Storage Technologies

COMP 25212 - Lecture 8

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Storage Technologies Outline

Lecture 1 Disks & Filesystems (20 April)

- Revisions
- Performance
- Limitations and solutions

Lecture 2 RAID (22 April)

- build server filestore from (inexpensive) PC parts

Lecture 3 Storage Systems and Virtualization (27 April)

- Logical Volume Management
- Storage Area Networks
- Solid State Disks

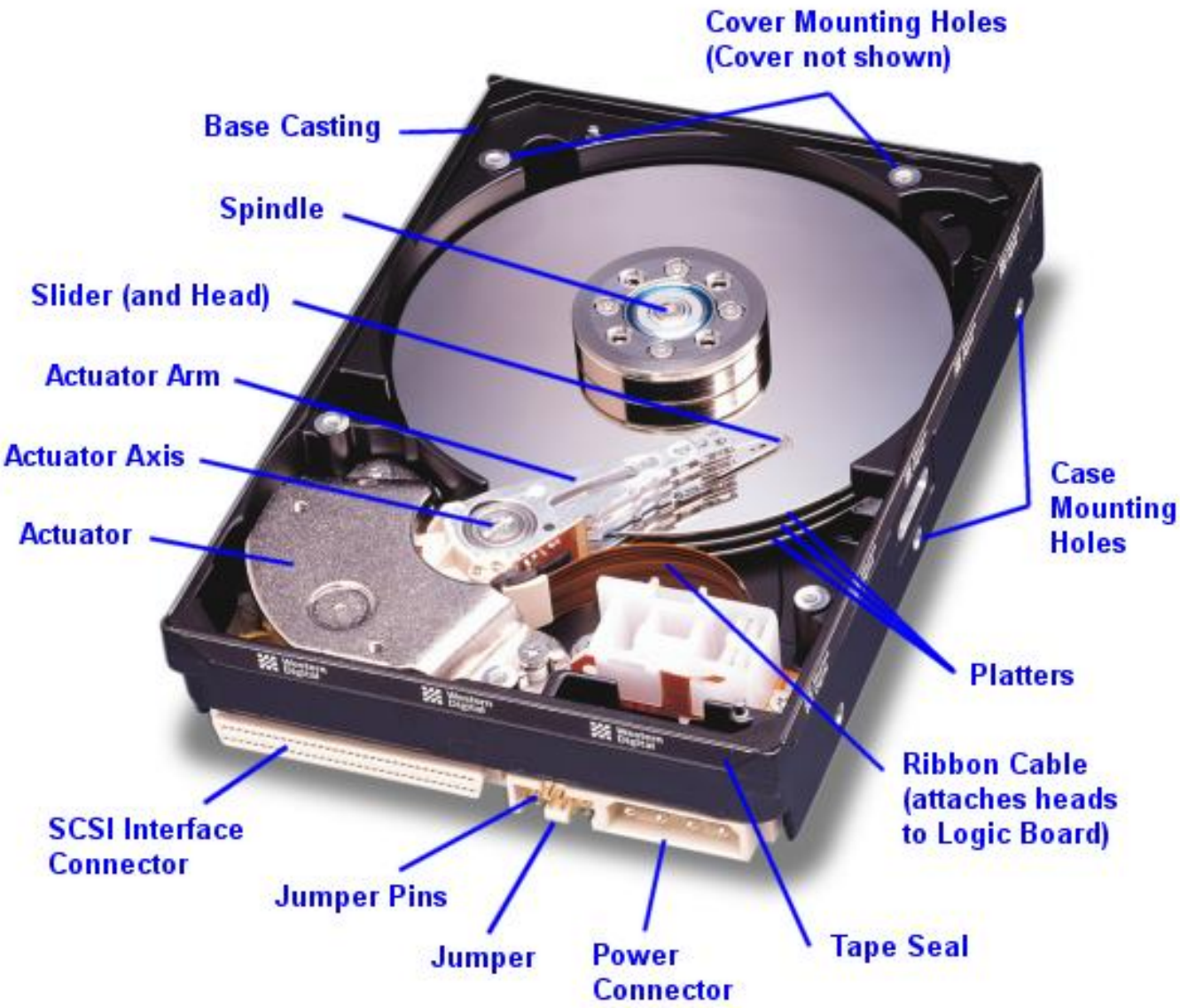
Learning Objectives - Storage 1

- Review disk and file system characteristics
- Understand the operational limitations of conventional disk usage
- Introduce simple solutions using multiple disks

Characterisation

- Write Once, Read Many (times) – *WORM*
  - CD-ROM, DVD, Blu-ray Disc
  - Irreversible writes
- Write Many, Read Many
  - Hard disk drive, tape drive
  - Fully reversible writes (almost)
- Write (not too) Many, Read Many
  - CD/DVD±RW (100s to 1000s)
  - Flash Memory (1000s to ...)
  - Mostly reversible writes – “**wear**”

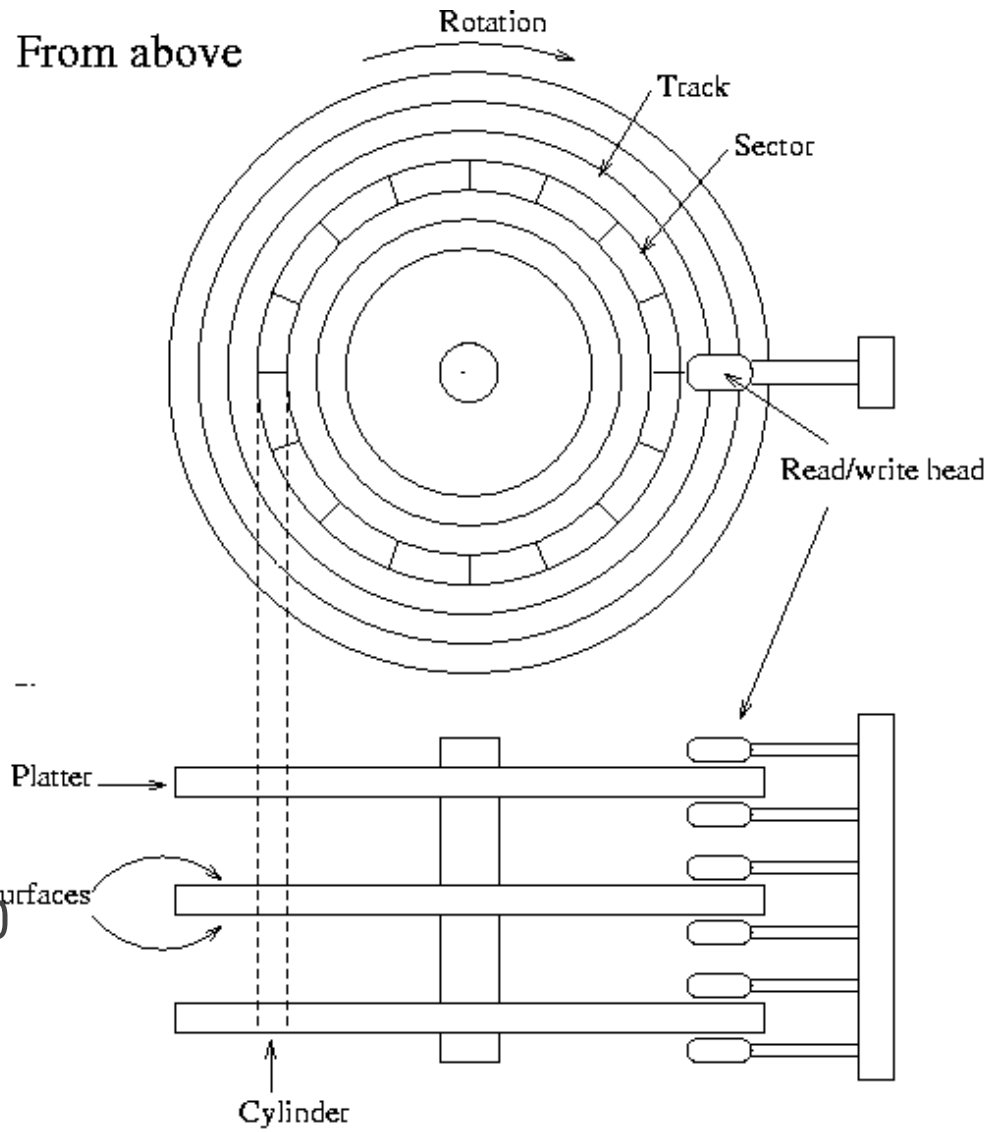
HDD Internals – tinyurl.com/disk-video



Source: http://systemspro.blogspot.co.uk/2011/09/hard-disk-drive.html

Hard Disk Drive Storage Structure

- Capacity
  - 2TB platter (2012/13)
  - 8TB HDD (Seagate 2014)
  - 10TB (WD HGST 2015?)
- Power consumption
  - Spinning platters
  - Moving the heads (seek)
  - Reading/Writing
  - Controllers
  - Data transfer (I/O)
- Rotation speed
  - 5400/7200/10000/15000



Source: `http://www.tldp.org/LDP/sag/html/hard-disk.html`

Hard Disk Attributes – *Performance*

Seek time — Time for the **head** to reach the target **track**.

Search time — Time for the target **sector** to arrive under the **head**. Also called *rotational latency*.

Transfer rate — Amount of data that can be read / written per unit of time. Dependent on access patterns.

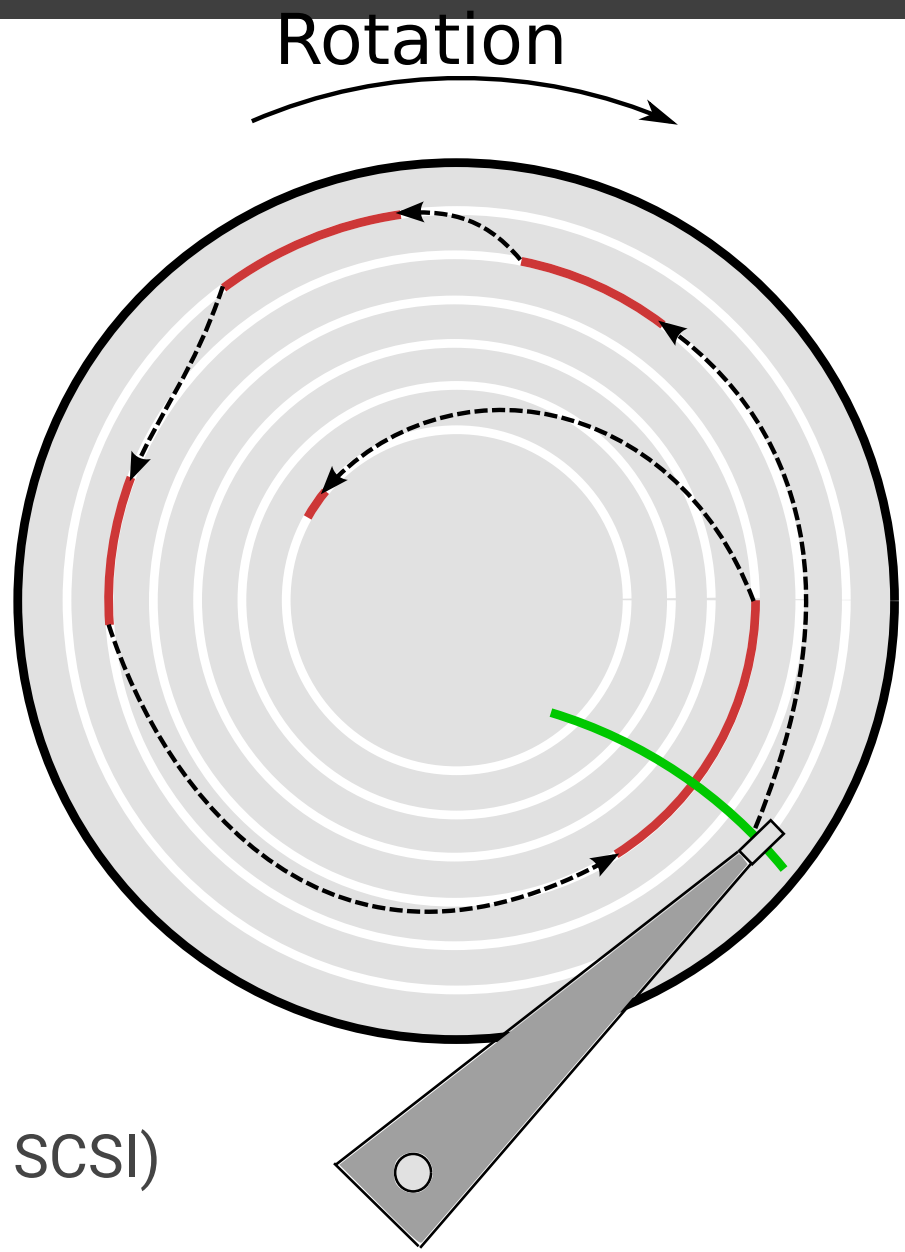
Aka. “sustained transfer rate” in contrast to “interface transfer rate”

Disk access time = seek time + search time + transfer time

Note: all values are average as they depend on many factors.

Disk access example

- Host initiates read
  sends a list of blocks to read
- Block schedule requested...
- ... may not be optimal
- and leads to extra revolutions
- HDD internal processor
  optimizes the schedule
- No direct mapping from
  block numbers to the
  sector/track/cylinder position
  (high-level interfaces like ATA / SCSI)



Example HDD specs

HGST Western Digital He6 HUS726060ALA640

- Capacity 6TB
- Power consumption: 7.3/5.3/3.7 W
- Rotational speed: 7200 RPM
- Seek time: 8.5 ms
- Sustained transfer rate: 177 MB/sec
- Interface transfer rate: 600 MB/sec (SATA)
- Data buffer: 64 MB
- MTBF: 2,500,000 hours
- Price: £250 to £400 (Q1 2015)

Example: disk access time (1)

How long would it take **on average** to read / write a 512 byte sector on this disk?

Disk access time = seek time + search time + transfer time

seek time: **8.5 ms**

search time: the disk must, on average, complete a half rotation

$$\textbf{7200 RPM} \Longrightarrow \frac{\textbf{0.5 rotations} \cdot \textbf{60} \frac{\textbf{sec}}{\textbf{min}}}{\textbf{7200 RPM}} = \textbf{4.16 ms}$$

transfer time: $\frac{\textbf{512 B}}{\textbf{177}\cdot\textbf{10}^{\textbf{6}}\ \textbf{B/sec}} = \textbf{2.89}\ \mu\textbf{s}$

$$\textbf{access time} = 8.5 + 4.16 + 2.89 \cdot 10^{-3} = \textbf{12.66 ms}$$

Example: disk access time (2)

How long would it take **on average** to read / write 512 MB on this disk? (assuming sectors are “contiguous”)

Disk access time = seek time + search time + transfer time

seek time: **8.5 ms**

search time: the disk must, on average, complete a half rotation

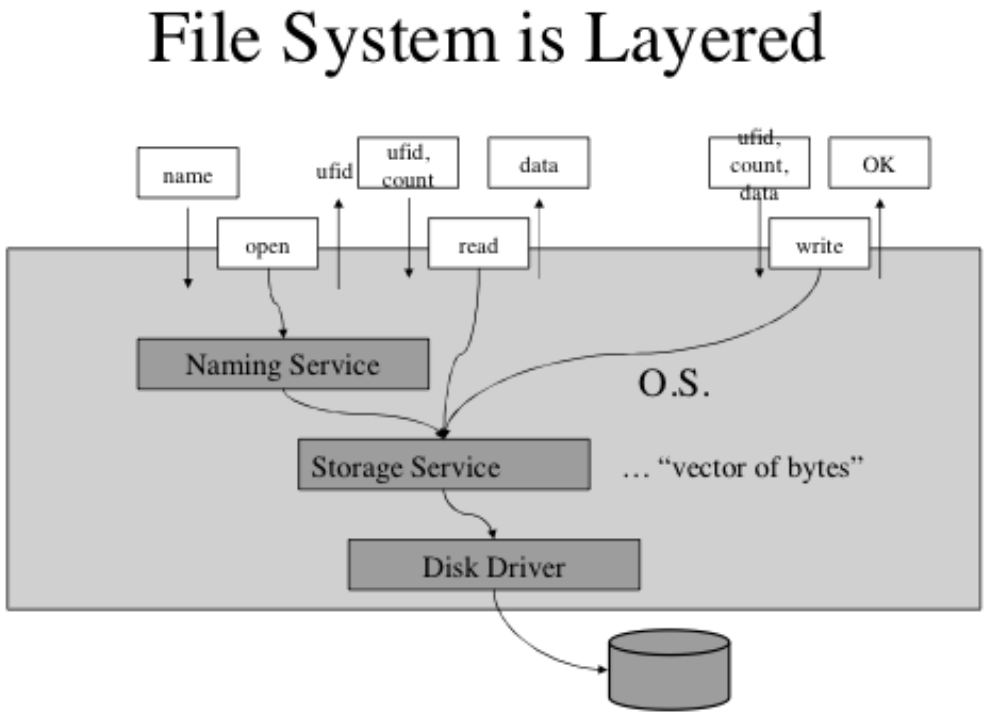
$$\textbf{7200 RPM} \Longrightarrow \frac{\textbf{0.5 rotations} \cdot \textbf{60}\,\frac{\textbf{sec}}{\textbf{min}}}{\textbf{7200 RPM}} = \textbf{4.16 ms}$$

transfer time: $\frac{512 \cdot 10^6 \text{ B}}{177 \cdot 10^6 \text{ B/sec}} = 2.89 \text{ s}$

$$\textbf{access time} = 8.5 \cdot 10^{-3} + 4.16 \cdot 10^{-3} + 2.89 = 2.9 \text{ s}$$

File System Review

- Naming service
  - files
  - directories
  - links
- Storage service
  - “vector of bytes”
  - owners, permissions...
- Data and metadata
- Space allocation
  - contiguous
  - linked
  - indexed
- Recovery
  - chkdsk, fsck



Problems with disks

Small

Slow

Unreliable

Disks are (were?) too small

1956 first HDD IBM 350: $\sim$ 3.5 MB (enough to store one selfie!)
2015 first 10 TB disk: 1000s of times smaller, $\mathbf{3 \cdot 10^6}\times$ capacity

10^{10} higher storage density in 60 years: is this enough ?

Source: `https://www-03.ibm.com/ibm/history/exhibits/storage/storage_350.html`

If one disk is not enough ...

Use multiple disks

- Independent disks
- Can we have a single volume with the combined capacity ?
- Storage virtualization

Redundant **A**rray of **I**ndependent **D**isks

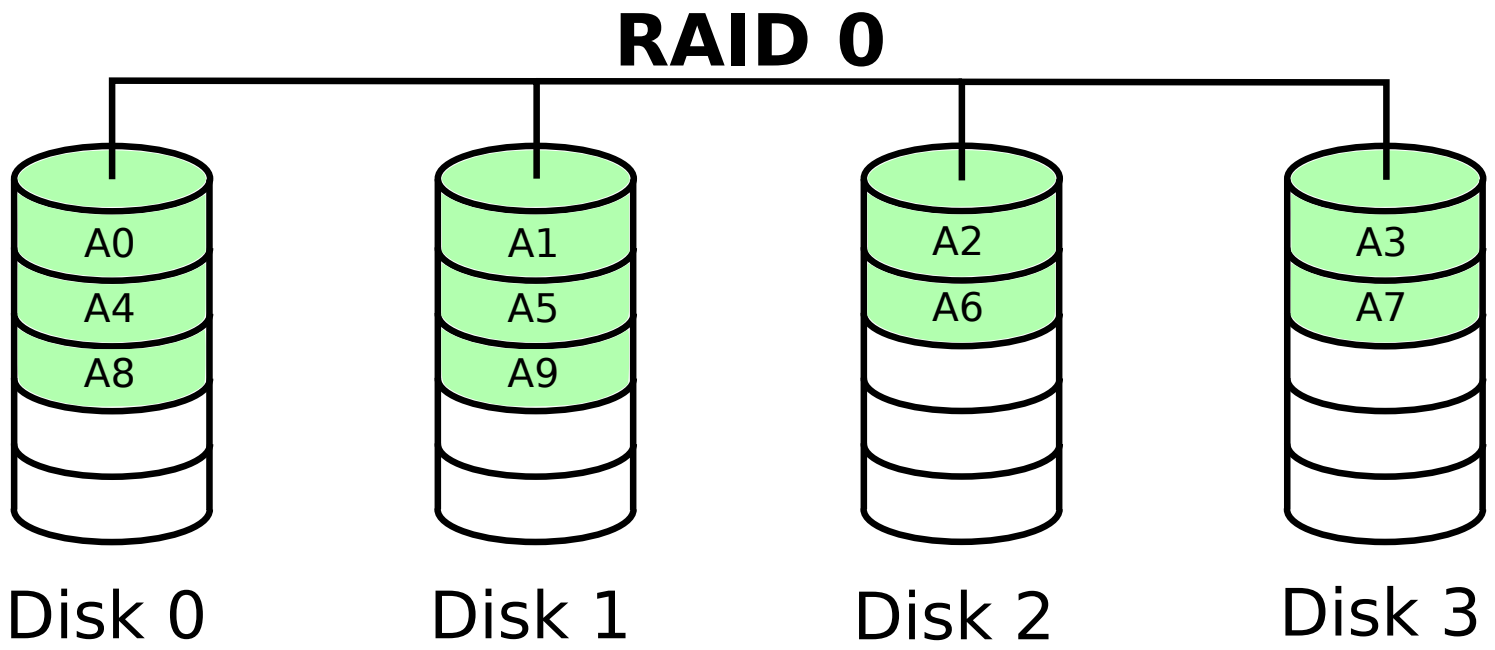
Disks are too slow

Slow because of:

- High seek time
  - Reduce the number of times the head must move
  - Multiple platters $\Longrightarrow$ more tracks/sectors per cylinder
- High search time (aka. rotational latency)
  - Increase the rotation speed (e.g., server disks up to 15000 RPM)
- Low sustained transfer rate
  - Increase rotation speed (physical limitations)
  - Increase the recording density (physical limitations)
  - Apply cache and prefetch principles
  - **“Stripe” file system across multiple disks**

Solution: Disk Striping (RAID 0)

- Split data evenly across multiple disks
- Distribute fixed-size “stripes” of a virtual volume
- Illusion of **faster** and **larger** disk



BUT lower reliability !

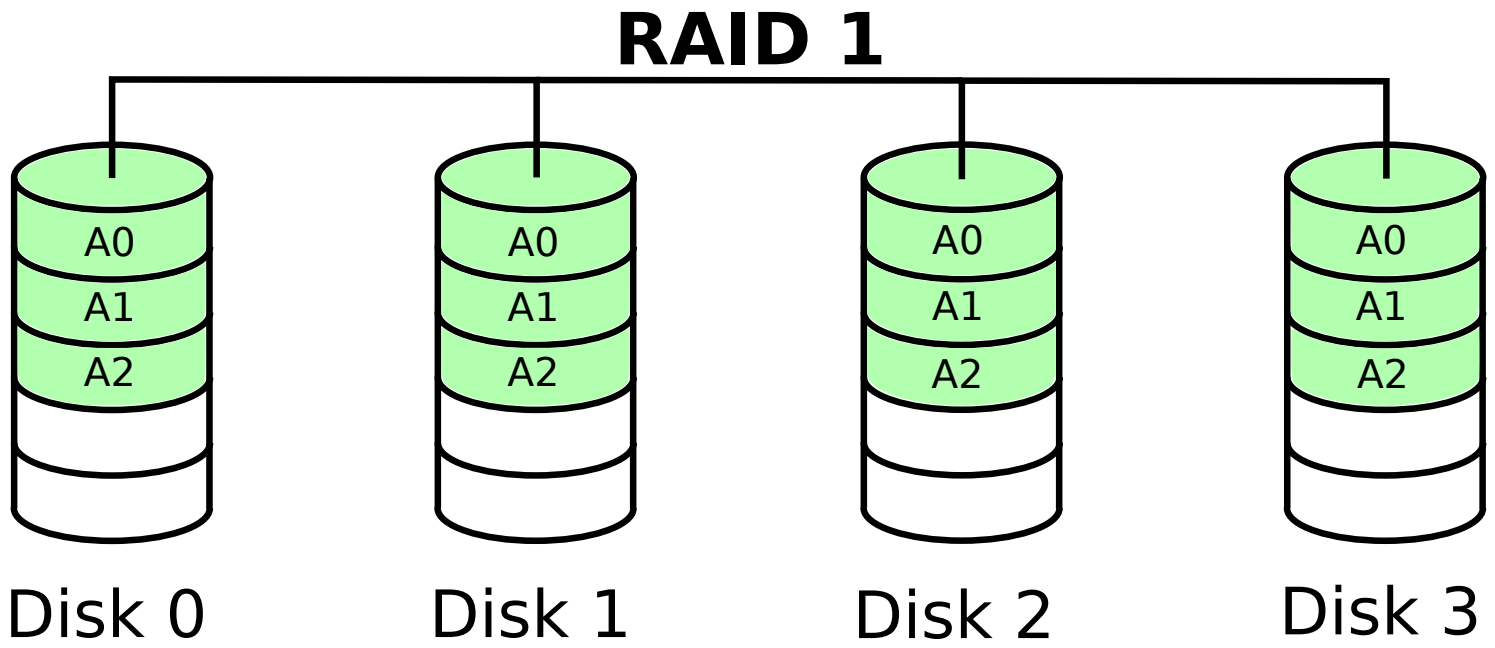
Disks are unreliable

- Mechanical components subject to wear
- Partial failure: sectors go bad
- Total failure: no data recoverable

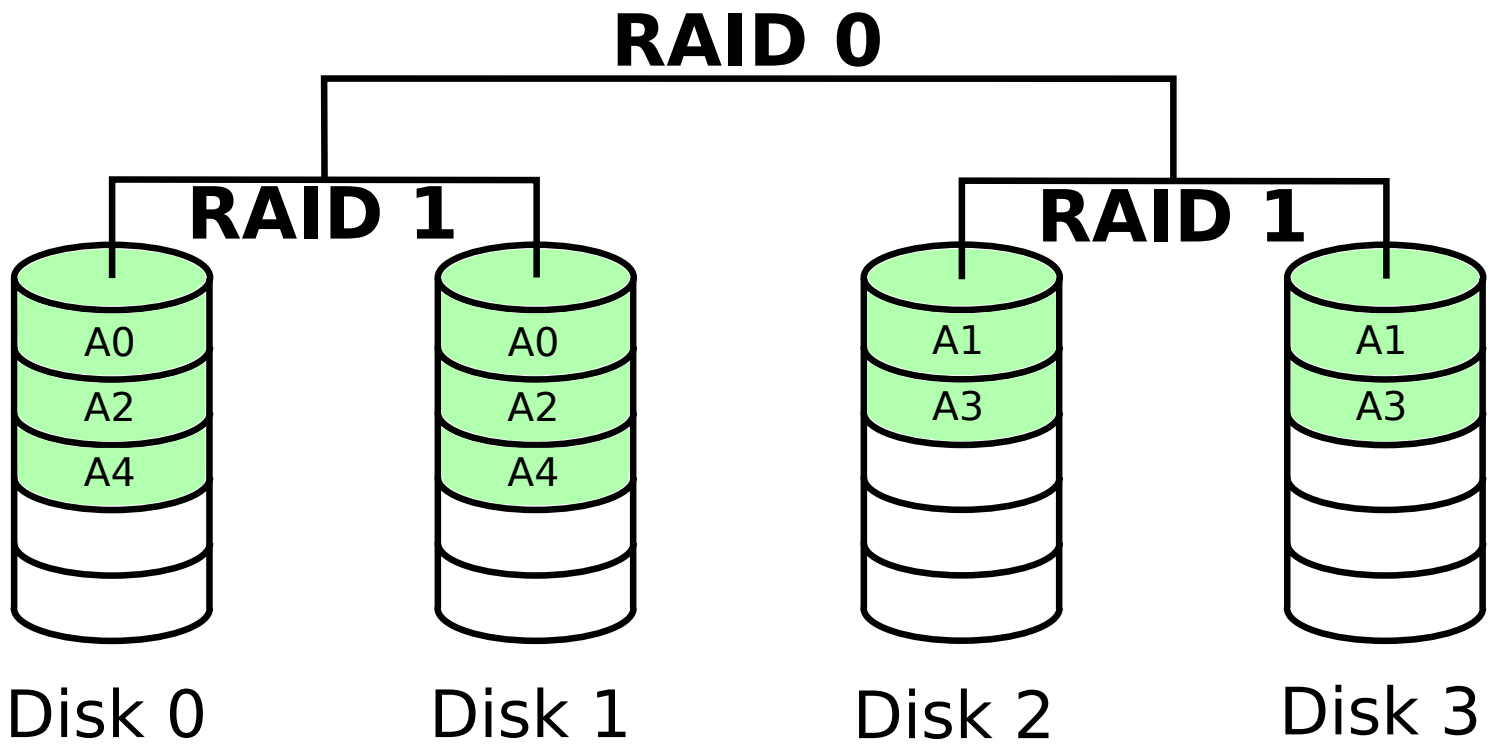
- If reliability cannot be improved: **tolerate failures**
  - Fault-tolerance through redundancy
  - Disk “mirror”

Solution: Disk Mirroring (RAID 1)

- Use two (or more) redundant disks
- Write to each (same, replicated data)
- Read from either (possibly choose “nearest” for performance)
- If one fails: use the other and re-create a new copy (slowly)



Nested RAID: RAID 1+0 (aka. RAID 10)



- Operation continues in case of disk failure
- Can tolerate failures as long as no mirror loses all drives

Summary: Problems and (simple) Solutions

- Disks are too small
  - Fixed: use multiple disks (possibly striped)
- Disks are too slow
  - Fixed: disk striping (RAID 0)
- Disks are unreliable
  - Fixed: disk mirroring (RAID 1)

- Disks may be in the wrong place !
  - What happens when we migrate a Virtual Machine ?

`Better solutions on Wednesday`