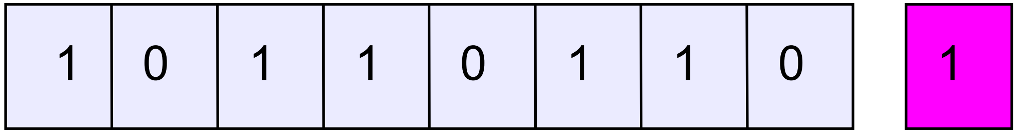
CSE 451
Week 9
OooOOOOooo
RAID and Project 3

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

Refresher: What's parity?



1 0 1 1 0 1 1 0 1

- To each byte, add a bit whose value is set so that the total number of 1's is even
- Any single-bit error can be detected
  - If you know which bit has failed, you can reconstruct it, but memory errors typically occur "silently"
- More sophisticated schemes (e.g., based on Hamming codes) can detect multiple bit errors and correct single bit errors – called ECC (error correcting code) memory

RAID

- A RAID is a Redundant Array of Inexpensive Disks
- Disks are small 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

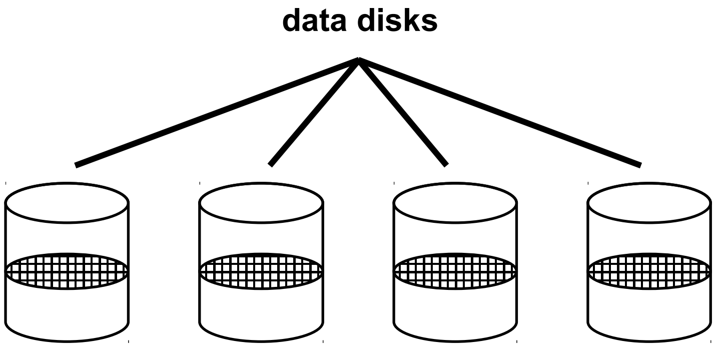
- Granularity
  - fine-grained: stripe each file over all disks
    - high throughput for the file
    - limits transfer to 1 file at a time
  - course-grained: stripe each file over only a few disks
    - limits throughput for 1 file
    - allows concurrent access to multiple files
- Redundancy
  - 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 metrics

- How do we measure the benefits of RAID?
  - Spatial efficiency
    - How much redundancy is needed?
  - Performance
    - These can be different for reads, writes (large or small)
  - Fault Tolerance
    - How many disks can fail concurrently?

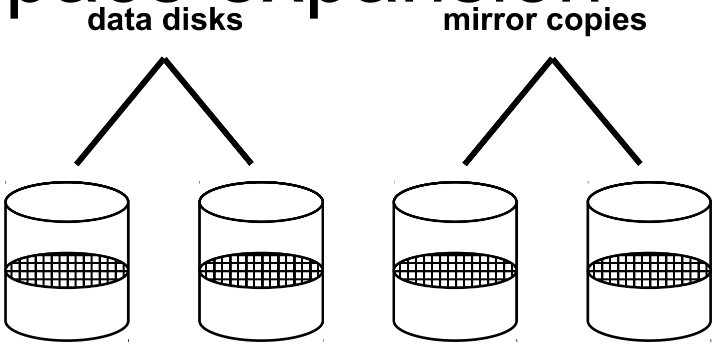
RAID Level 0

- RAID Level 0 is a non-redundant disk array
- Files/blocks 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



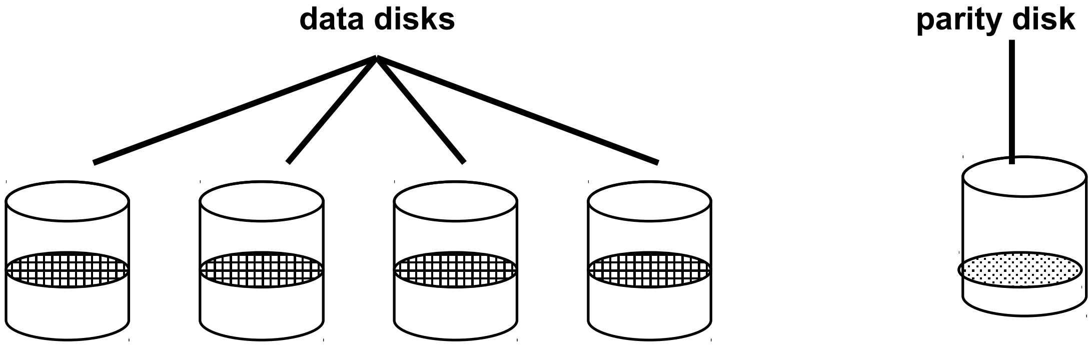
RAID Level 1

- RAID Level 1: mirrored disks
- Files/blocks are striped across half the disks
- Data is written to two places
  - a data disk and a mirror disk
- On failure, just use the surviving disk
- 2x space expansion



RAID Levels 2, 3, and 4

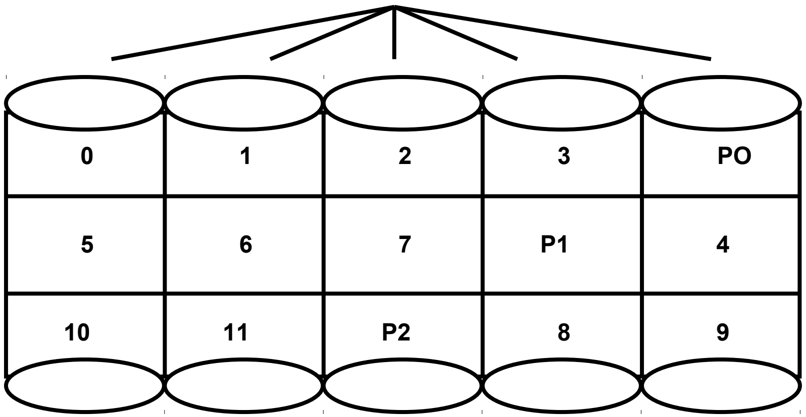
- RAID levels 2, 3, and 4 use ECC or parity disks
  - e.g., each byte on the parity disk is a parity function of the corresponding bytes on all the other disks
  - details between the different levels have to do with kind of ECC used, and whether it is bit-level or block-level
- A read accesses all the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

data & parity drives



0	1	2	3	PO
5	6	7	P1	4
10	11	P2	8	9

File Block Numbers

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.

Other RAIDs

- It's possible to create hybrid RAID schemes
  - RAID 10
  - RAID 01
  - RAID 51
- Also, there are also none-RAID architectures
  - JBOD (Just a bunch of disks)

Project 3

- Undelete in ext2
- Fairly straightforward. Only real words of warning:
  - Don't store try to entire file system in memory.
  - This is the first real opportunity for us to automate some grading. Follow the directions or you'll break the scripts.
  - Please don't take this away from me...