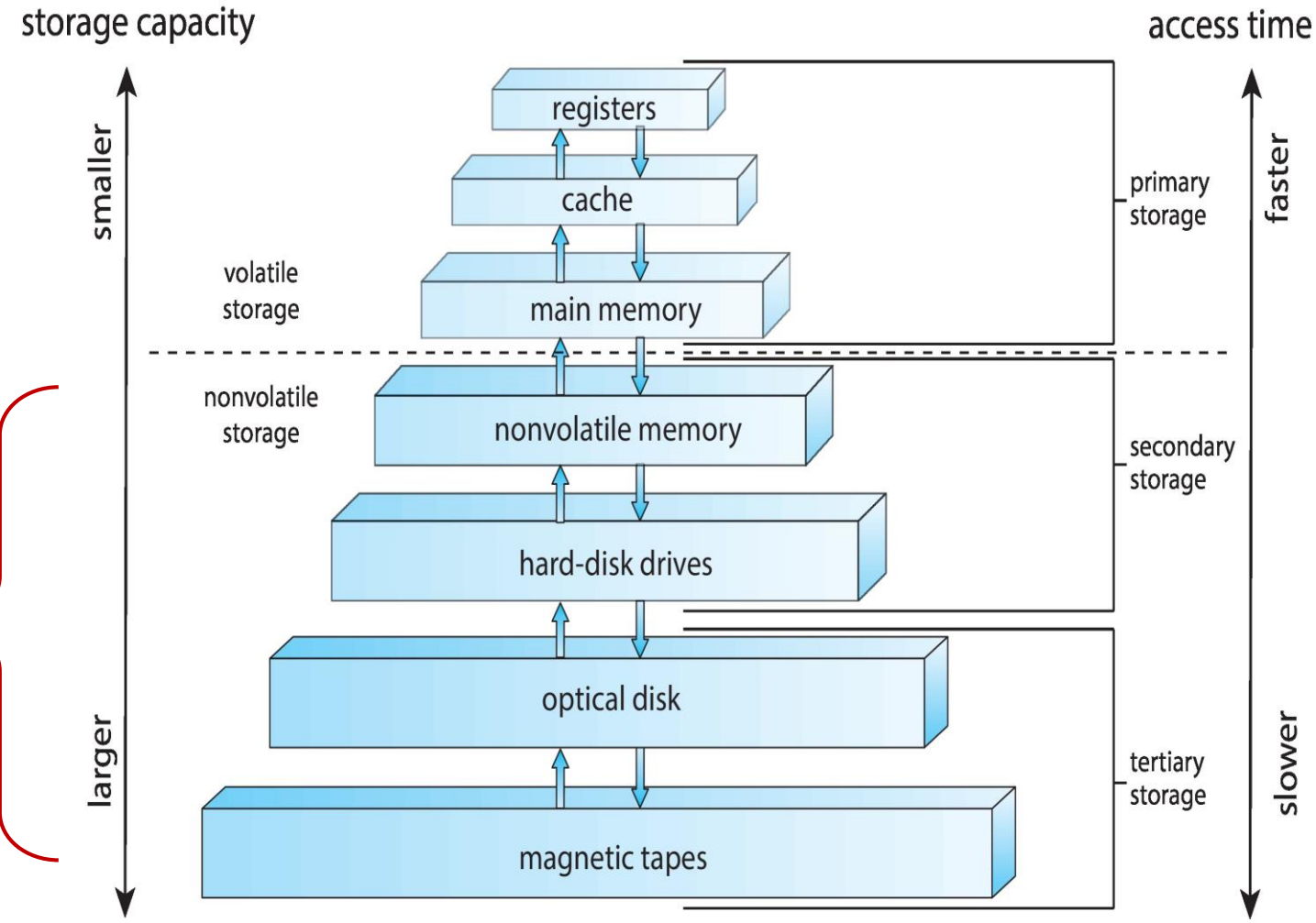
Objectives

- 大容量存储器结构：磁盘结构，传输时间，寻道时间，延迟时间，主机附属存储，网络附属存储NAS，存储区域网络SAN。
- 磁盘调度：调度时机，FCFS算法，SSTF算法，SCAN算法，C-SCAN算法，LOOK算法，C-LOOK算法。
- 磁盘管理：磁盘格式化，主引导块MBR。
- 交换空间管理。
- RAID结构。

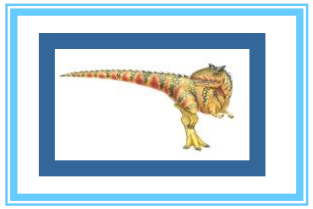
Hierarchical Storage Architecture

数据即资产
数据即权力

大容量
存储器

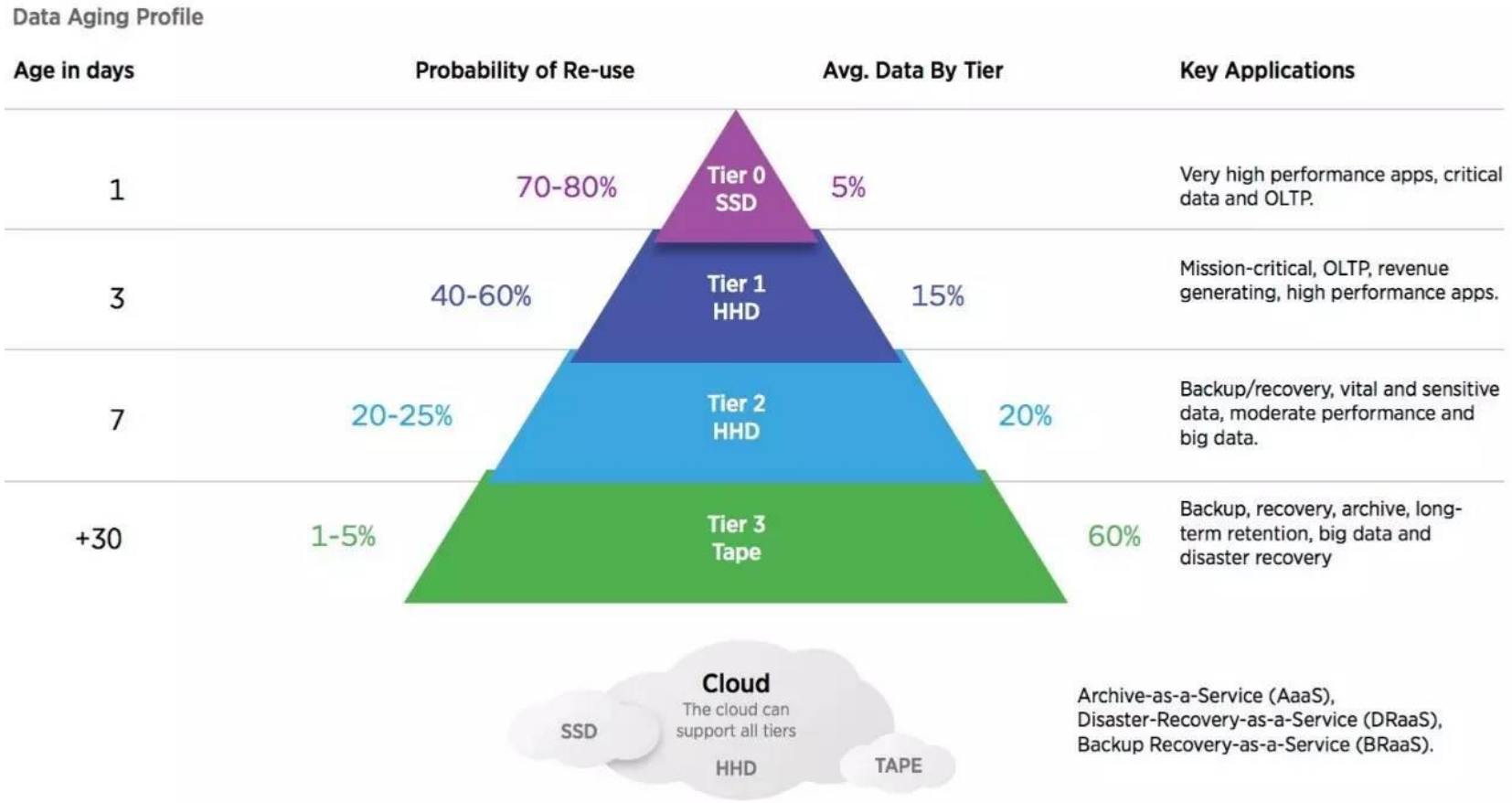


12.1 Overview of Mass Storage Structure



Overview of Mass Storage Structure

- 分层存储体系

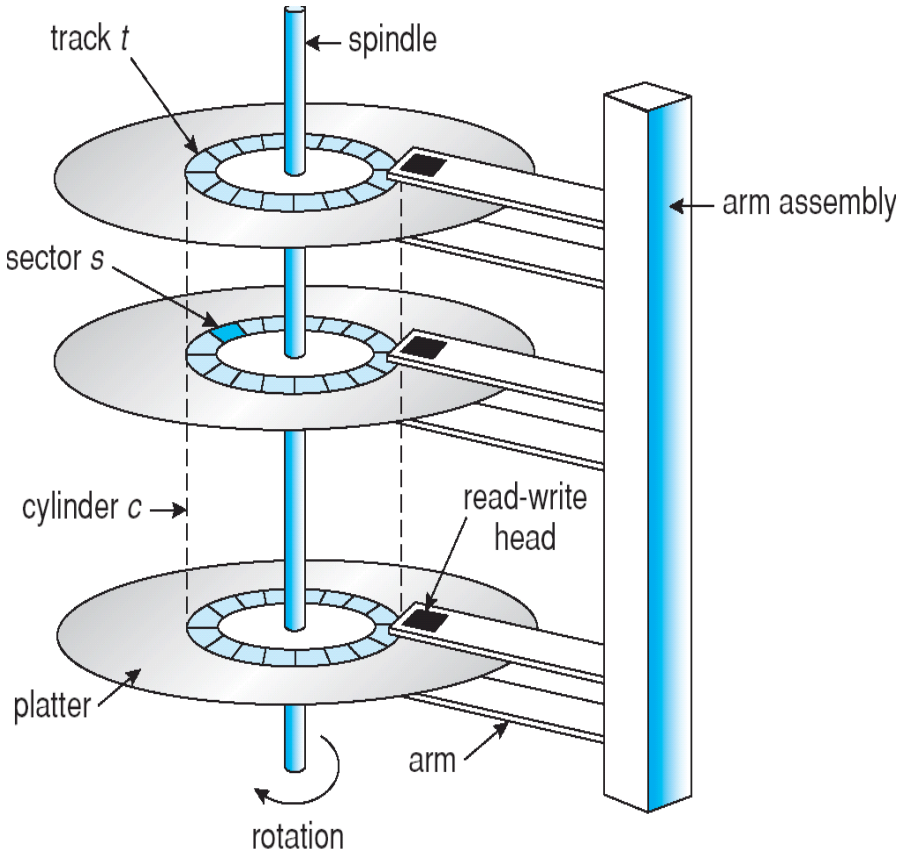


Overview of Mass Storage Structure

- Magnetic disks（磁盘） provide bulk of secondary storage of modern computers
  - Transfer rate 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
- 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

磁盘结构

- 磁盘设备是以一种逻辑块的一维大数组的形式编址的，这里的逻辑块（512B）是传输的最小单位。
- 逻辑块的一维数组映射到磁盘上一些相连的扇区。
  - **0扇区**是最外边柱面的第一个磁道的第一个扇区。
  - 数据首先都映射到一个磁道，其余的数据映射到同一柱面的其他磁道，然后按照从外向里的顺序映射到其余的柱面。



Overview of Mass Storage Structure (Cont)

■ **固态驱动器（Solid State Drives），**称**固态硬盘**，固态硬盘用固态电子存储芯片阵列制成的硬盘，由控制单元和存储单元（**FLASH芯片**、DRAM芯片）组成。

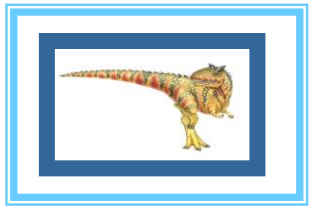
- 第一只SSD出现在1978年（STK 4305，每MB售价8800美元，DRAM）。
- 全闪存阵列（AFAS）和混合闪存阵列（HFA）呈爆发式增长。
- 现在SSD的容量超过15TB。
- 非易失性、低功耗（只有HDD的三分之一）。
- 无活动部件、可靠性高——位误码率（BER）1 x 1017
- **读取存取时间：500MB/s～4000MB/s，存取时间比HDD大概快100倍。**

Overview of Mass Storage Structure (Cont)

Magnetic tape （磁带）

- 出货的磁带驱动器中超过85%是LTO（Linear Tape Open）。
- 磁带驱动器的可靠性、数据传输速率和容量已超过磁盘。
- 磁带的原生容量超过10TB，压缩容量超过25TB。(LTO-10:48TB)
- 磁带的原生数据传输速率为360MB/s。
- **LTFS(Liner Tape File System)为磁带提供了一种通用、开放的文件系统。**
- 由于总体拥有成本，云采用磁带解决方案用于归档服务。
- 对企业级磁带和LTO而言，磁带介质的寿命至少是30年。

12.3 Disk（外存）Attachment



Disk Attachment

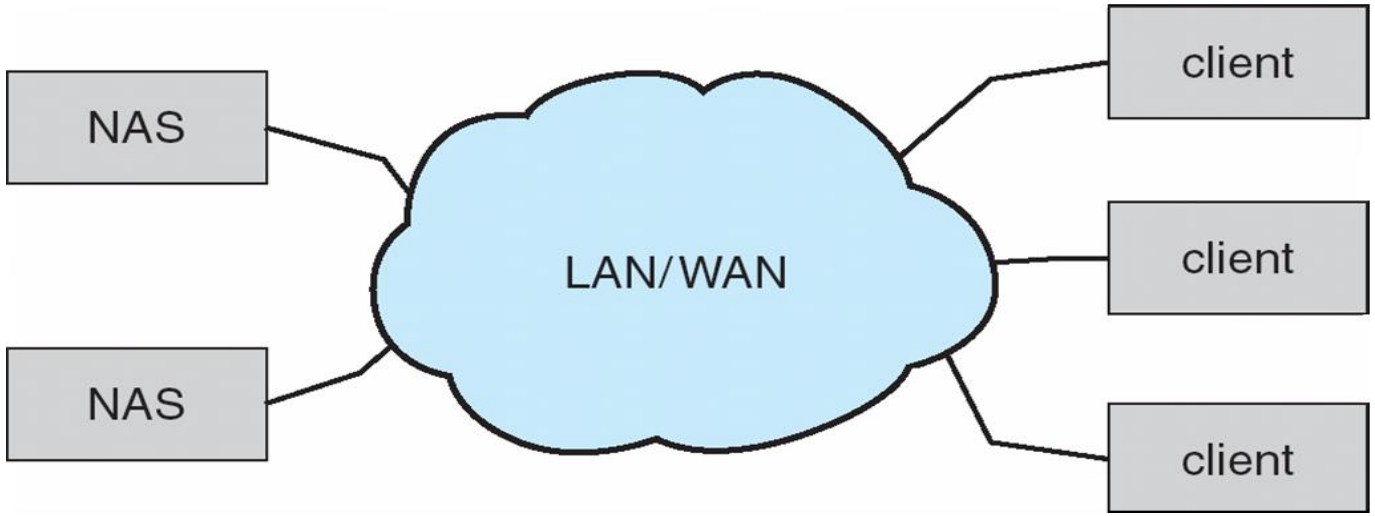
- Disks may be attached one of two ways:
  1. Host attached via an I/O port
  2. Network attached via a network connection
- 当前三种方式：
  - DAS（Direct(Host-) Attached Storage）
  - NAS（Network Attached Storage 网络附加存储）
  - SAN（ Storage-Area Network 存储区域网）

Host-attached storage

- Host-attached storage accessed through I/O ports talking to I/O busses
- I/O bus like IDE
  - a maximum of 2 drives per I/O bus
- SCSI itself is a bus, up to 16 devices on one cable, SCSI initiator requests operation and SCSI targets perform tasks
  - Each target can have up to 8 logical units (disks attached to device controller
- FC（Fibre Channel，光纤通道） is high-speed serial architecture
  - Can be switched fabric with 24-bit address space – the basis of storage area networks (SANs) in which many hosts attach to many storage units
  - Can be arbitrated loop (FC-AL) of 126 devices

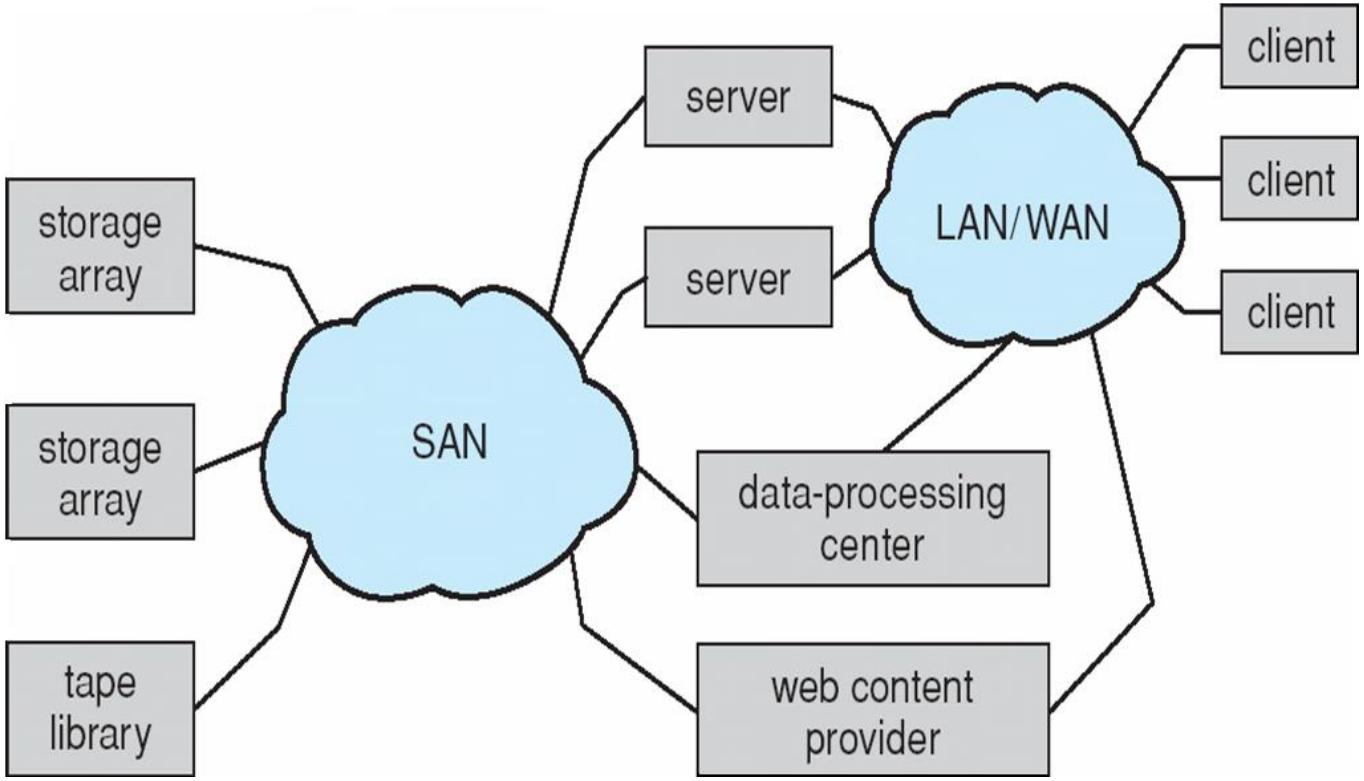
Network-Attached Storage

- Network-attached storage (NAS) is storage made available over a network rather than over a local connection (such as a bus)
- NFS and CIFS are common protocols
- Implemented via remote procedure calls (RPCs) between host and storage
- New iSCSI protocol uses IP network to carry the SCSI protocol



Storage Area Network（SAN）

- Common in large storage environments (and becoming more common)
- Multiple hosts attached to multiple storage arrays - flexible



存储虚拟化技术

- SNIA（Storage Networking Industry Association，存储网络联合会）官方对于Virtualization（存储虚拟化技术）的定义，如下：
  - 是将存储（子）系统内部功能与具体应用、主机及通用网络资源分离、隐藏及抽象的行为。以期达到存储或数据管理的网络无关性。
  - 对于存储服务及设备的虚拟化应用，以期达到整合设备功能、隐藏复杂细节以及向已经存在的底层存储资源添加新的应用。

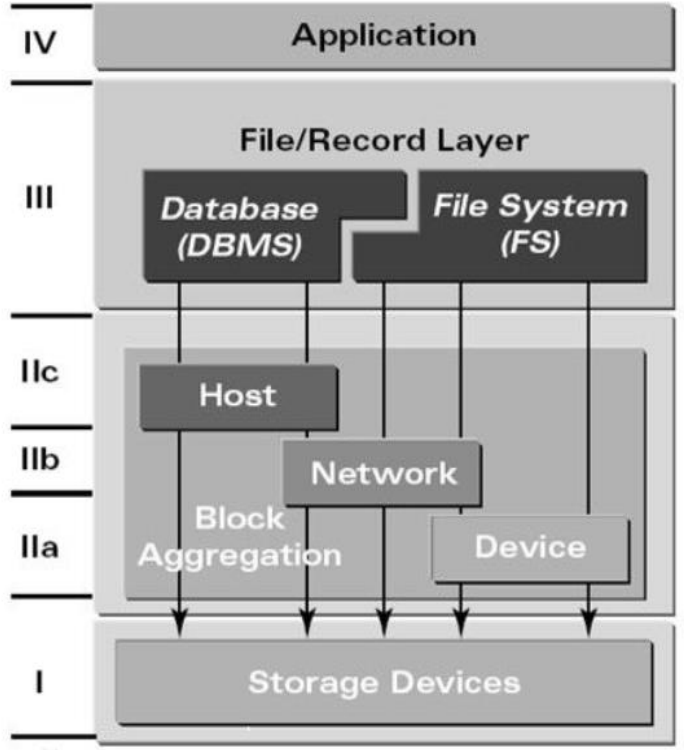
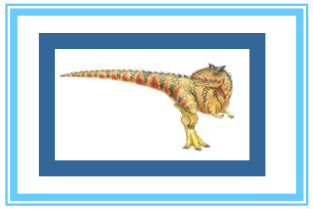


图 1 SNIA 共享存储模型

12.4 Disk Scheduling（注：传统机械式磁盘）



Disk Scheduling

- The operating system is responsible for using hardware efficiently — for the disk drives, this means having a fast access time and disk bandwidth
- Access time has three major components
  - **Seek time（寻道时间）** is the time for the disk are to move the heads to the cylinder containing the desired sector
  - **Rotational latency（旋转延迟）**is the additional time waiting for the disk to rotate the desired sector to the disk head
  - **Transfer time（传输时间）**
- Minimize seek time
  - **Seek time ≈ seek distance 寻道时间 ≈ 寻道距离**
- Disk bandwidth 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

数据计算

- 7200(转／每分钟)的硬盘，每旋转一周所需时间为60×1000（毫秒）÷7200＝8.33毫秒，
  则平均旋转延迟时间为8.33÷2＝4.17毫秒(平均情况下，需要旋转半圈)。

- 7200转机械硬盘的寻道时间一般为12-14毫秒，固态硬盘可以达到0.1毫秒甚至更低。

- 固态硬盘持续读写速度超过500MB/s
- 机械硬盘读写速度超过50~200MB/s（接口不同）
- 磁带的原生数据传输速率为360MB/s。

Disk Scheduling (Cont)

- Several algorithms exist to schedule the servicing of disk I/O requests
- 常用的磁盘调度算法有：先来先服务(FCFS)、最短寻道时间优先(SSTF)、扫描(SCAN)算法和循环扫描(C-SCAN)算法等

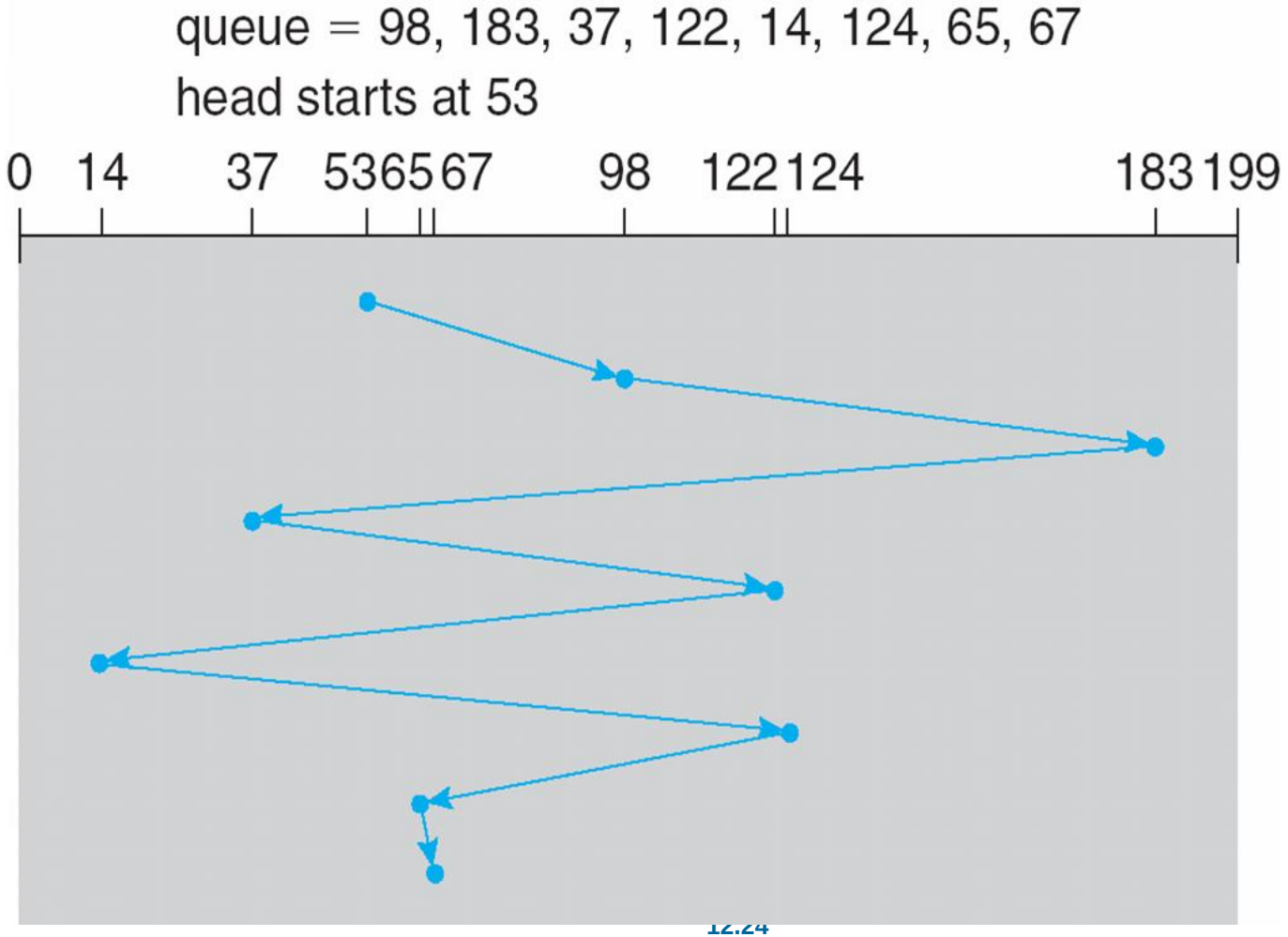
- We illustrate them with a request queue (0-199)

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

  Head pointer 53

1. FCFS 先来先服务

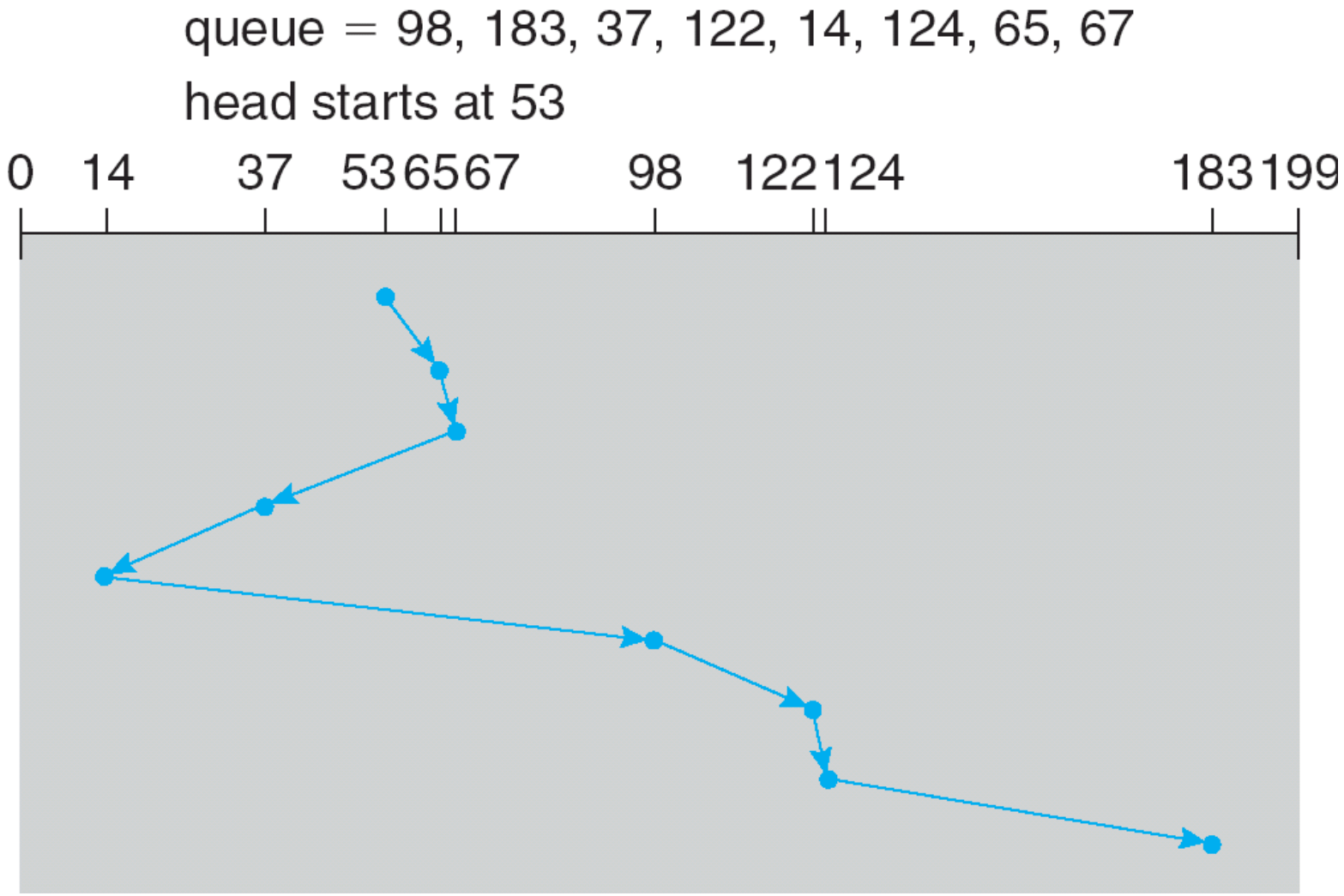
- 基本思想：根据进程请求访问磁盘的先后次序进行调度。
- Illustration shows total head movement of 640 cylinders



2、最短寻道时间优先SSTF调度

- **基本思想：选择从当前磁头位置所需寻道时间最短的请求。**
- SSTF(Shortest Seek Time First)是SJF调度的一种形式；有可能引起某些请求的饥饿。
- 如图所示，磁头移动的总距离是236柱面。

SSTF (Cont)

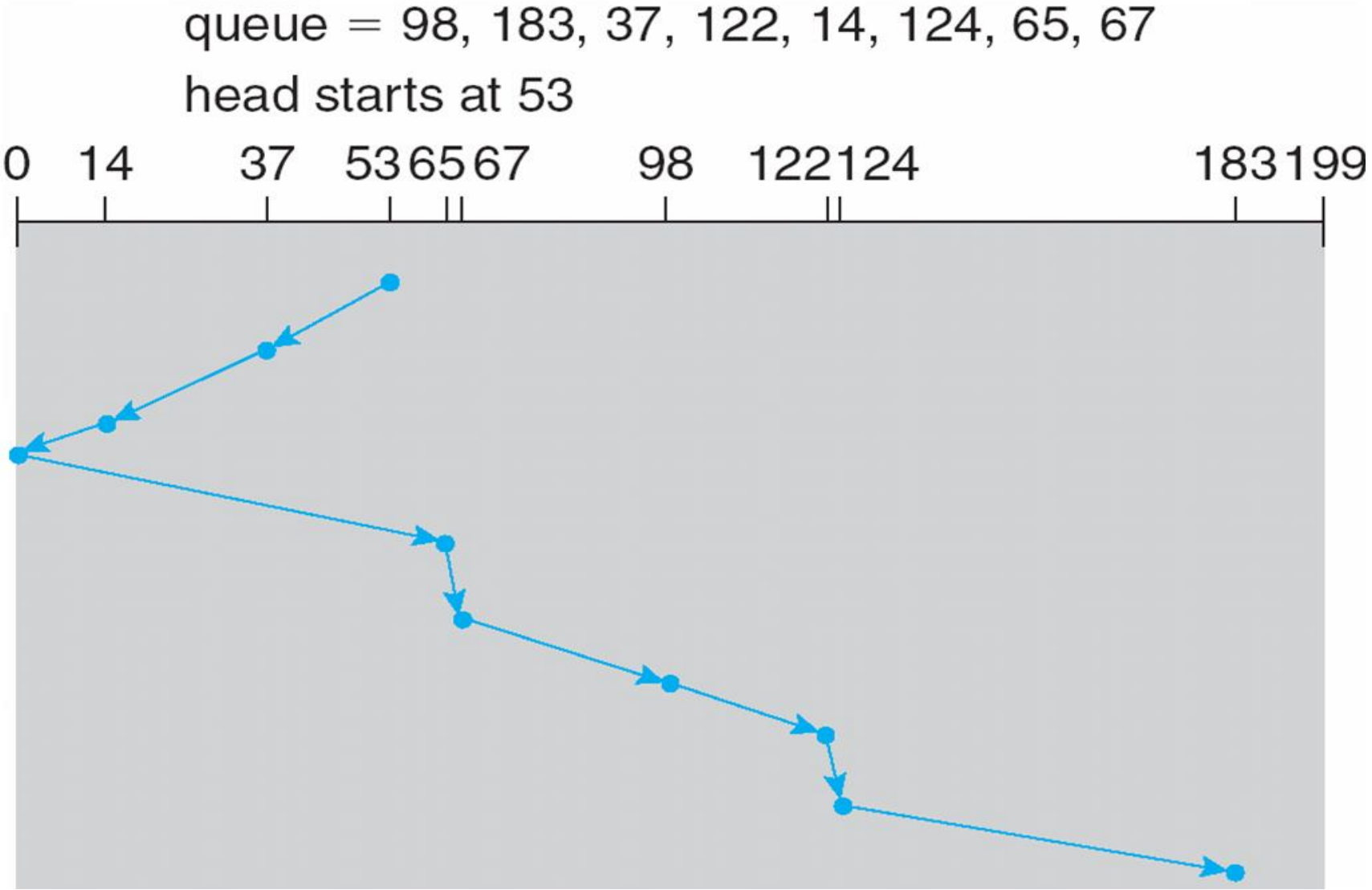


total head movement of 236 cylinders

3、扫描调度 SCAN

- 基本思想：磁头从磁盘的一端开始向另一端移动，沿途响应访问请求，直到到达了磁盘的另一端，此时磁头反向移动并继续响应服务请求。
- 也称为**电梯算法** *elevator algorithm*。
- 如图所示，磁头移动的总距离是**236**柱面。
- LOOK:208

SCAN (Cont.)


queue = 98, 183, 37, 122, 14, 124, 65, 67
head starts at 53
0
14
37
53
65
67
98
122
124
183
199

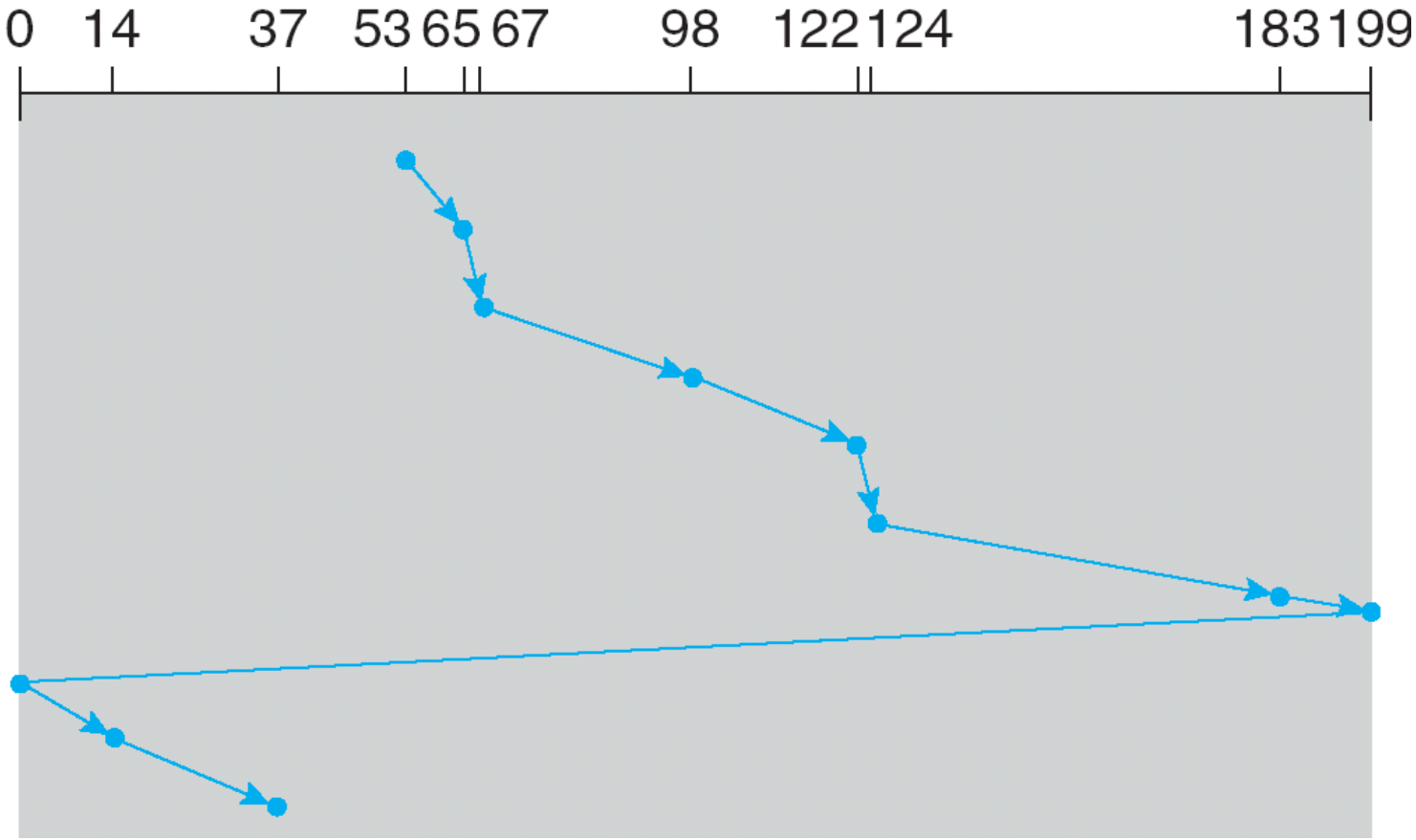
4、 C-SCAN Scheduling

- 提供比扫描算法更均衡的等待时间。
- 基本思想：**磁头从磁盘的一段向另一端移动，沿途响应请求。当它到了另一端，就立即回到磁盘的开始处，在返回的途中不响应任何请求。**
- 把所有柱面看成一个循环的序列，最后一个柱面接续第一个柱面。

C-SCAN (Cont)

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

head starts at 53

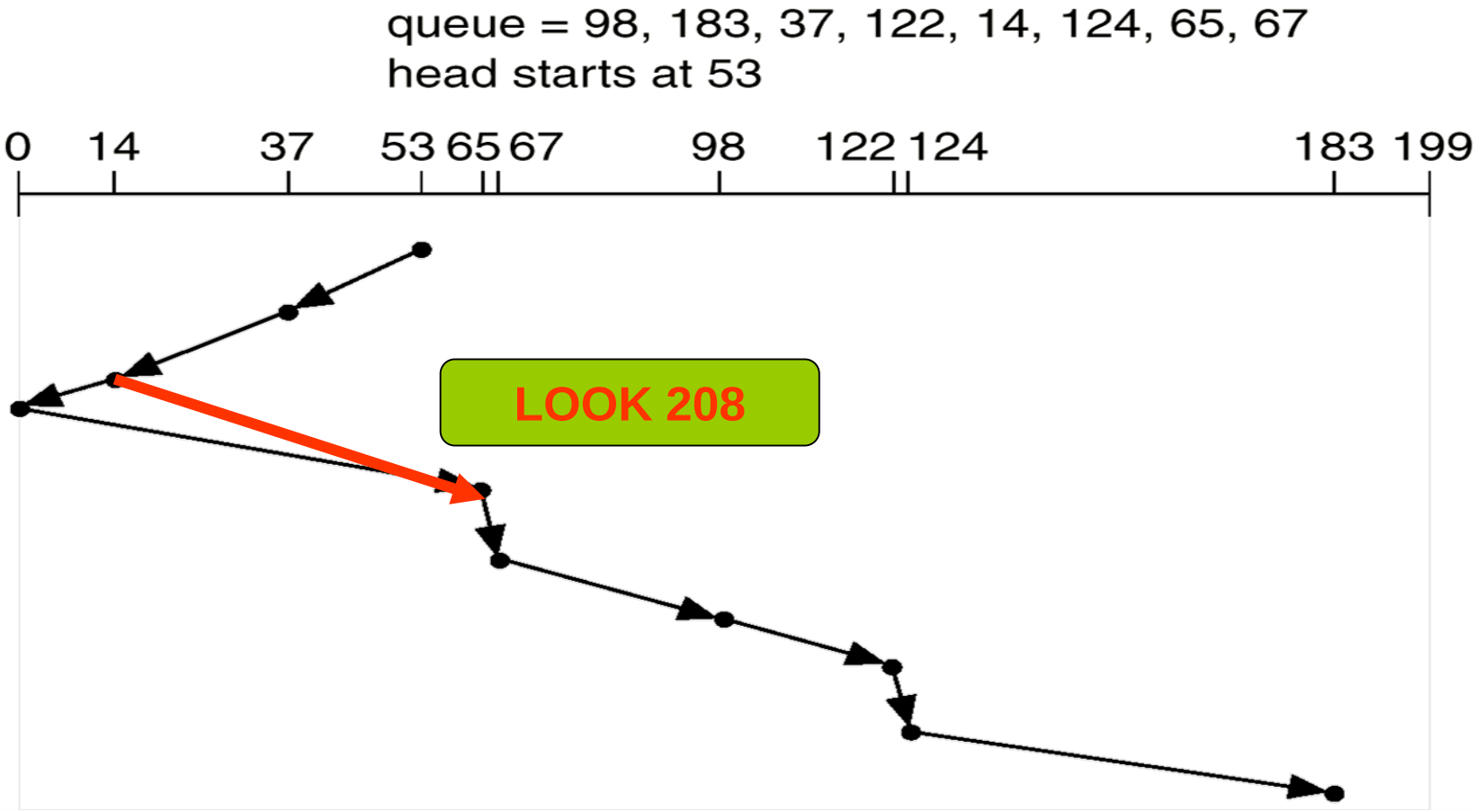


total head movement of 382 cylinders

5、LOOK、 C-LOOK Scheduling

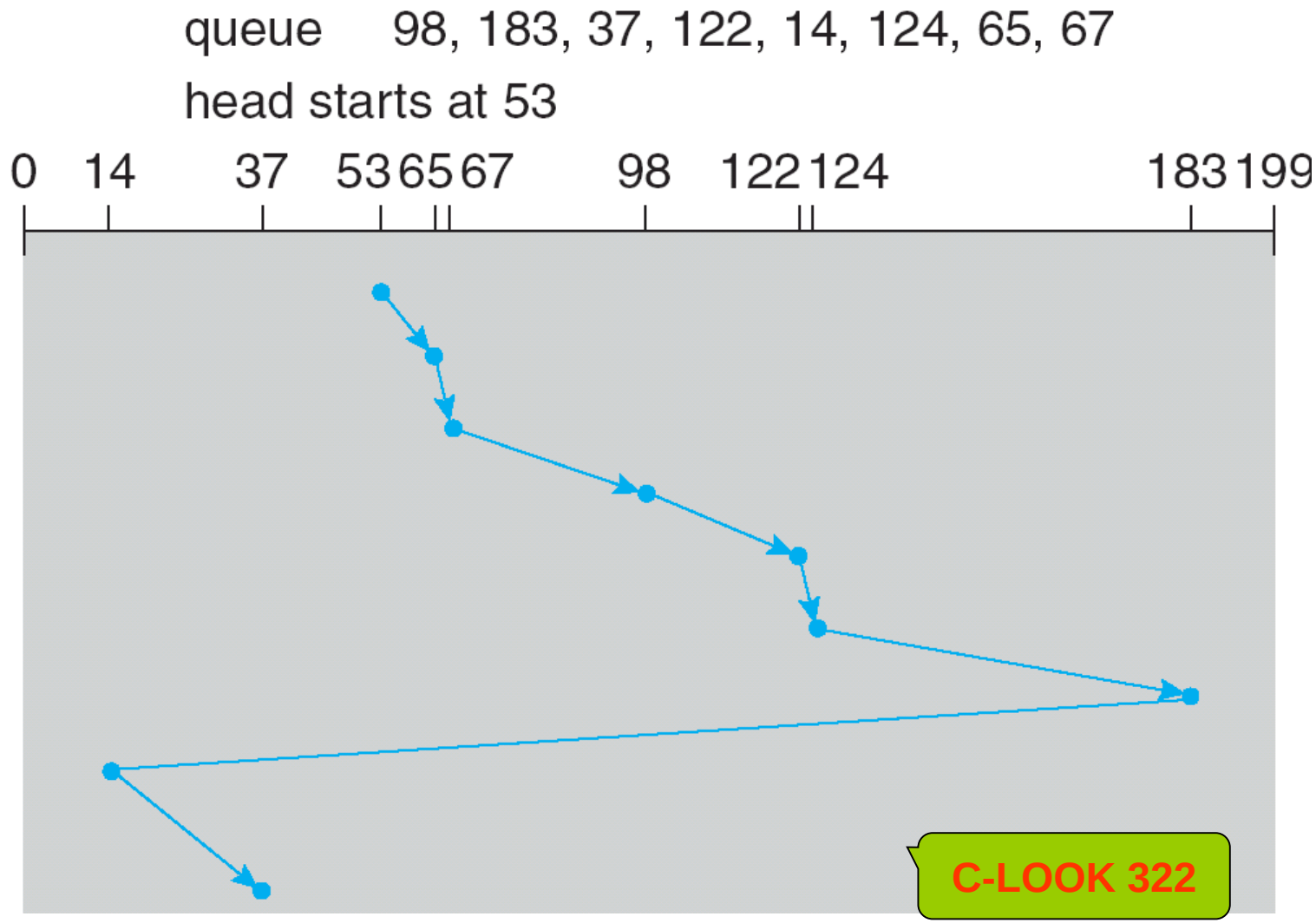
- LOOK--- SCAN算法的一种形式。
- C-LOOK-C-SCAN算法的一种形式。
- 磁臂在每个方向上仅仅移动到最远的请求位置，然后立即反向移动，而不需要移动到磁盘的一端。

LOOK-- Version of SCAN



total head movement of 208 cylinders

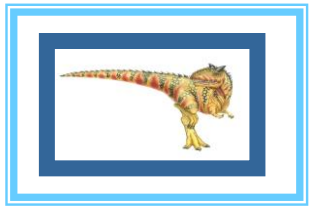
C-LOOK (Cont)


queue 98, 183, 37, 122, 14, 124, 65, 67
head starts at 53
0 14 37 53 65 67 98 122 124 183 199
C-LOOK 322

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
- Requests for disk service can be influenced by the file-allocation method
- The disk-scheduling algorithm should be written as a separate module of the operating system, allowing it to be replaced with a different algorithm if necessary
- Either SSTF or LOOK is a reasonable choice for the default algorithm

12.5 Disk Management



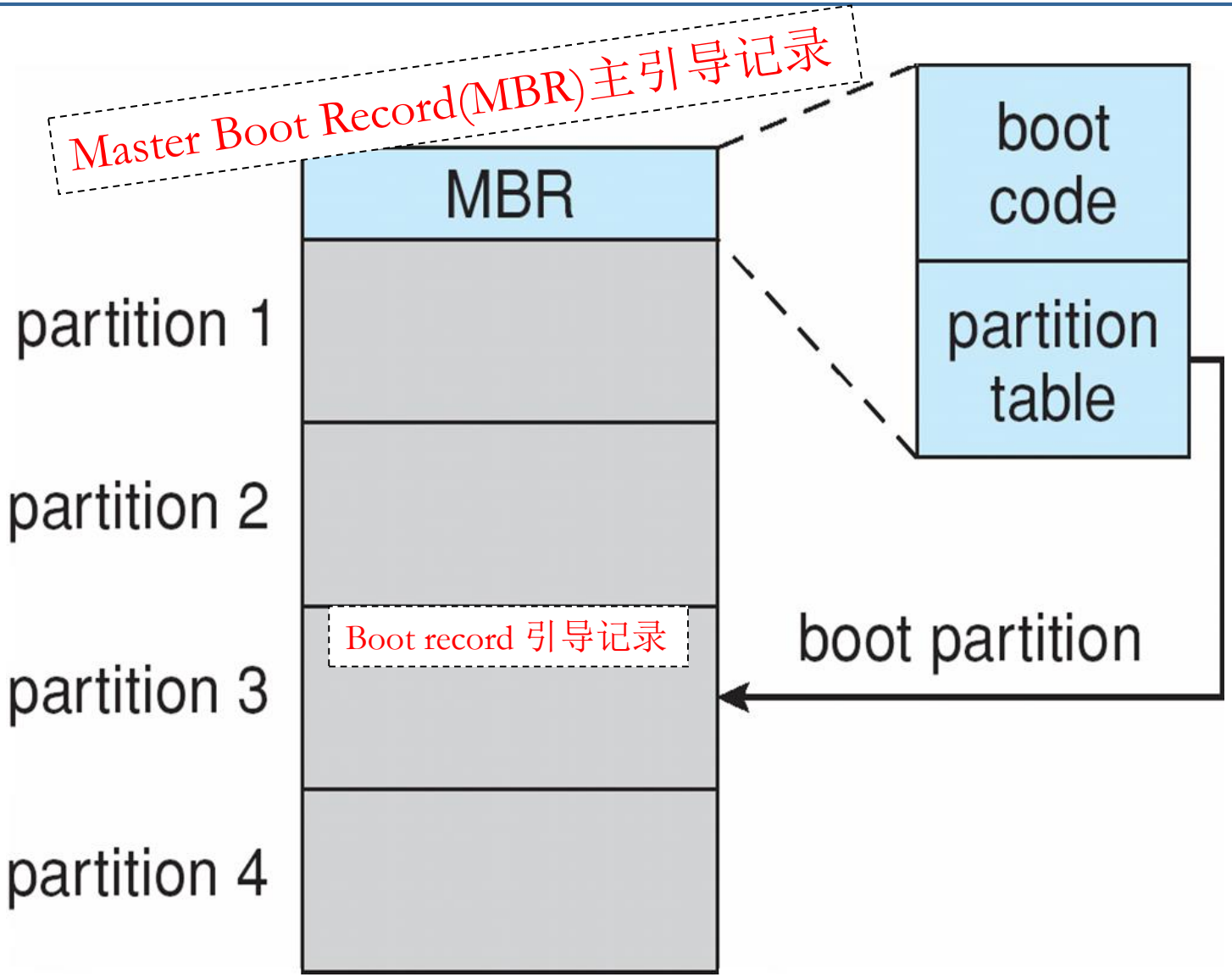
磁盘格式化*Disk Format*

- **低级格式化，或物理格式化**（*Low-level formatting*, or *physical formatting*）——把磁盘划分成扇区，以便磁盘控制器可以进行读写。
- **分区**（*Partition*）：把磁盘划分成一个或多个柱面组。
- **逻辑格式化**或“**创建文件系统**” *Logical formatting* or “making a file system”。

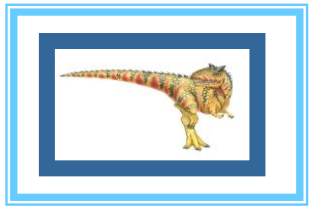
Disk Management (Cont.)

- 启动块Boot Block
  - 启动块初始化系统
    - 引导（bootstrap自举）程序存储在ROM中
    - 引导程序装载程序。
  - Fig 13.6 MS-DOS Disk Layout
- 坏块Bad Block
  - 坏块的处理方法
  - MS-DOS的处理方法: format,chkdsk命令

Booting from a Disk in Windows



12.6 Swap-Space Management



Swap-Space Management

- Swap-space — Virtual memory uses disk space as an extension of main memory
- Swap-space can be carried out in two forms：
  - in the normal file system
    e.g. Windows family

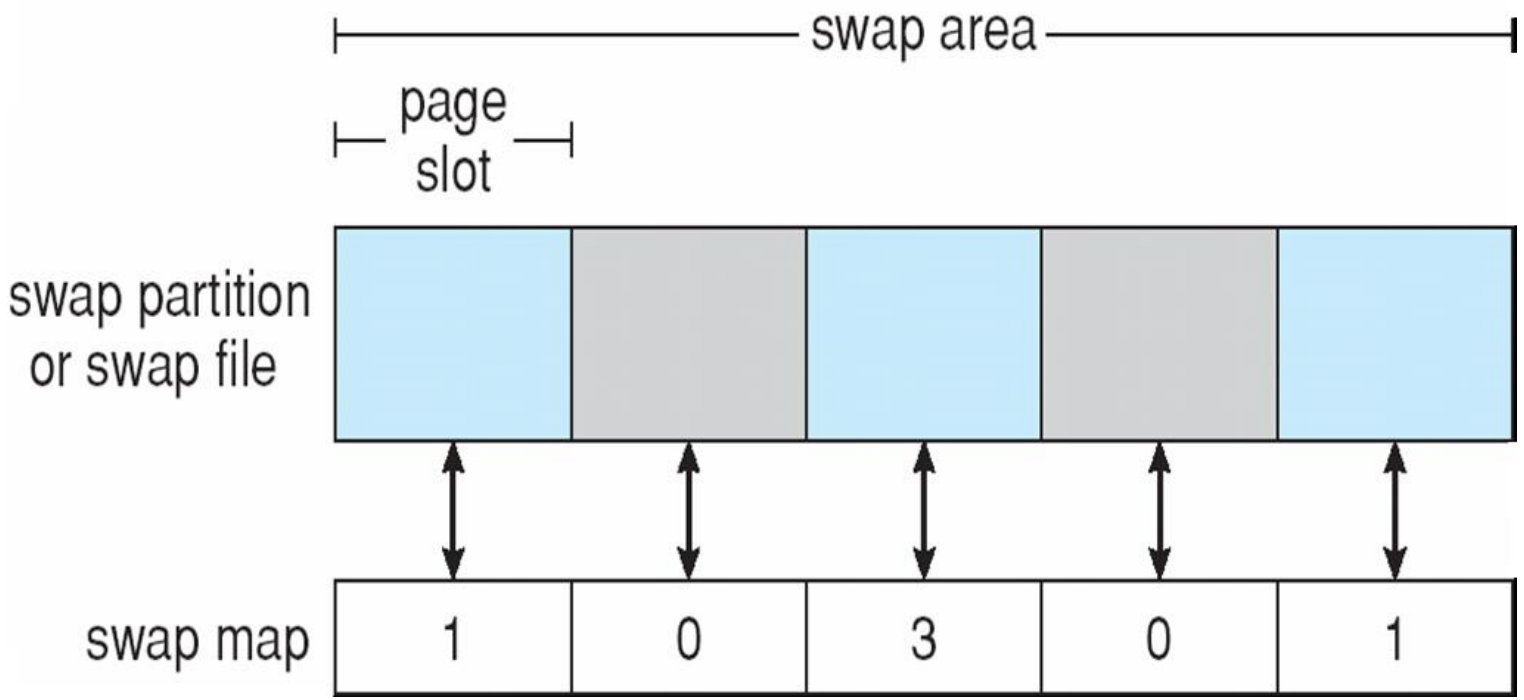
    pagefile.sys文件
  - in a separate disk partition
    e.g. Linux、Unix、solaris

    SWAP分区

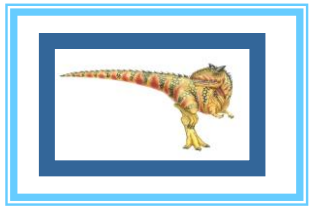
交换空间管理

- 交换空间的位置
  - 交换空间在普通文件系统上加以创建。**通常是文件系统内的一个简单大件**（如Windows：**pagefile.sys文件**）。这种方式实现简单但效率较低。（外部碎片）
  - 交换空间创建在独立的**磁盘分区上**（如Unix/Linux）。（内部碎片）
  - 有些OS较为灵活，可以由系统管理员来选择使用以上哪种方式。

Data Structures for Swapping on Linux Systems



12.7 RAID Structure



RAID Structure

- **RAID**： Redundant Arrays of Inexpensive (independent) Disks（冗余廉价磁盘阵列）.RAID是一种把多块独立的硬盘（物理硬盘）按不同的方式组合起来形成一个硬盘组（逻辑硬盘），从而提供比单个硬盘更高的存储性能和提供数据备份技术。
- Inexpensive -> Independent
- RAID – multiple disk drives provides reliability via redundancy
- Increases the mean time to failure
- Frequently combined with NVRAM to improve write performance
- RAID is arranged into six different levels（较早），RAID 7、10、53、5E、5EE

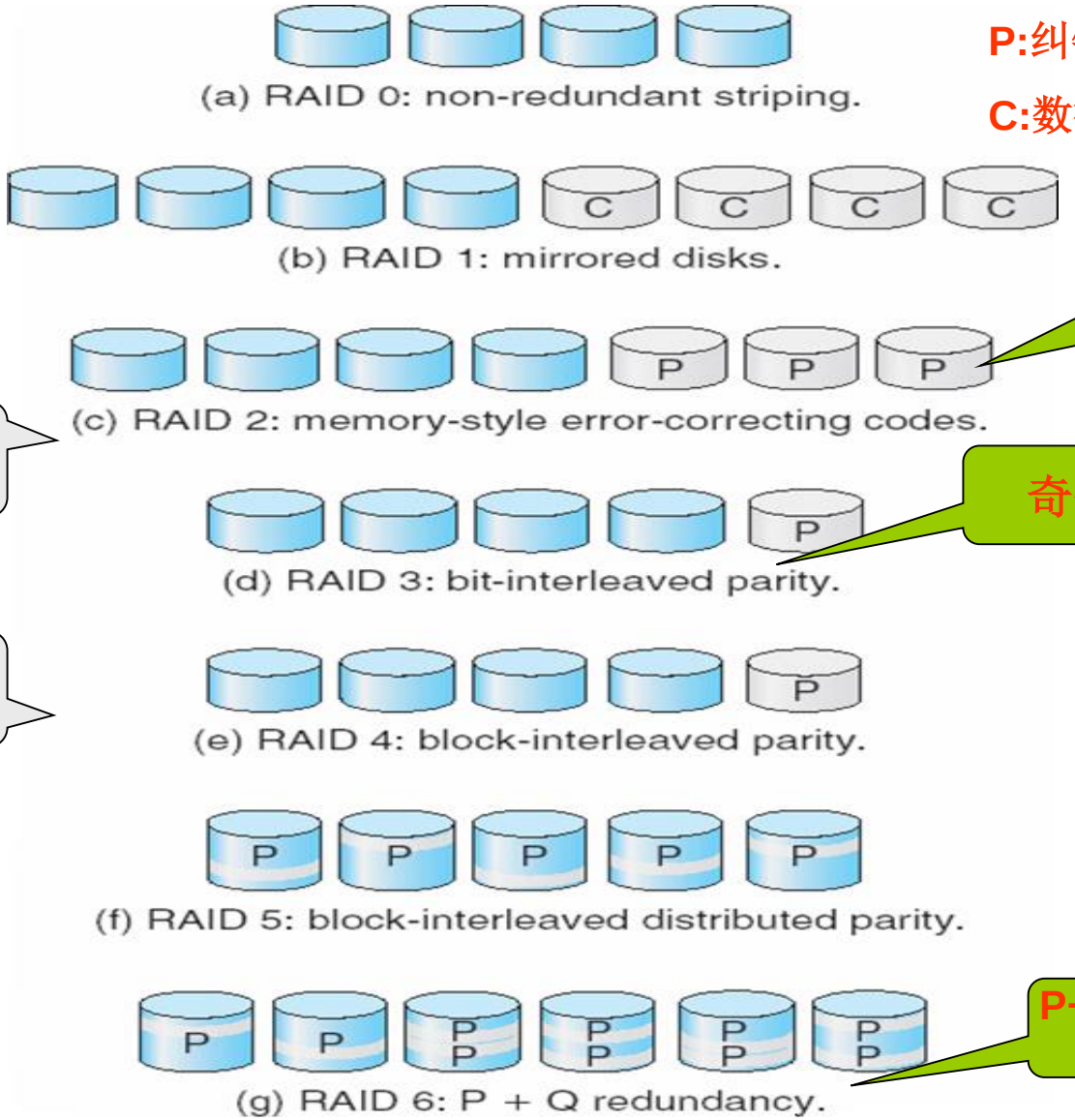
RAID (Cont)

- Several improvements in disk-use techniques involve the use of multiple disks working cooperatively
- Disk **striping**（条带化） 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（镜像） or shadowing (RAID 1) keeps duplicate of each disk
  - Striped mirrors (RAID 1+0) or mirrored stripes (RAID 0+1) provides high performance and high reliability
  - Block interleaved parity (RAID 4, 5, 6) uses much less redundancy

RAID (Cont)

- RAID within a storage array can still fail if the array fails, so automatic replication of the data between arrays is common
- Frequently, a small number of hot-spare disks are left unallocated, automatically replacing a failed disk and having data rebuilt onto them

RAID Levels



P:纠错位

C:数据的第二拷贝

Hamming码

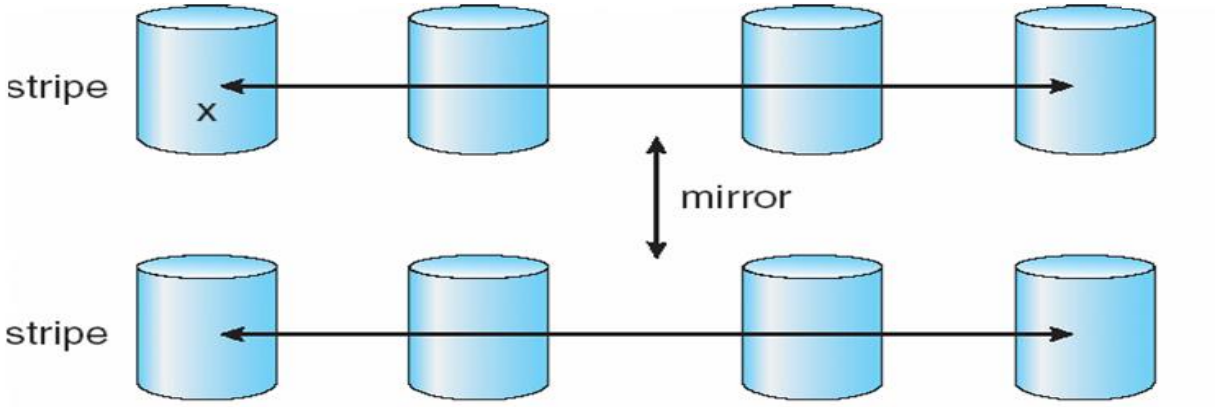
RAID2、3按字节或位striping

奇偶校验

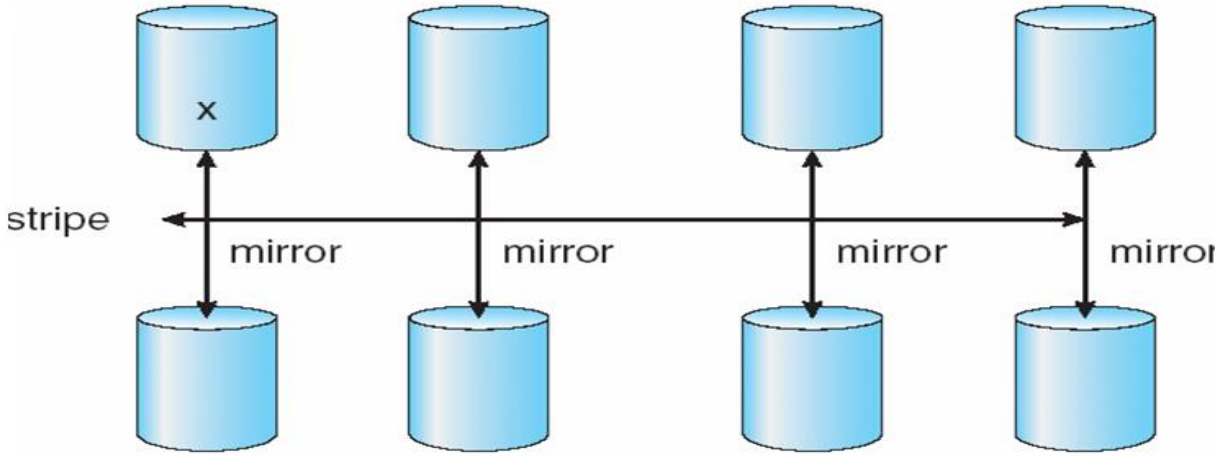
按块striping

P+Q冗余，差错纠正码

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



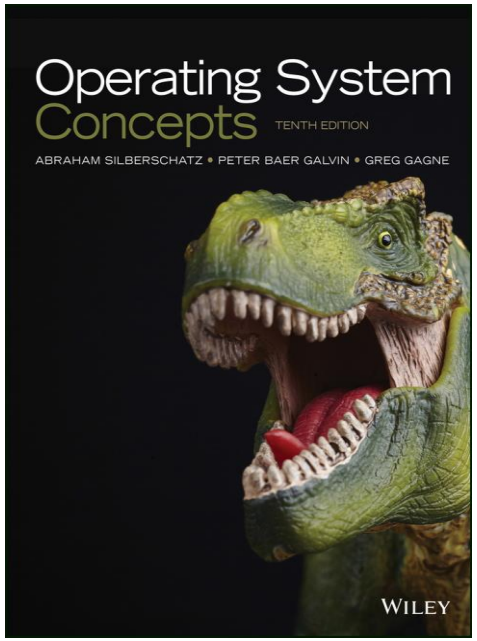
a) RAID 0 + 1 with a single disk failure.

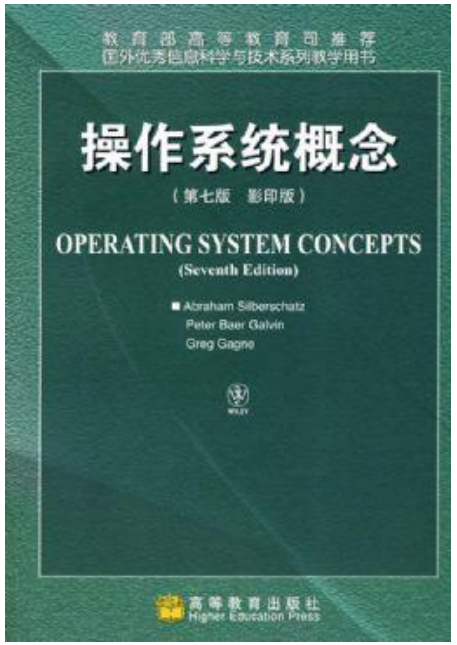


b) RAID 1 + 0 with a single disk failure.

Reading Assignments

- Read for this week:
  - Chapters 12
    of the text book:
- Read for next week:
  - Chapters 13
    of the text book:





End of Chapter 12