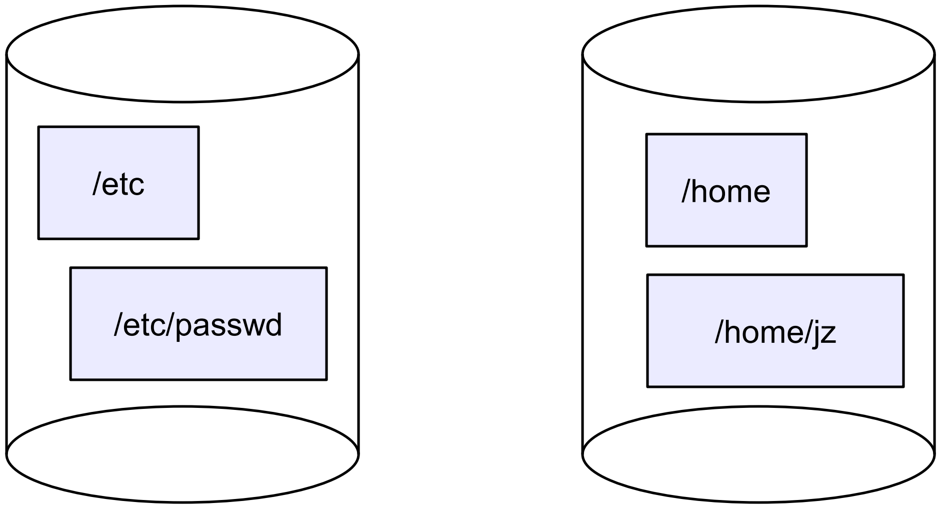
Redundant Arrays of Inexpensive Disks (RAID)

Module 12

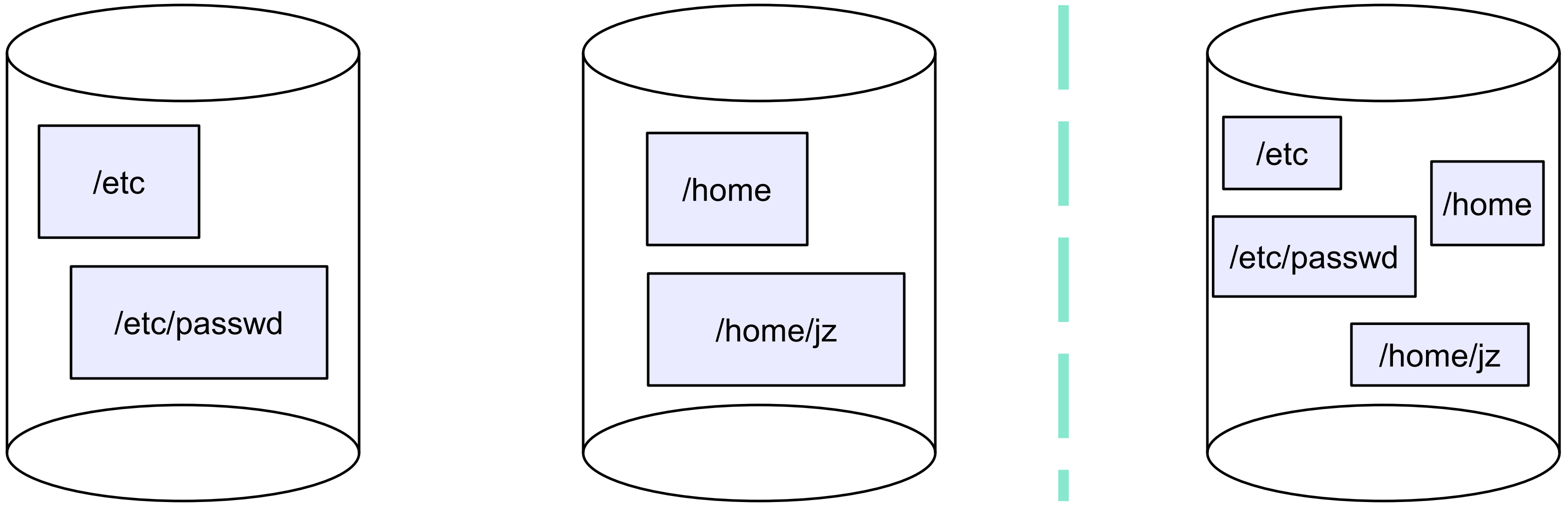
Background

- Disks are cheap
  - An individual system can have more than one

- Standard file system implementations manage all of an individual disk/partition



Two disks vs. one



- How is “peak performance” affected?
  - Are read times cut in half? Is write throughput doubled?
- How is reliability affected?
  - Is it more or less likely a disk failure will cause data loss?
  - How much of your data do you lose?

Basic Idea

- Performance: By *striping* individual files across multiple disks, we can use parallel I/O to improve access time even when overall I/O demand is bursty/low
  - There's only one file to read right now. Get it fast.
- Reliability: Striping reduces reliability
  - 10 disks have about 1/10th the MTBF (mean time between failures) of one disk
- So, we want striping for performance, but we need something to help with reliability

Reliability through Redundancy

- To achieve this level of reliability, add redundant data that allows a disk failure to be tolerated
  - We'll see how in a minute
- At the scales we're currently considering (tens of disks), it's typically enough to be resilient to the failure of a single disk
  - What are the chances that a second disk will fail before you've replaced the first one?
    - Er, it has happened to us!
- So:
  - Obtain performance from striping
  - Obtain reliability from redundancy

RAID

- RAID: Redundant Array of Inexpensive Disks
- Disks are small and cheap, so it's easy to put lots of disks (10s, say) 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

RAID Implementation

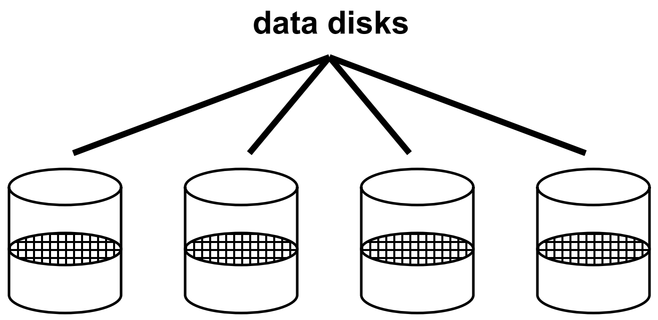
- Option A: hardware
  - The hardware RAID controller deals with this
    - From the OS’s perspective, the multi-disk RAID looks like one big array of blocks
- Option 2: software
  - A low level layer of the OS knows there are multiple disks, but presents them to upper layers as a single block device
    - That is, it does what the hw RAID controller does
- It doesn’t matter to what follows which approach is used

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

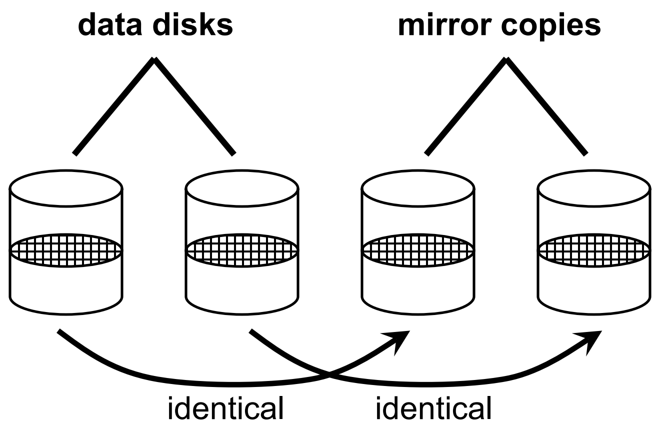
RAID Level 0: Non-Redundant Striping

- RAID Level 0 is a <u>non-redundant</u> disk array
- Files/blocks are striped across disks, no redundant info
- High (single-file) read throughput
- Best write throughput (no redundant info to write)
- Maximum use of disk capacity
- Any disk failure results in data loss

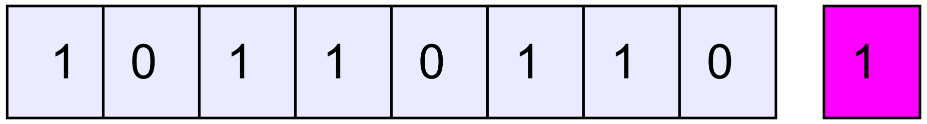


RAID Level 1: Mirrored Disks

- Files are striped across half the disks, and mirrored to the other half
  - 2x space expansion
- Reads: Read from either copy
- Writes: Write both copies
- On single drive failure, just use the surviving disk during repair
- If two disks fail, you rely on luck…



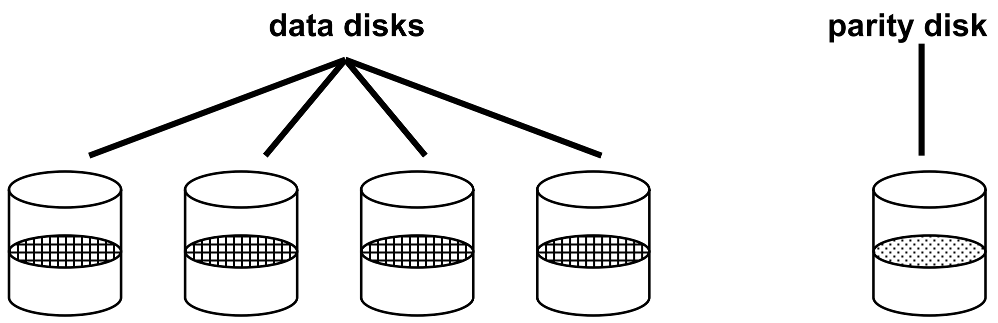
Prelude to RAID Levels 2-5: A parity refresher



- To each byte, add a bit whose value is set so that the total number of 1's is even
- Any single missing bit can be reconstructed
- More sophisticated schemes, called ECC (error correcting codes), can correct multiple bit errors

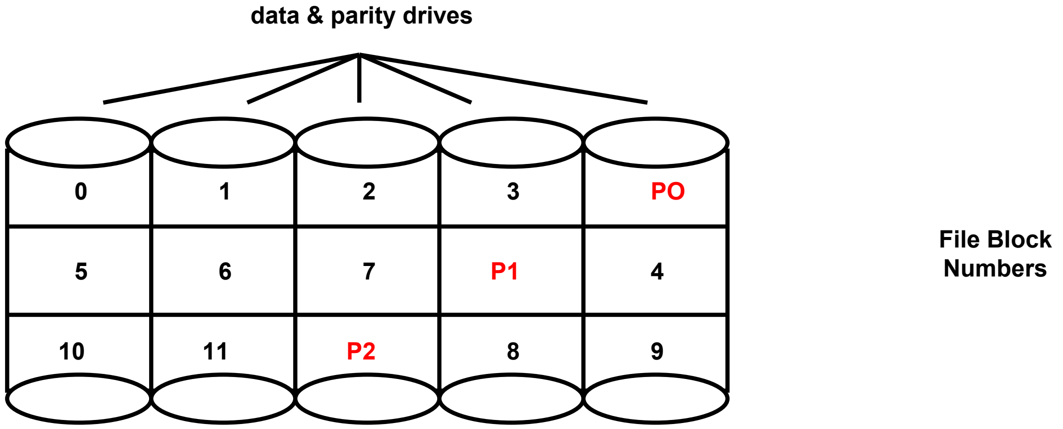
RAID Levels 2, 3, and 4: Striping + Parity Disk

- RAID levels 2, 3, and 4 use <u>parity</u> or <u>ECC</u> disks
  - e.g., each byte on the parity disk is a parity function of the corresponding bytes on all the other disks
  - details between the different levels have to do with kind of ECC used, and whether it is bit-level, byte-level, or block-level
- 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



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



RAID Level 6

- Basically like RAID 5 but with replicated parity blocks so that it can survive two disk failures.
- Useful for larger disk arrays where multiple failures are more likely.

RAID Summary

- Why use multiple disks (vs. one bigger disk)?
- What kinds of errors is RAID designed to protect against?
- If you have RAID, do you need journaling?
- If you have RAID, is a log structured file system of any use?
- If you have RAID, do you need file system backups?
- Is there any realistic situation in which you might lose “too many” disks at once?
  - For example, all of them?