

2023 Fall ECE 344: Operating Systems

Lecture 25

1.0.0

Disks

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Solid State Drives (SSD) Are More Modern

Use transistors (like RAM) to store data rather than magnetic disks

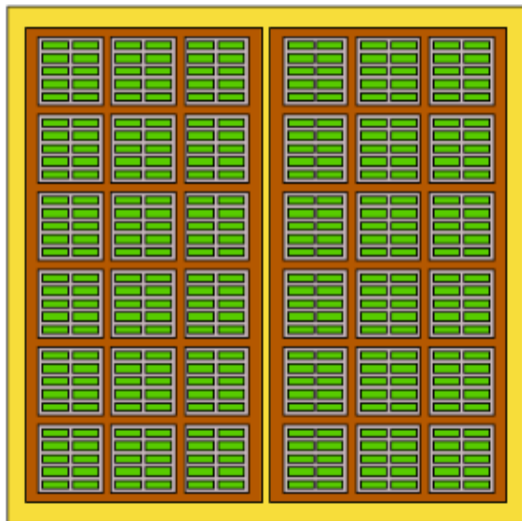
Pros

- No moving parts or physical limitations
- Higher throughput, and good random access
- More energy efficient
- Better space density

Cons

- More expensive
- Lower endurance (number of writes)
- More complicated to write drivers for

A SSD Contains Pages



Die



Plane



Block



Page

SSDs Using NAND Flash Are Much Faster Than HDDs

Pages are typically 4 KiB

Reading a page: 10 μ s

Writing a page: 100 μ s

Erasing a block: 1 ms

NAND Flash Programming Uses Pages and Blocks

You can only read complete pages and write to freshly erased pages

Erasing is done per block (a block has 128 or 256 pages)

An entire block needs to be erased before writing

Writing is slow (may need to create a new block)

The OS Can Help Speed Up SSDs

SSDs need to garbage collect blocks

Move any pages that are still alive to a new block (may be overhead)

The disk controller doesn't know what blocks are still alive

SSD may think the disk is full, when a file could be deleted (not erased)

The OS can use the *TRIM* command to inform the SSD a block is unused

The SSD can freely erase the block without moving overhead

So Far We've Been Talking About Single Devices

Sometimes called Single Large Expensive Disk (SLED)

- Just one large disk for data

- Single point of failure

There's also Redundant Array of Independent Disks (RAID)

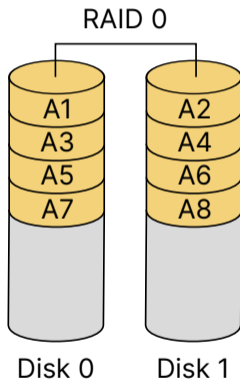
- Data distributed on multiple disks

- Use redundancy to prevent data loss

- Use redundancy to increase throughput

RAID 0 is Called a Striped Volume

Data stripes (128KB and 256KB) are distributed over disks



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RAID 0 is For Performance Only

The data is striped across all disks in the array (you can have more than 2)

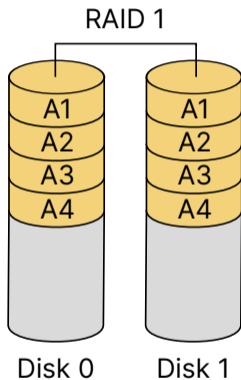
Pro

Faster parallel access, roughly N times speed

Con

Any disk failure results in a data loss (more points of failure)

RAID 1 Mirrors All Data Across All Disks



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RAID 1 is Simple, But Wasteful

Every disk in the array has a mirrored copy of all the data

Pro

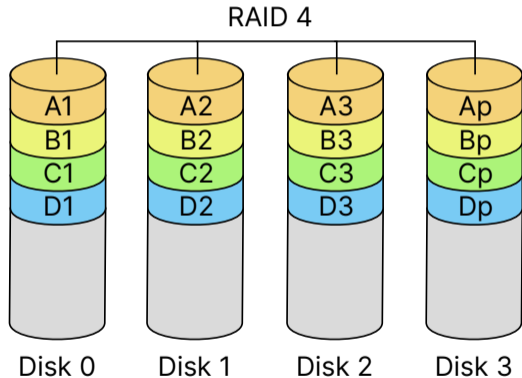
Good reliability, as long as one disk remains, no data loss
Good read performance

Con

High cost for redundancy (we can do better)
Write performance is the same as a single disk

RAID 4 Introduces Parity

Data stripes distributed over disks with a dedicated parity disk (p = parity)
Parity stores xor \oplus of copies 1-3, any one copy can be reconstructed



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RAID 4 Can Use the Parity Drive to Recover

With parity, we can use $1 - \frac{1}{N}$ of the available space
Requires at least 3 drives

Pro

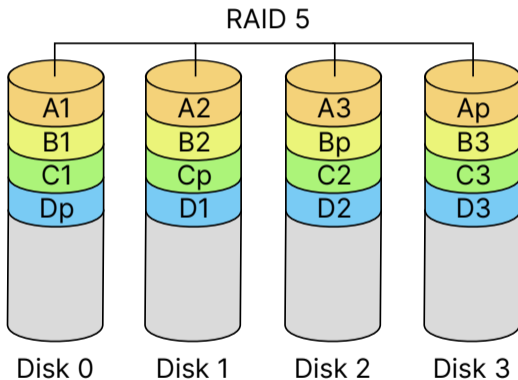
We get $(N - 1)$ times performance (removing parity disk)
We can replace a failed disk and rebuild

Con

Write performance can suffer, every write must write to parity disk

RAID 5 Distributes Parity Across All Disks

Data stripes distributed over disks and each disk takes turns with parity blocks



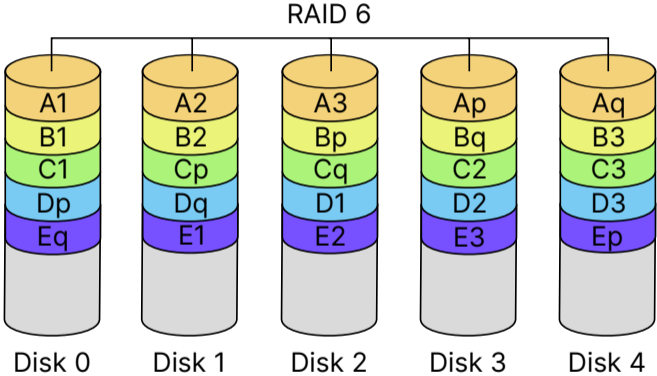
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RAID 5 is an Improved Raid 4

It has all the same pros as RAID 4

Write performance is improved, no longer a bottleneck on a single parity drive

RAID 6 Adds Another Parity Block Per Stripe



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RAID 6 Can Recover from 2 Simultaneous Drive Failures

Due to the extra parity, we can use $1 - \frac{2}{N}$ of the available space
Requires at least 4 drives

Write performance is slightly less than RAID 5, due to another parity calculation

Disks Enable Persistence

We explored two topics: SSDs and RAID

- SSDs are more like RAM except accessed in pages and blocks
- SSDs also need to work with the OS for best performance (TRIM)
- Use RAID to tolerate failures and improve performance using multiple disks