Betriebssysteme

11. Tutorium - Storage

Peter Bohner

23. Januar 2024

ITEC - Operating Systems Group

ÜB 9

- Lief gut - von meiner Seite aus kein Besprechungsbedarf
- Fragen euerseits?

Wiederholung - Scheduling

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- Was ist thrashing?
- Welche threading Modelle kennt ihr? Vor- / Nachteile? One-to-One (Langsam, Kernel Support, einfach), Many-to-one (kein Kernel support, kein SMP), Many-to-Many (upcalls, komplexität)
- Unterschied KLT, KMT?

Wiederholung - Klausuraufgaben

- Speicher - Segmentation: WS21 final1 T3
- Caching: WS1617 final1 T4 c,d

Device Management

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- Examples? SSD, HDD, ...

Character Devices

- Provide a stream of characters
- Examples? Mice, Keyboard, (classic) text terminals

Communication with Devices

Port Based I/O

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Separate address space with dedicated instructions for reading/writing

- \+ Clear distinction in code $\Rightarrow$ Optimizing easier (reordering, caching, ...)
- \- Less flexible, often lower performance

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Device registers are mapped into the physical address space. How do you access that?

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Memory-mapped I/O

Device registers are mapped into the physical address space. How do you access that? Normal instructions!

+ Higher flexibility: Virtual memory, larger instruction set, mostly transparent
- Some special rules apply to I/O regions software needs to be aware of

Similar Names - Compare DMA, memory-mapped I/O and memory-mapped files

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Memory Mapped Files

- OS abstraction: Treat a file like a normal range of virtual memory
- No real relation to DMA, though the OS might use it to synchronize Memory Mapped Files with the underlying device

I/O Operations

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- Interrupts $\Rightarrow$ I/O devices send an interrupt signal

Hard Disks

Hard Disk Layout

What parts can you find in a hard disk?

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What parts can you find in a hard disk?

- Heads

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- Heads
- Arms

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What parts can you find in a hard disk?

- Heads
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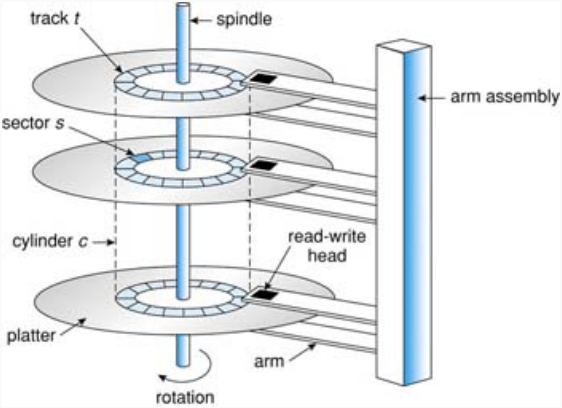
- Platters

Hard Disk Layout

What parts can you find in a hard disk?

- Heads
- Arms
- Platters
- Spindle

Hard Disk Layout



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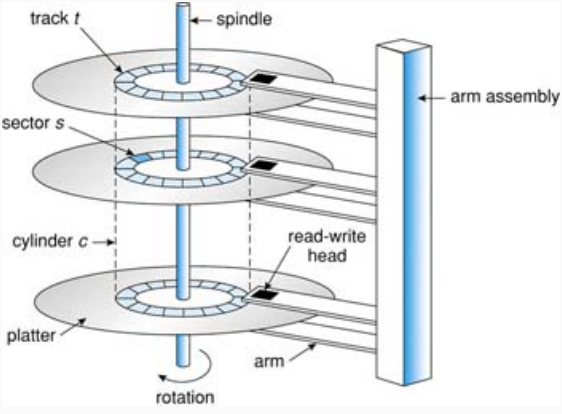

What do they do?

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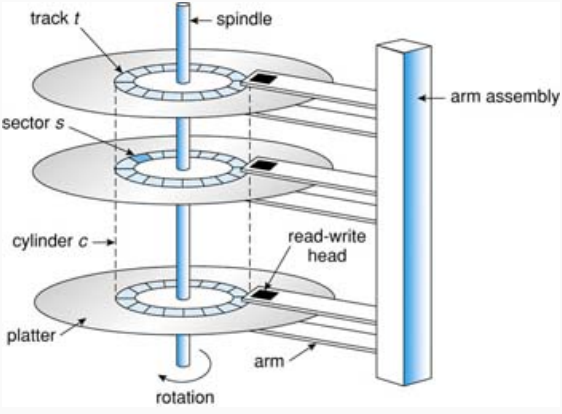

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- Spindle: Spin connected platters!

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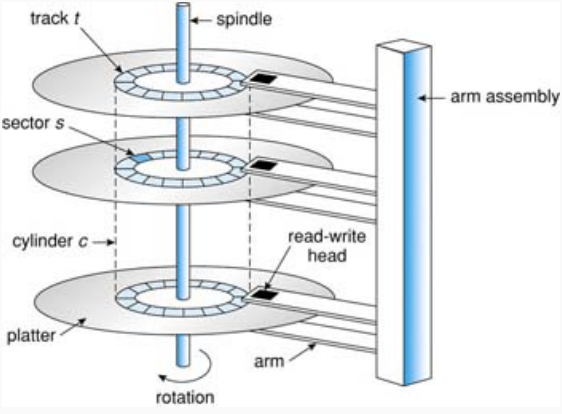

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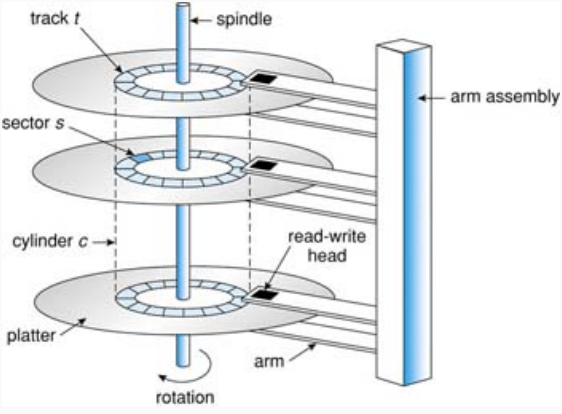

What do they do?

- Spindle: Spin connected platters!
- Head: Read/Write
- Arm: Move heads

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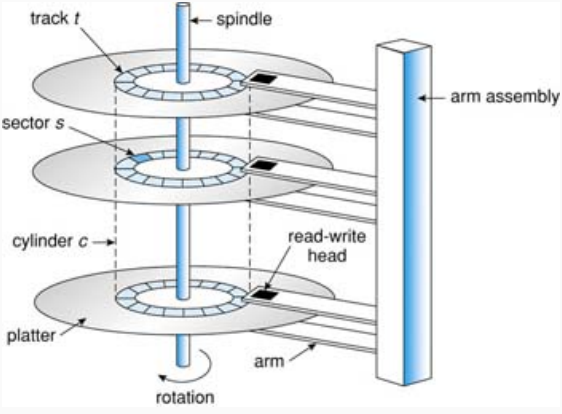

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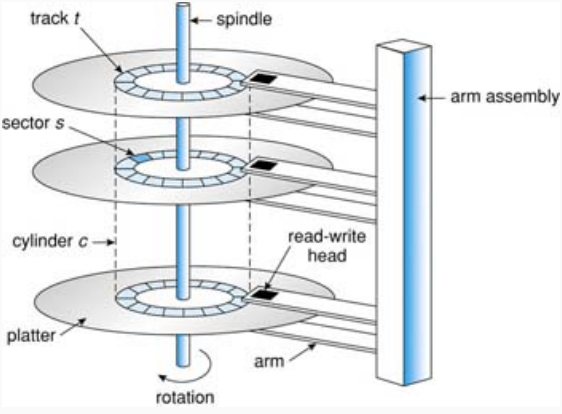

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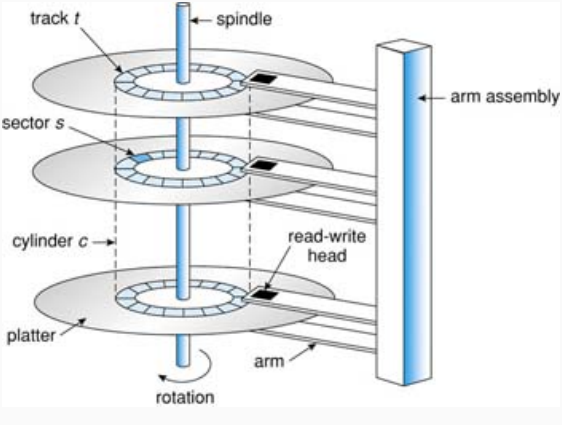

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- Cylinder - Head - Sector (CHS). Limited to „small“ disks (< 8GB), rarely used these days
- Logical Block Addressing (LBA). Each data block has its own unique number.

How could you optimize the OS $\Leftrightarrow$ Disk interface?

Native-Command-Queuing. OS sends reads and writes in batches and (the disk | the OS) reorders them based on internal geometry.

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Wear and Tear

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Disk marks it as such and never uses it again ⇒ *Sector sparing*.

What adverse effect might this have?

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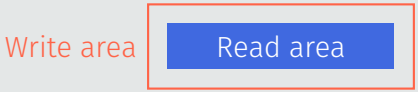
What adverse effect might this have? OS disk scheduler is unaware and optimizes for wrong geometry.

Hard Disk Layout - More Data!

Optimizing storage



What can you do with this?

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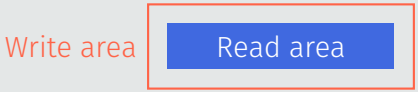

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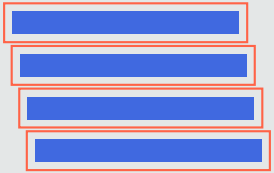

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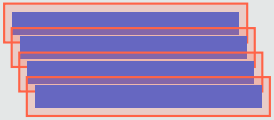

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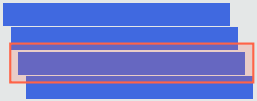

What happens when you write to this track?

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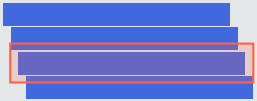

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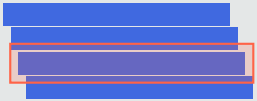

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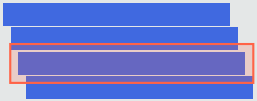

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⇒ Append only and group shingled tracks

⇒ Can rewrite the whole group at once

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- Compromise. Tell the OS where your singled zones are and expose their tail. If the OS writes to the tail, directly commit it - else buffer.
  $\Rightarrow$ *Host Aware*

Solid-State Drives

NAND based flash memory

Rejoice, TI might be useful once

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What happens when you just write to a random page?

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$\Rightarrow$ You do not pay the erase penalty!

- When do you create / reserve / erase those spare pages?

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Deleting files

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What can the OS do to combat that?

The `trim` command

Can be issued by the OS to tell the SSD firmware what pages can be safely erased.

RAID

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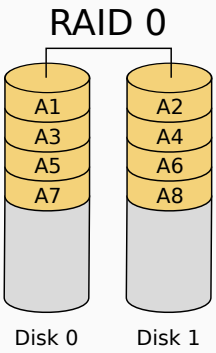
- Might be more resilient
- Might be faster

RAID - And now?

Great, you now have multiple disks. How do you store your files on them?

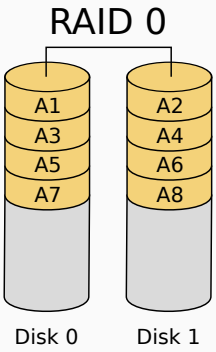
- „I like to live dangerously“ - RAID Level 0
- Mirroring: RAID Level 1
- Historic variants: RAID Level 2 and 3
- Block striping and parity: RAID Level 4
- Block striping and *distributed* parity: RAID Level 5

RAID 0



Benefits / Drawbacks?

RAID 0



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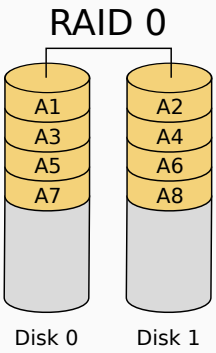

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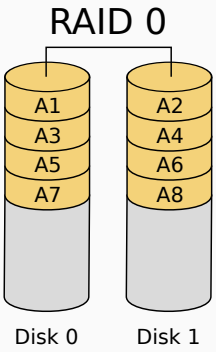
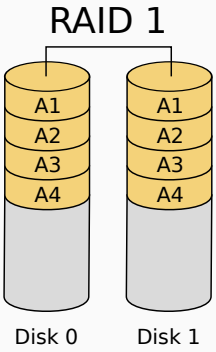


Benefits / Drawbacks?

+ Extremely fast (parallel reads and writes)
+ Can use full capacity
- If a single disk fails your files are toast

RAID 1



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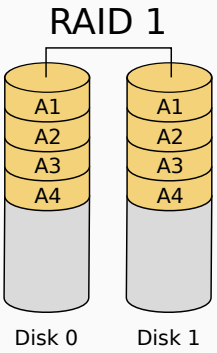

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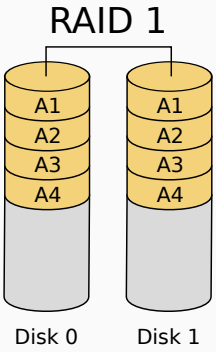

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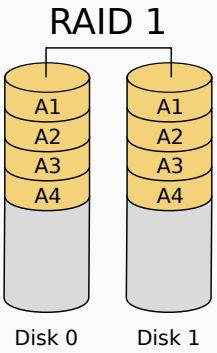

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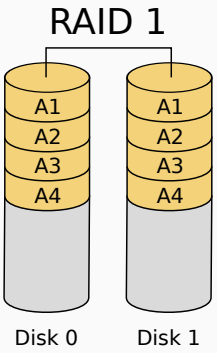

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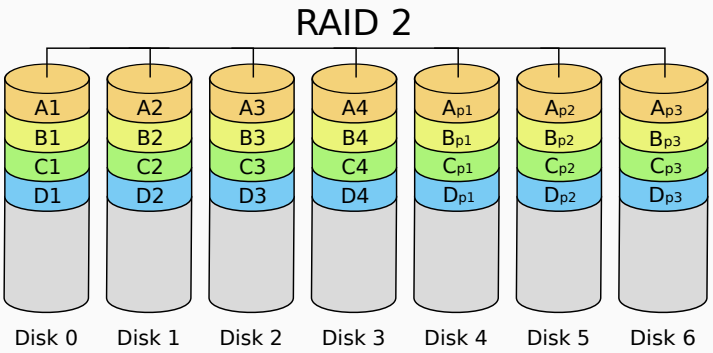
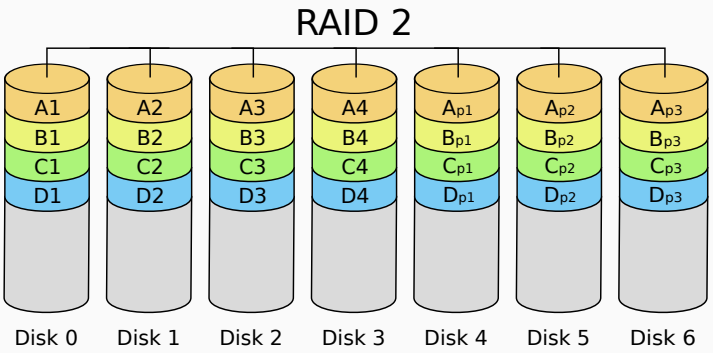
- Writes slower as they need to write to all disks
- Size equals the size of a single disk



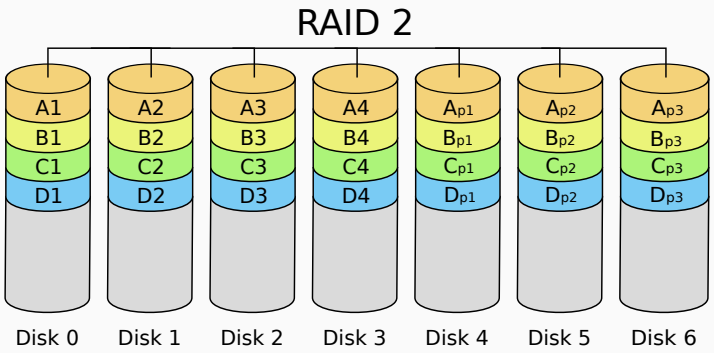
What is that?

- Have $\log_2(N)$ parity disk



What is that?

- Have $\log_2(N)$ parity disk
- Stripe data at the *bit* level



What is that?

- Have $\log_2(N)$ parity disk
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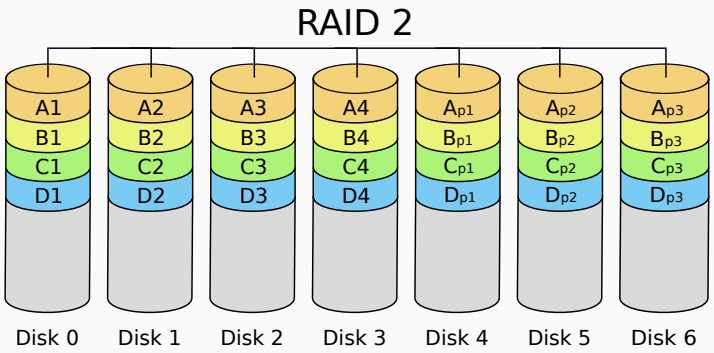
- Use a hamming code of proper size



What is that?

- Have $\log_2(N)$ parity disk
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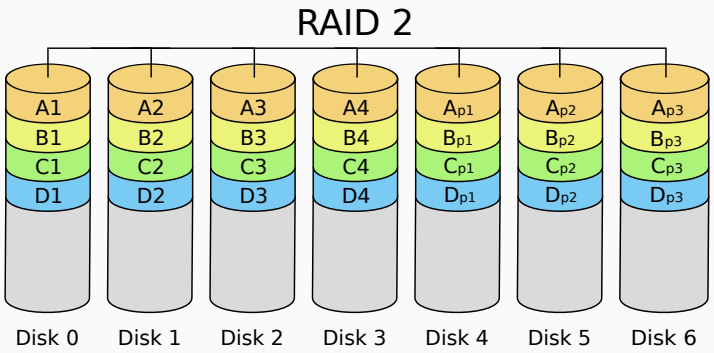
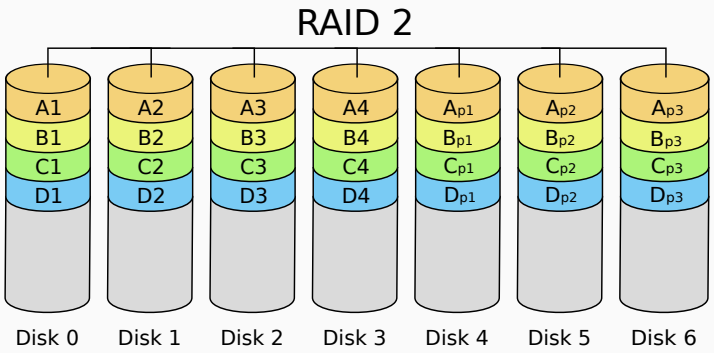
- Use a hamming code of proper size
- Spin the disks in lockstep (so you read all bits of your word at once)

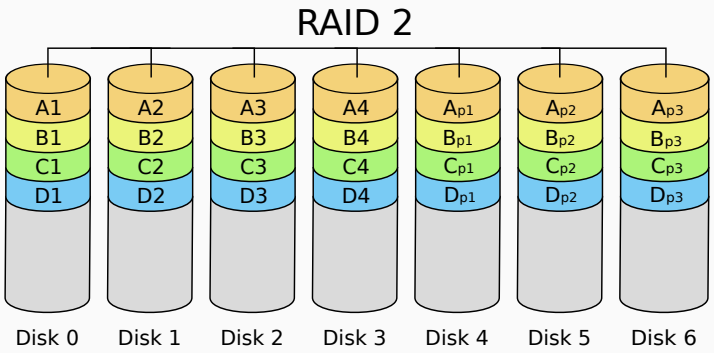


Benefits / Drawbacks



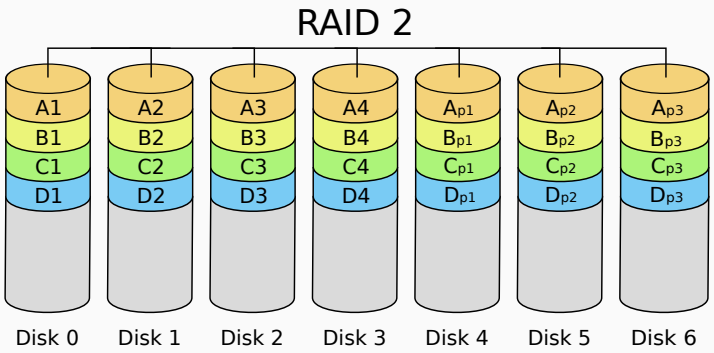
Benefits / Drawbacks

+ External error checking



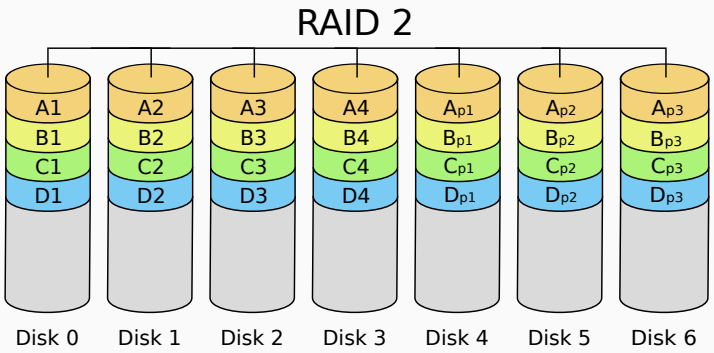
Benefits / Drawbacks

+ External error checking
- Really slow



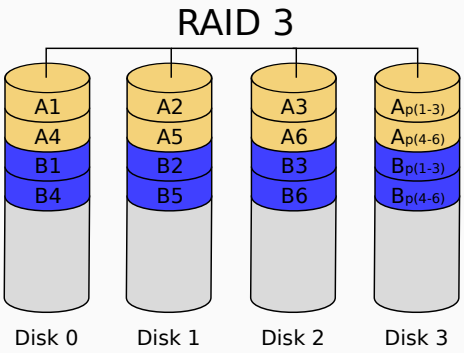
Benefits / Drawbacks

+ External error checking
- Really slow
- Not that useful as disks have internal error checking by now



Benefits / Drawbacks

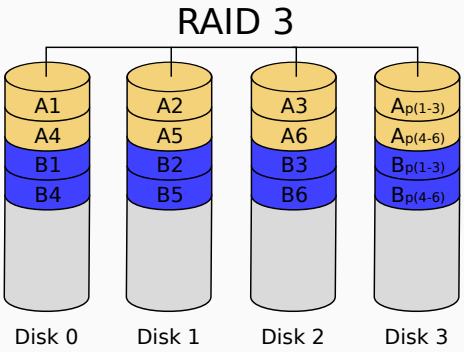
+ External error checking
- Really slow
- Not that useful as disks have internal error checking by now
- Spins in lockstep ⇒ Can only service one request at a time



What is that?

- Have a dedicated parity disk

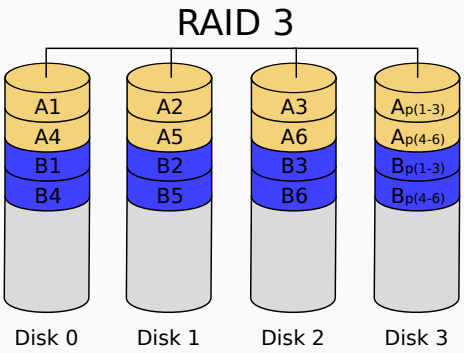
RAID 3



What is that?

- Have a dedicated parity disk
- Stripe data at the *byte* level

RAID 3



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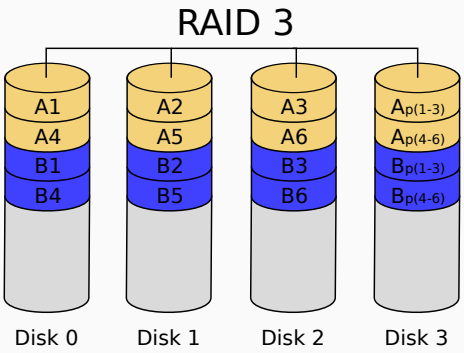
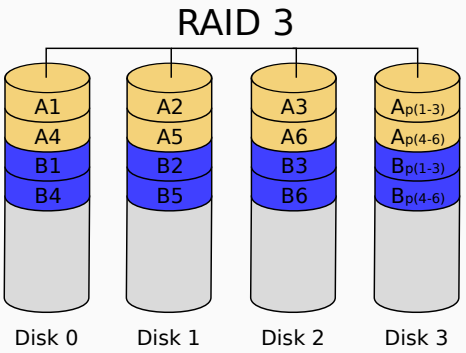
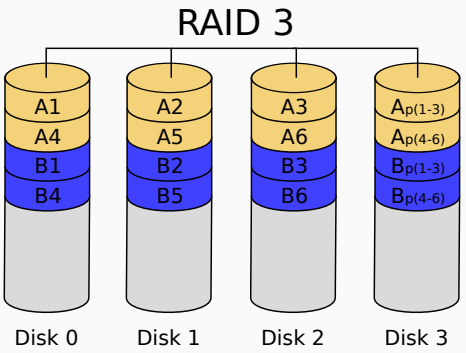


Benefits / Drawbacks



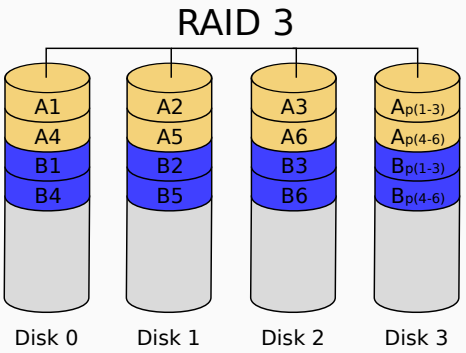
Benefits / Drawbacks

+ You can lose a disk and restore it using the parity



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity
- Slow when reading/writing small files at random locations



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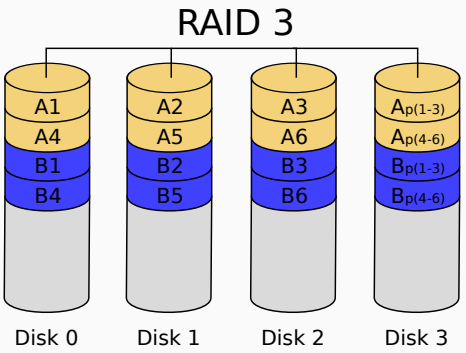
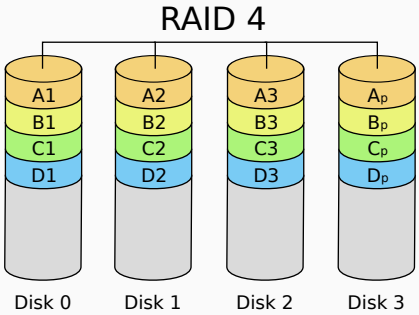
RAID 3



Benefits / Drawbacks

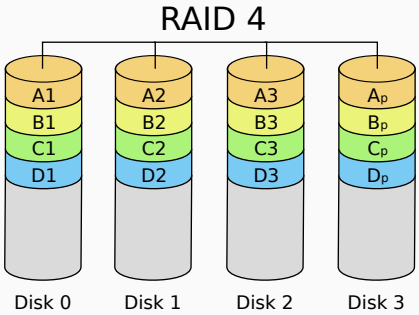
+ You can lose a disk and restore it using the parity
- Slow when reading/writing small files at random locations
- Spins in lockstep ⇒ Can only service one request at a time
- Every write and read hits the same single parity disk



What is that?

- Have a dedicated parity disk

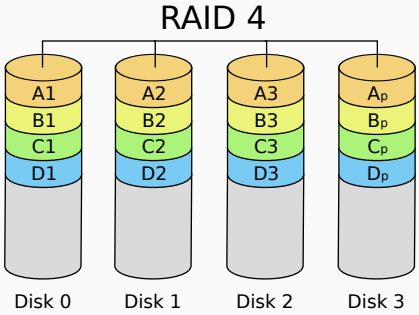
RAID 4



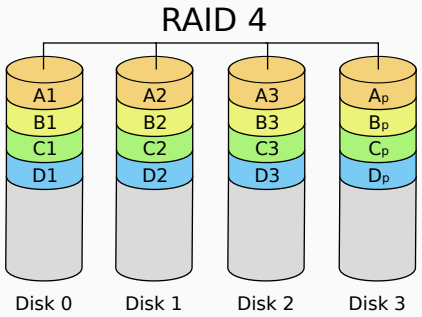
What is that?

- Have a dedicated parity disk
- Stripe data at the *block* level

RAID 4

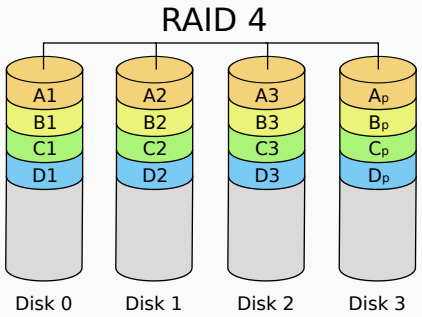


Benefits / Drawbacks



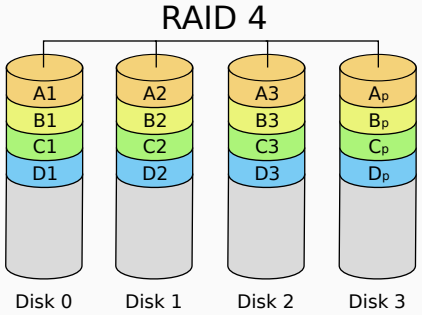
Benefits / Drawbacks

+ You can lose a disk and restore it using the parity



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity
+ Good read performance



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity
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- Every write and read hits the same single parity disk ⇒ Bottleneck, prone to failure

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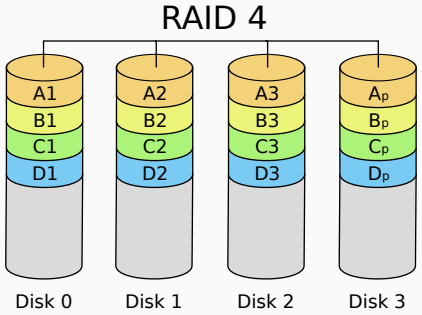
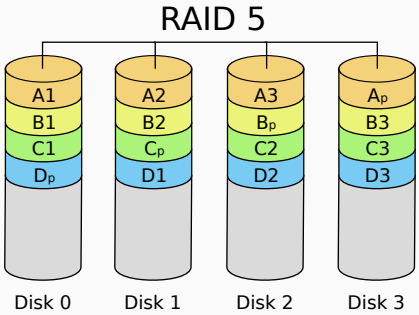


Benefits / Drawbacks

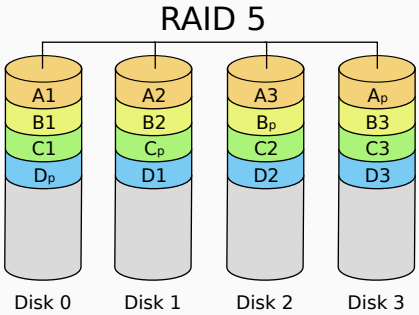
+ You can lose a disk and restore it using the parity
+ Good read performance
- Every write and read hits the same single parity disk $\Rightarrow$ Bottleneck, prone to failure
- Slow writes (write to same parity disk)



What is that?

- Stripe data at the *block* level

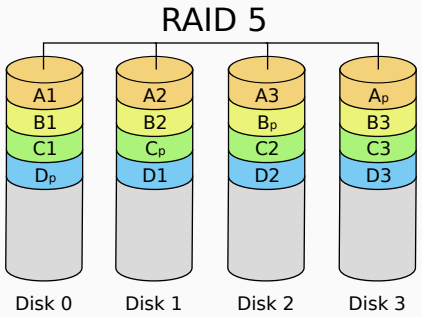
RAID 5



What is that?

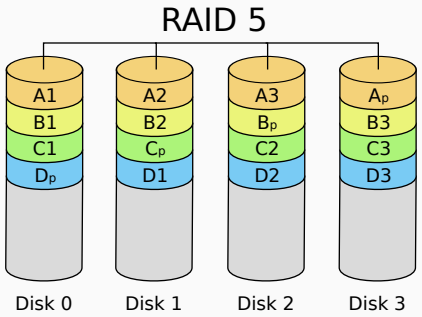
- Stripe data at the *block* level
- Distribute parity across your disks

RAID 5



Benefits / Drawbacks

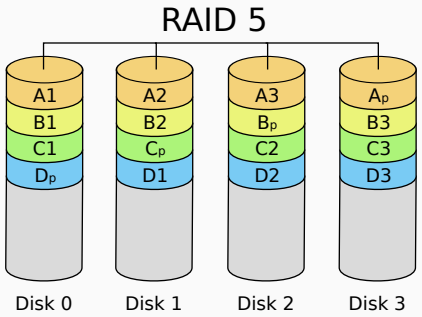
RAID 5



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity

RAID 5



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity
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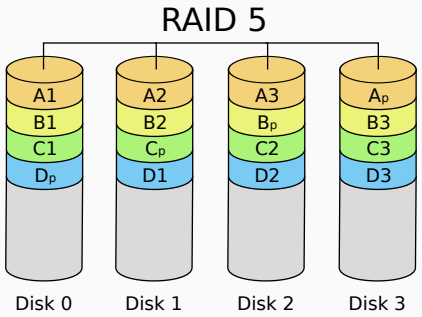
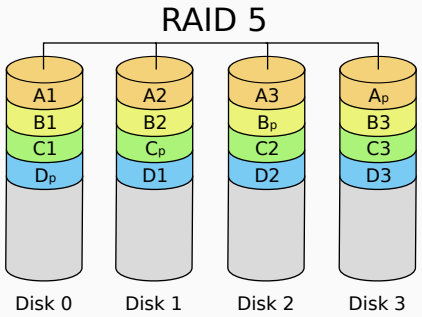
RAID 5



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity
+ Good read performance
+ Okay write performance

RAID 5



Benefits / Drawbacks

+ You can lose a disk and restore it using the parity
+ Good read performance
+ Okay write performance
- Still slower than RAID 0 or a SLED

Compare SLED and RAID (Level 0, 1, 4, 5)

Each RAID uses 4 disks for actual data storage.

How many disks do you need?

- SLED: **1**

Compare SLED and RAID (Level 0, 1, 4, 5)

Each RAID uses 4 disks for actual data storage.

How many disks do you need?

- SLED: **1**
- RAID 0: **4**

Compare SLED and RAID (Level 0, 1, 4, 5)

Each RAID uses 4 disks for actual data storage.

How many disks do you need?

- SLED: **1**
- RAID 0: **4**
- RAID 1: **8**

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- RAID 5: **5**

You want to modify one byte of data. How many blocks do you need to read/write?

- SLED: 1 read + 1 write

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- RAID 0: 1 read + 1 write

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- SLED: 1 read + 1 write
- RAID 0: 1 read + 1 write
- RAID 1: 1 read + 2 write (1 data + 1 mirror)

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- RAID 4: 2 read (data + old parity) + 2 write (data + new parity)

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RAID vs. Backup

You are using RAID

- You accidentally delete a file.

RAID vs. Backup

You are using RAID

- You accidentally delete a file. ***GONE***
- You accidentally overwrite a file.

RAID vs. Backup

You are using RAID

- You accidentally delete a file. ***GONE***
- You accidentally overwrite a file. ***GONE***
- Some data gets corrupted on one disk.

RAID vs. Backup

You are using RAID

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- You accidentally overwrite a file. ***GONE***
- Some data gets corrupted on one disk. ***GONE*** *(probably)*
- The poor intern connects to the production database. (Or here)

RAID vs. Backup

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- A crypto-locker takes out your computer.

RAID vs. Backup

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RAID vs. Backup

You are using RAID

- You accidentally delete a file. ***GONE***
- You accidentally overwrite a file. ***GONE***
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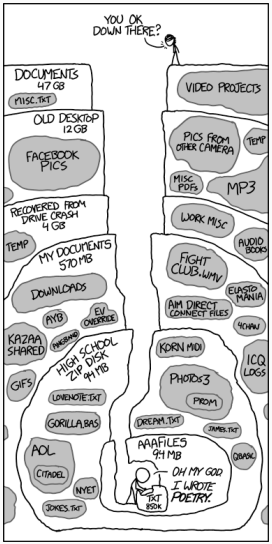
So what do we learn?

RAID IS NO SUBSTITUTE FOR A BACKUP

Ende



XKCD 1360 - Old Files

F R A G E N?

https://forms.gle/9CwJSKidKibubran9

Bis nächste Woche