Module 13
Redundant Arrays of Inexpensive Disks (RAID) and OS structure

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The challenge

- Disk transfer rates are improving, but much less fast than CPU performance
- We can use multiple disks to improve performance
  - by *striping* files across multiple disks (placing parts of each file on a different disk), we can use parallel I/O to improve access time
- Striping reduces reliability
  - 100 disks have 1/100th the MTBF (mean time between failures) of one disk
- So, we need striping for performance, but we need something to help with reliability / availability
- To improve reliability, we can add redundant data to the disks, in addition to striping

RAID

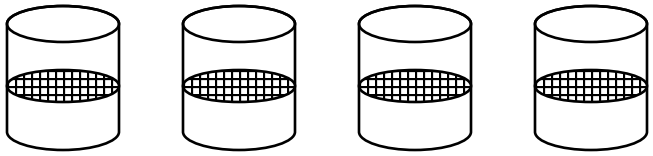
- A RAID is a Redundant Array of Inexpensive Disks
- Disks are small (physically) and cheap, so it's easy to put lots of disks (10s to 100s) in one box for increased storage, performance, and availability
- Data plus some redundant information is striped across the disks in some way
- How striping is done is key to performance and reliability

Some RAID tradeoffs

- Granularity
  - fine-grained: stripe each file over all disks
    - high throughput for the file
    - limits transfer to 1 file at a time
  - coarse-grained: stripe each file over only a few disks
    - limits throughput for 1 file
    - allows concurrent access to multiple files
- Redundancy
  - uniformly distribute redundancy information on disks
    - avoids load-balancing problems
  - concentrate redundancy information on a small number of disks
    - partition the disks into data disks and redundancy disks

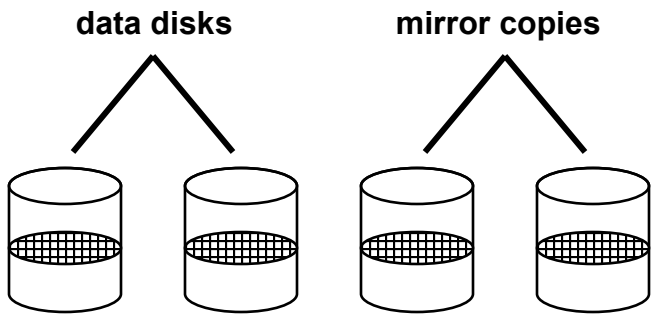
RAID Level 0

- RAID Level 0 is a non-redundant disk array
- Files are striped across disks, no redundant info
- High read throughput
- Best write throughput (no redundant info to write)
- Any disk failure results in data loss; sometimes a file, sometimes the entire *volume*



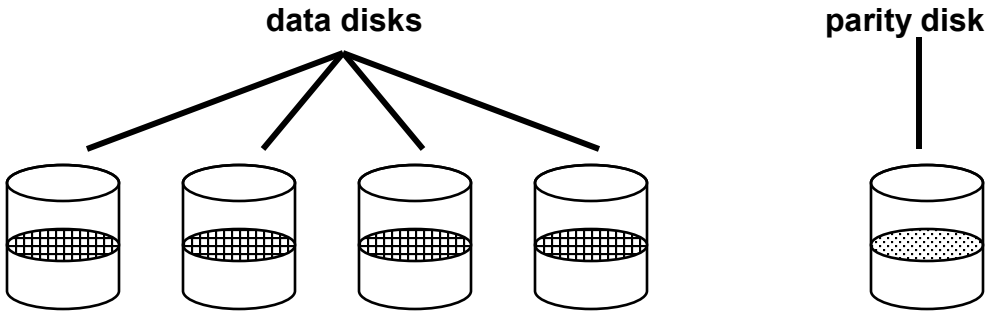
RAID Level 1

- RAID Level 1 is mirrored disks
- Files are striped across (half) the disks
- Data is written to multiple (two) places – data disks and mirror disks
- On failure, just use the surviving disk(s)
- Factor of N (2x) space expansion

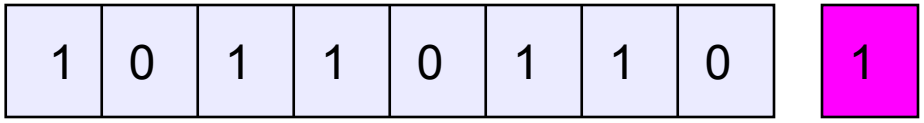


RAID Levels 2, 3, and 4

- RAID levels 2, 3, and 4 use ECC (error correcting code) or parity disks
  - E.g., each byte on the parity disk is a parity function of the corresponding bytes on all the other disks
- A read accesses all the data disks
- A write accesses all the data disks plus the parity disk
- On disk failure, read the remaining disks plus the parity disk to compute the missing data



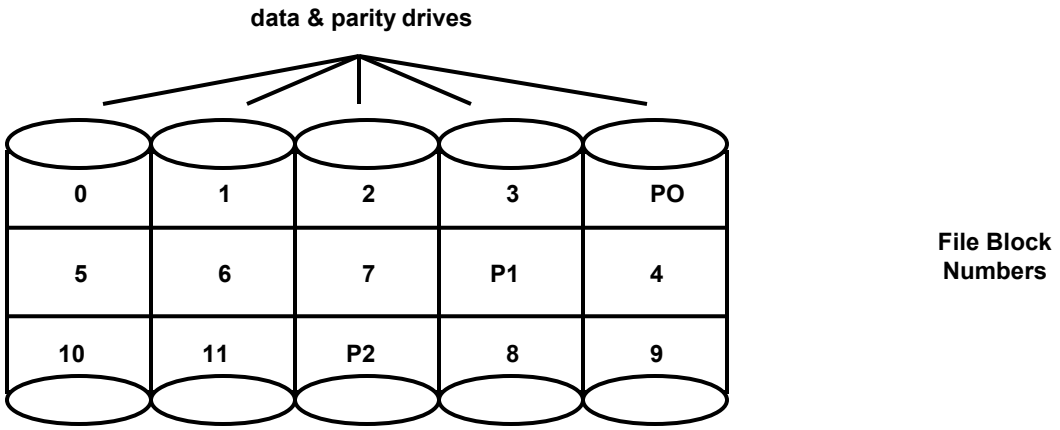
Refresher: What's parity?



- To each byte, add a bit set so that the total number of 1's is even
- Any single missing bit can be reconstructed
- (Why does memory parity not work quite this way?)

RAID Level 5

- RAID Level 5 uses block interleaved distributed parity
- Like parity scheme, but distribute the parity info (as well as data) over all disks
  - for each block, one disk holds the parity, and the other disks hold the data
- Significantly better performance
  - parity disk is not a hot spot

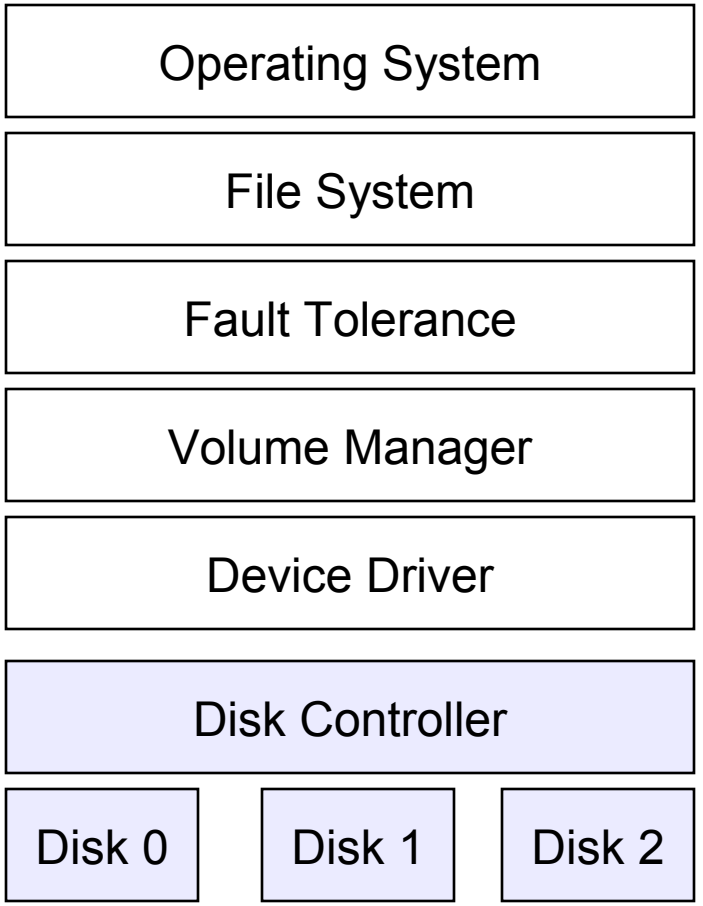


Management

- Multiple spindles complicates things
  - Visible to: Apps? File system?
  - Allocation of space (per user on a “file server”)
  - SANs
  - Differing disk sizes
- Partitions!
  - Logical division of spindle into blocks
  - Assemble volumes from partitions

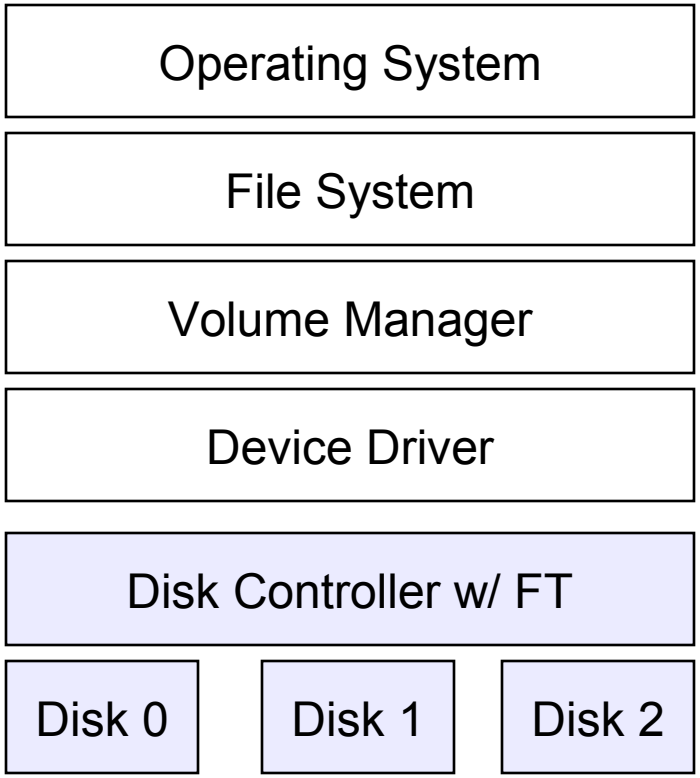
OS and Hardware Layering

- Who needs to know?
  - FS: probably not



OS and Hardware Layering

- Why put FT into hardware?
  - Speed
  - Simplicity of OS
- Why not?
  - Fixes
  - CvI data



One tiny problem with RAID and multiple spindles…

- How do you boot?
  - ROM on motherboard doesn't have a lot of room for logic
  - Boot zone on disk doesn't have a lot of room for logic (and needs to be replicated, striped, etc.)
  - Put partition info into "well-known place"
  - Put RAID info into "well-known place"
  - Still… too complicated
- "Real systems"…
  - Don't boot from multi-partition volumes
  - Boot from RAID 0, at most RAID 1 (simple failover)