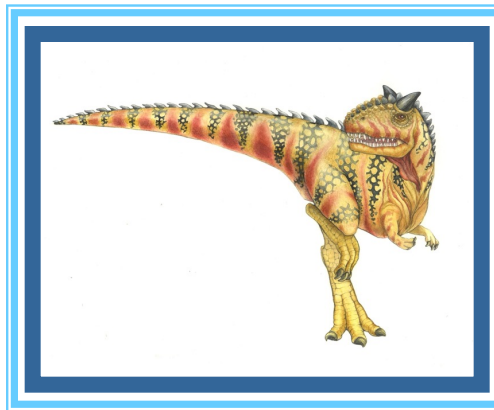


Chapter 9: Mass-Storage Systems





Chapter 9: Mass-Storage Systems

- Overview of Mass Storage Structure
- Disk Structure
- Disk Attachment
- Disk Scheduling
- Disk Management
- Swap-Space Management
- RAID Structure
- Stable-Storage Implementation





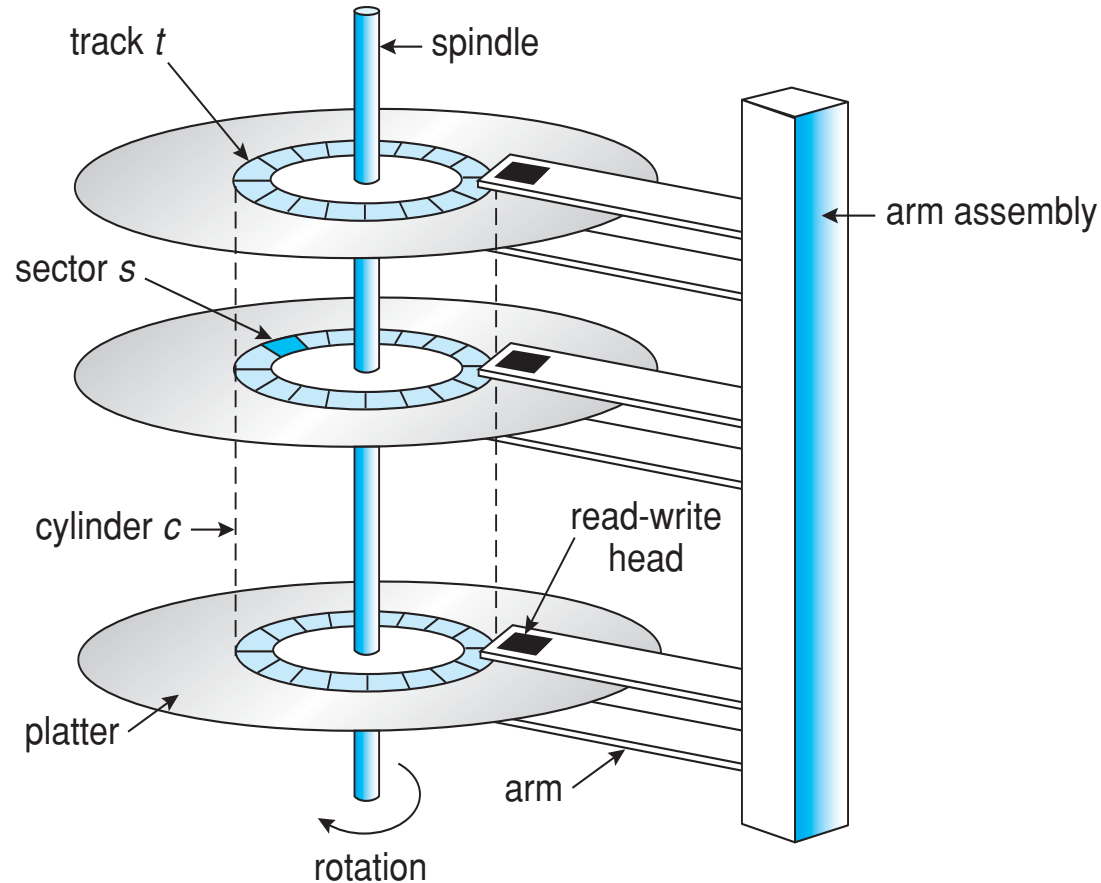
Overview of Mass Storage Structure

- **Magnetic disks** provide bulk of secondary storage of modern computers
 - Drives rotate at 60 to 250 times per second
 - **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**, **SAS**, **Firewire**
 - **Host controller** in computer uses bus to talk to **disk controller** built into drive or storage array





Moving-head Disk Mechanism





Hard Disks

- Platters range from .85” to 14” (historically)
 - Commonly 3.5”, 2.5”, and 1.8”
- Range from 30GB to 3TB per drive
- Performance
 - Transfer Rate – theoretical – 6 Gb/sec
 - Effective Transfer Rate – real – 1Gb/sec
 - Seek time from 3ms to 12ms – 9ms common for desktop drives
 - Average seek time measured or calculated based on 1/3 of tracks
 - Latency based on spindle speed
 - ▶ $1 / (\text{RPM} / 60) = 60 / \text{RPM}$
 - Average latency = $\frac{1}{2}$ latency

Spindle [rpm]	Average latency [ms]
4200	7.14
5400	5.56
7200	4.17
10000	3
15000	2

(From Wikipedia)





Hard Disk Performance

- **Access Latency** = **Average access time** = average seek time + average latency
 - For fastest disk $3\text{ms} + 2\text{ms} = 5\text{ms}$
 - For slow disk $9\text{ms} + 5.56\text{ms} = 14.56\text{ms}$
- Average I/O time = average access time + (amount to transfer / transfer rate) + controller overhead
- For example to transfer a 4KB block on a 7200 RPM disk with a 5ms average seek time, 1Gb/sec transfer rate with a .1ms controller overhead =
 - $5\text{ms} + 4.17\text{ms} + 0.1\text{ms} + \text{transfer time} =$
 - Transfer time = $4\text{KB} / 1\text{Gb/s} * 8\text{Gb} / \text{GB} * 1\text{GB} / 1024^2\text{KB} = 32 / (1024^2) = 0.031 \text{ ms}$
 - Average I/O time for 4KB block = $9.27\text{ms} + .031\text{ms} = 9.301\text{ms}$





The First Commercial Disk Drive



1956
IBM RAMDAC computer
included the IBM Model
350 disk storage system

5M (7 bit) characters
50 x 24" platters
Access time = < 1 second





Solid-State Disks

- Nonvolatile memory used like a hard drive
 - Many technology variations
- Can be more reliable than HDDs
- More expensive per MB
- Maybe have shorter life span
- Less capacity
- But much faster
- Busses can be too slow -> connect directly to PCI for example
- No moving parts, so no seek time or rotational latency





Magnetic Tape

- Was early secondary-storage medium
 - Evolved from open spools to cartridges
- 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
 - 140MB/sec and greater
- 200GB to 1.5TB typical storage
- Common technologies are LTO- $\{3,4,5\}$ and T10000





Disk Structure

- Disk drives are addressed as large 1-dimensional arrays of **logical blocks**, where the logical block is the smallest unit of transfer
 - Low-level formatting creates **logical blocks** on physical media
- The 1-dimensional array of logical blocks is mapped into the sectors of the disk sequentially
 - 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
 - Logical to physical address should be easy
 - ▶ Except for bad sectors
 - ▶ Non-constant # of sectors per track via constant angular velocity





Disk Attachment

- Host-attached storage accessed through I/O ports talking to I/O busses
- 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 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
- I/O directed to bus ID, device ID, logical unit (LUN)





Storage Array

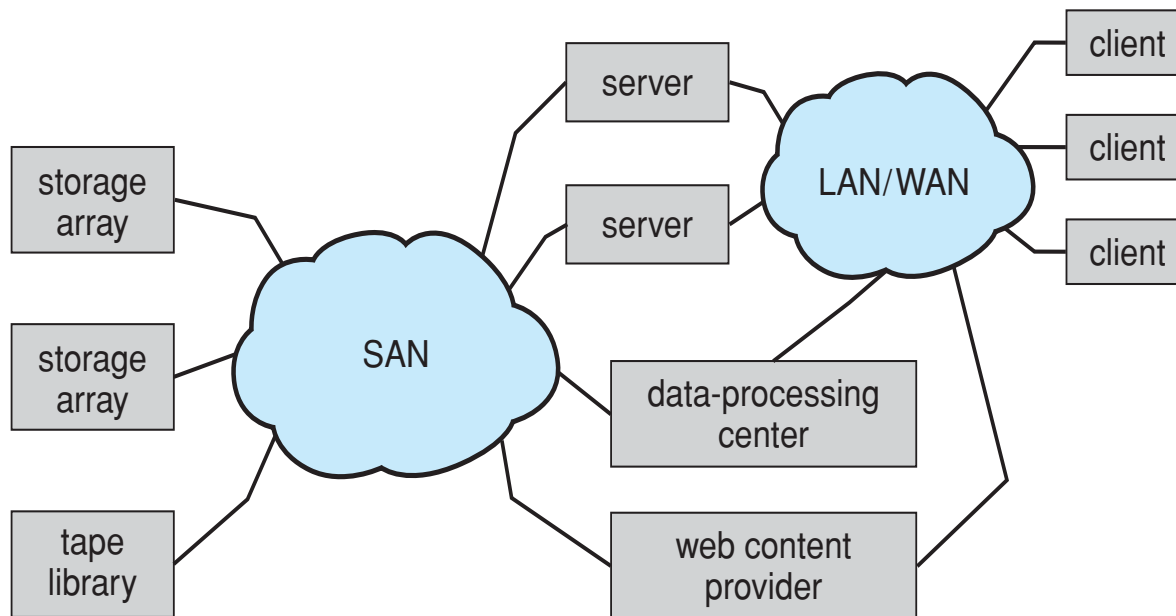
- Can just attach disks, or arrays of disks
- Storage Array has controller(s), provides features to attached host(s)
 - Ports to connect hosts to array
 - Memory, controlling software (sometimes NVRAM, etc)
 - A few to thousands of disks
 - RAID, hot spares, hot swap (discussed later)
 - Shared storage -> more efficiency
 - Features found in some file systems
 - ▶ Snapshots, clones, thin provisioning, replication, deduplication, etc





Storage Area Network

- Common in large storage environments
- Multiple hosts attached to multiple storage arrays - flexible



End of Lecture

