Betriebssysteme

12. Tutorium - Files and Directories

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ITEC - Operating Systems Group

Solid-State Drives

NAND based flash memory

Rejoice, TI might be useful once

How long do writes/reads take normally?

NAND based flash memory

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How long do writes/reads take normally?

- Reading a page: 25µs

NAND based flash memory

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How long do writes/reads take normally?

- Reading a page: 25µs
- Writing a page: 250µs

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How long do writes/reads take normally?

- Reading a page: 25µs
- Writing a page: 250µs
- Erasing a block:

NAND based flash memory

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How long do writes/reads take normally?

- Reading a page: 25µs
- Writing a page: 250µs
- Erasing a block: 2ms

What happens when you just write to a random page?

NAND based flash memory

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- Reading a page: 25µs
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What happens when you just write to a random page?

Speeding things up

What could you change so writing pages is faster?

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- Keep around spare *erased* pages

⇒ You do not pay the erase penalty!

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

NAND based flash memory

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⇒ You do not pay the erase penalty!

- When do you create / reserve / erase those spare pages? Probably in the background. Any problems?

NAND based flash memory

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- Writing a page: 250µs
- Erasing a block: 2ms

What happens when you just write to a random page?

Speeding things up

What could you change so writing pages is faster?

- Keep around spare *erased* pages

⇒ You do not pay the erase penalty!

- When do you create / reserve / erase those spare pages? Probably in the background. Any problems? Might get exhausted if you write too much data in a short timeframe or the disk is full!

NAND based flash memory

Deleting files

What happens when you delete a file? What effect does that have on the SSD performance?

NAND based flash memory

Deleting files

What happens when you delete a file? What effect does that have on the SSD performance? The block is not freed ⇒ Can't be used as an erased empty page

What can the OS do to combat that?

NAND based flash memory

Deleting files

What happens when you delete a file? What effect does that have on the SSD performance? The block is not freed ⇒ Can’t be used as an erased empty page

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

RAID

What is that?

A **R**edundant **A**rray of **I**ndependent/**I**nexpensive **D**isks

RAID

What is that?

A **R**edundant **A**rray of **I**ndependent/**I**nexpensive **D**isks

Why would you use that?

RAID

What is that?

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Why would you use that?

- Probably cheaper than a SLED (Single Large Expensive Disk)

RAID

What is that?

A **R**edundant **A**rray of **I**ndependent/**I**nexpensive **D**isks

Why would you use that?

- Probably cheaper than a SLED (Single Large Expensive Disk)
- Might be more resilient

RAID

What is that?

A **R**edundant **A**rray of **I**ndependent/**I**nexpensive **D**isks

Why would you use that?

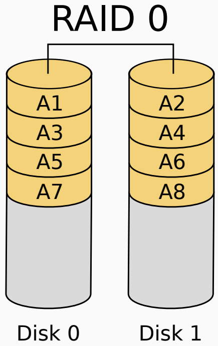
- Probably cheaper than a SLED (Single Large Expensive Disk)
- Might be more resilient
- Might be faster

RAID - And now?

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

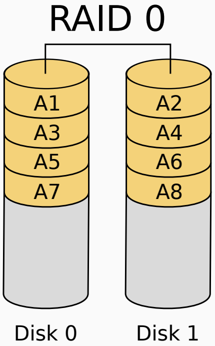
- „I like to live dangerously“ - RAID Level 0
- Mirroring: RAID Level 1
- Historic variants: RAID Level 2 and 3
- Block striping and parity: RAID Level 4
- Block striping and *distributed* parity: RAID Level 5

RAID 0



Benefits / Drawbacks?

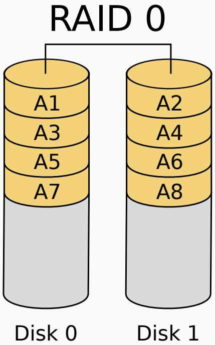
RAID 0



Benefits / Drawbacks?

+ Extremely fast (parallel reads and writes)

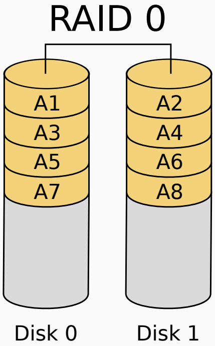
RAID 0



Benefits / Drawbacks?

- + Extremely fast (parallel reads and writes)
- + Can use full capacity

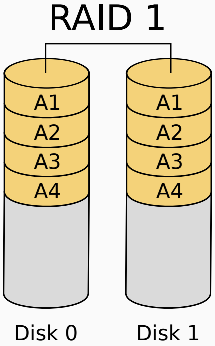
RAID 0



Benefits / Drawbacks?

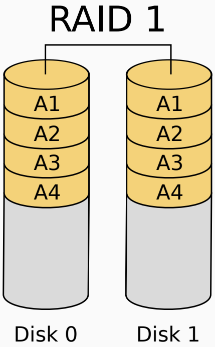
- + Extremely fast (parallel reads and writes)
- + Can use full capacity
- - If a single disk fails your files are toast

RAID 1



Benefits / Drawbacks?

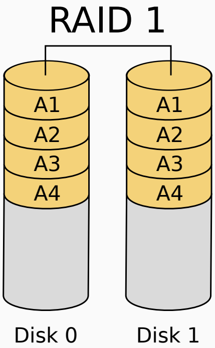
RAID 1



Benefits / Drawbacks?

+ You can lose all but one disk without losing data

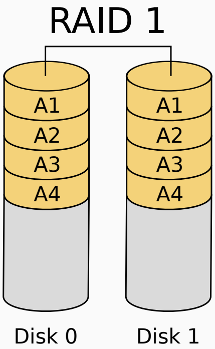
RAID 1



Benefits / Drawbacks?

- + You can lose all but one disk without losing data
- + Parallel reads possible

RAID 1



Benefits / Drawbacks?

- + You can lose all but one disk without losing data
- + Parallel reads possible
- – Writes slower as they need to write to all disks

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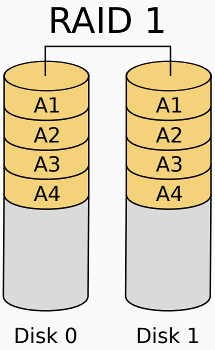
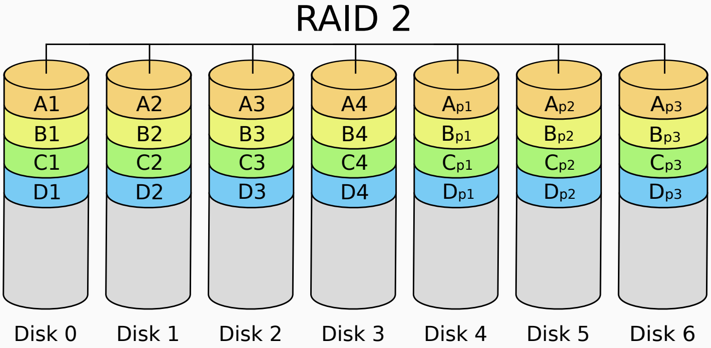


Benefits / Drawbacks?

- + You can lose all but one disk without losing data
- + Parallel reads possible
- – Writes slower as they need to write to all disks
- – Size equals the size of a single disk

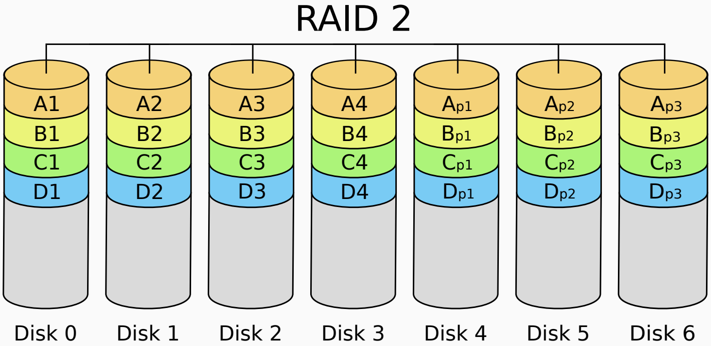
RAID 2



What is that?

- Have $\log_2(N)$ parity disk

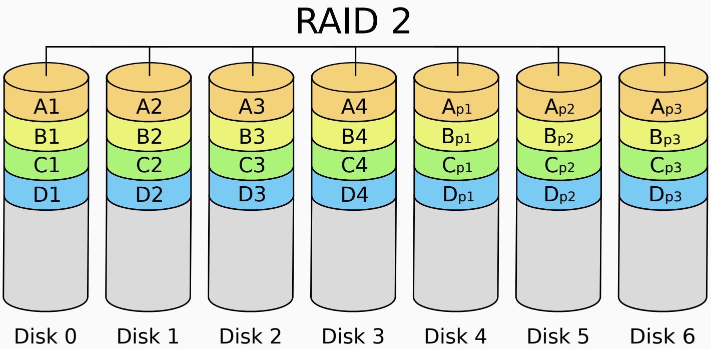
RAID 2



What is that?

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

RAID 2



What is that?

- Have $\log_2(N)$ parity disk
- Stripe data at the *bit* level
- Use a hamming code of proper size

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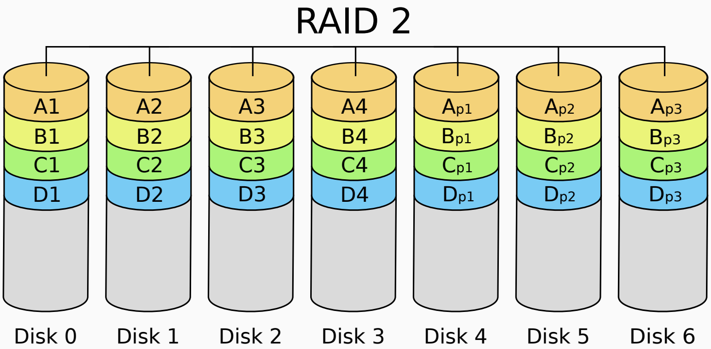
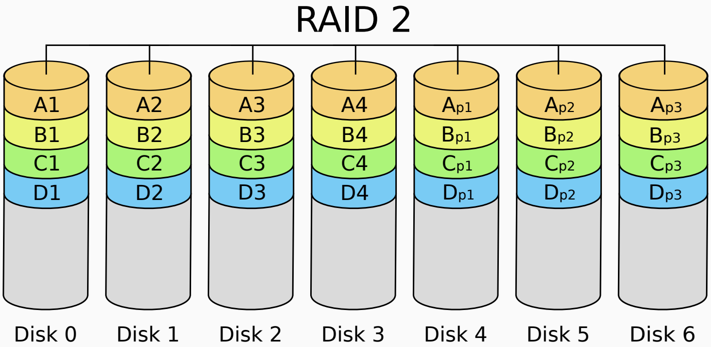


What is that?

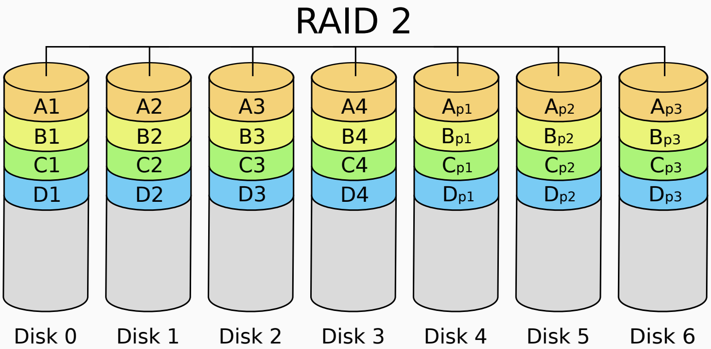
- Have $\log_2(N)$ parity disk
- Stripe data at the *bit* level
- Use a hamming code of proper size
- Spin the disks in lockstep (so you read all bits of your word at once)

RAID 2



Benefits / Drawbacks

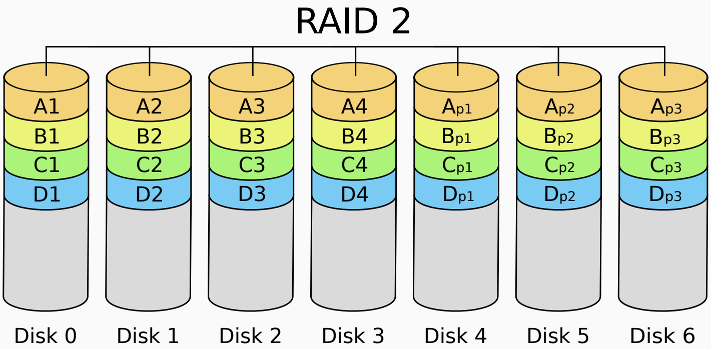
RAID 2



Benefits / Drawbacks

+ External error checking

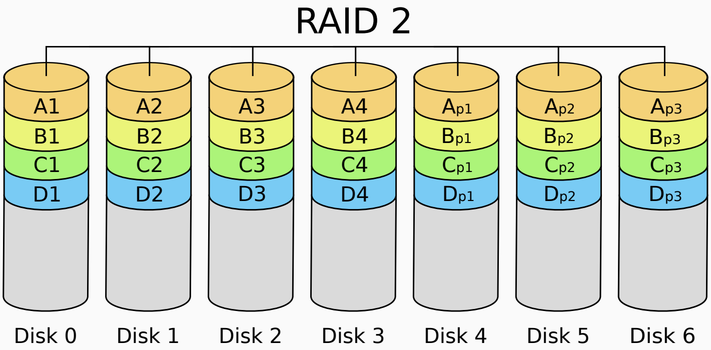
RAID 2



Benefits / Drawbacks

+ External error checking
- Really slow

RAID 2



Benefits / Drawbacks

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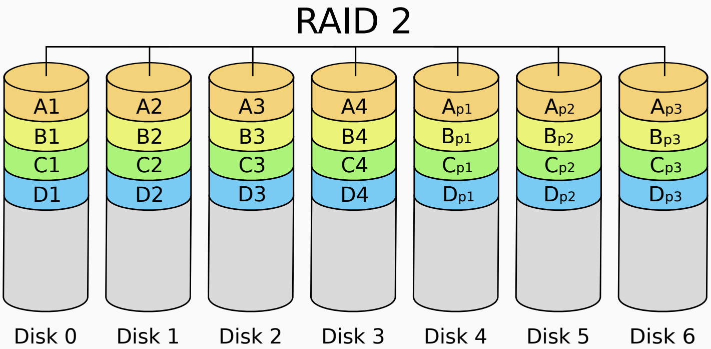
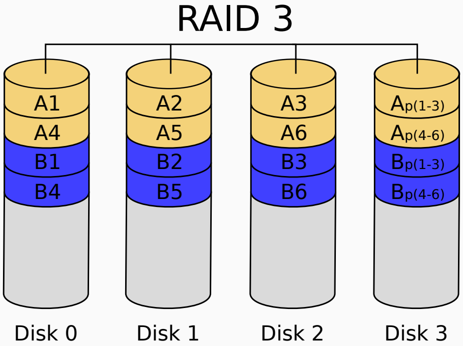


Benefits / Drawbacks

+ 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

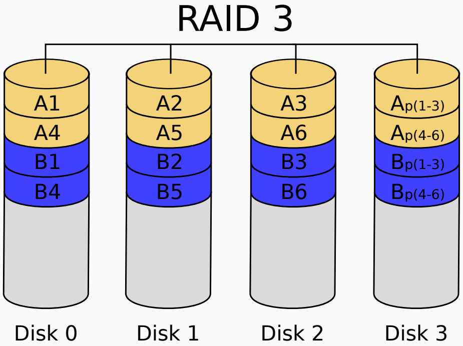
RAID 3



What is that?

- Have a dedicated parity disk

RAID 3



What is that?

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

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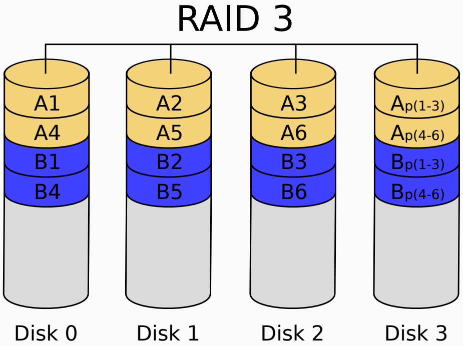

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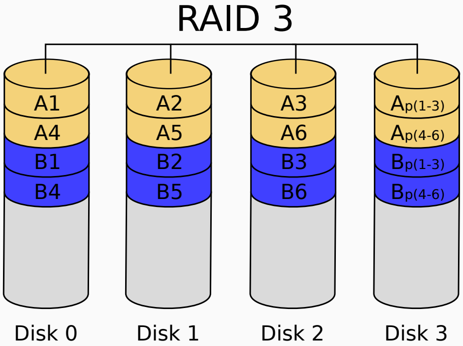

Benefits / Drawbacks

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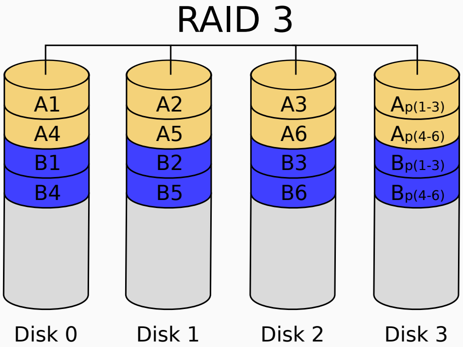
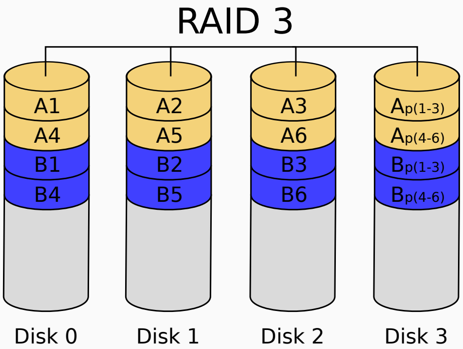


Benefits / Drawbacks

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

RAID 3

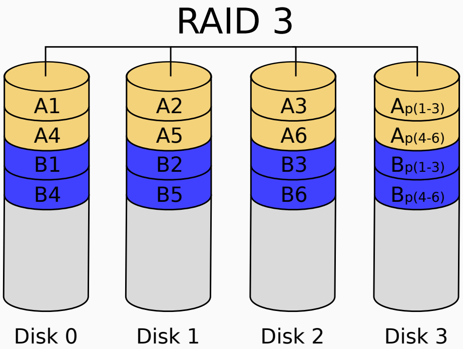


Benefits / Drawbacks

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

– Slow when reading/writing small files at random locations

RAID 3



Benefits / Drawbacks

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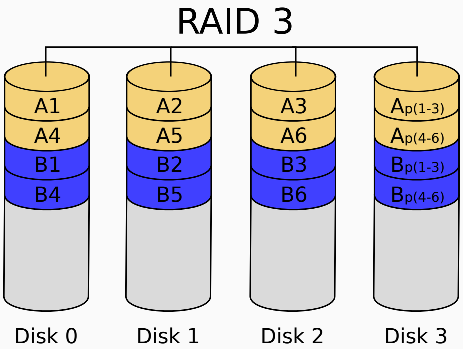
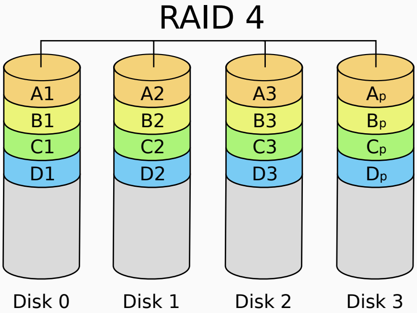


Benefits / Drawbacks

+ 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

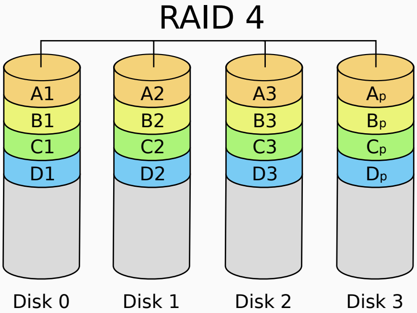
RAID 4



What is that?

- Have a dedicated parity disk

RAID 4



What is that?

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

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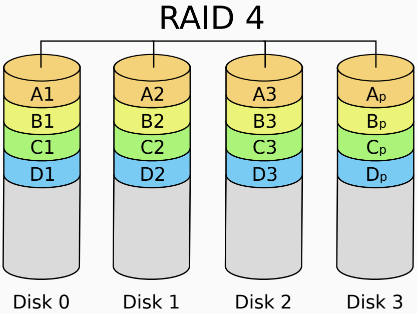
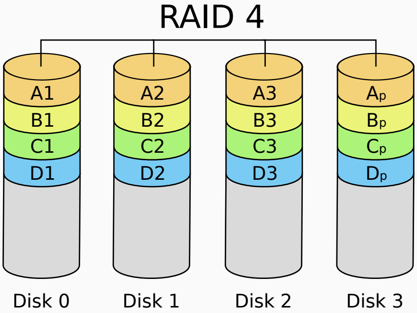


Benefits / Drawbacks

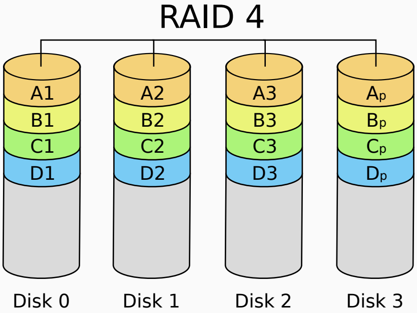
RAID 4



Benefits / Drawbacks

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

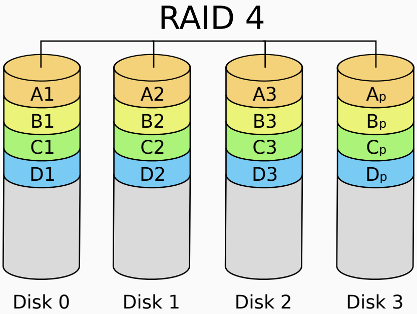
RAID 4



Benefits / Drawbacks

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

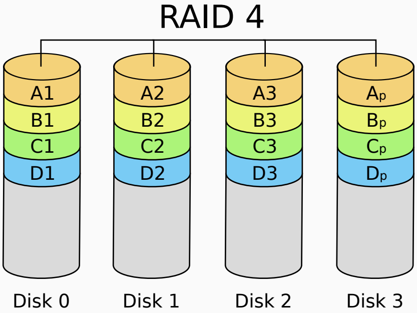
RAID 4



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 ⇒ Bottleneck, prone to failure

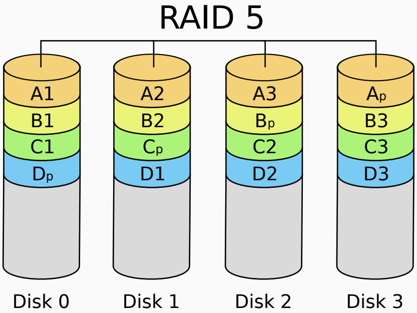
RAID 4



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 ⇒ Bottleneck, prone to failure
- Slow writes (write to same parity disk)

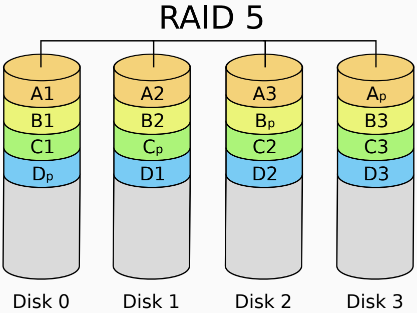
RAID 5



What is that?

- Stripe data at the *block* level

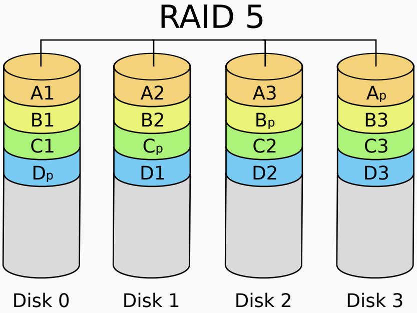
RAID 5



What is that?

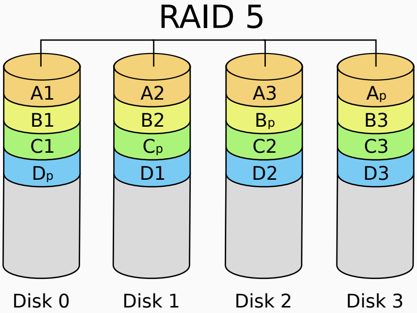
- Stripe data at the *block* level
- Distribute parity across your disks

RAID 5



Benefits / Drawbacks

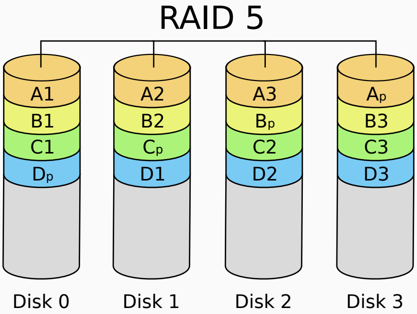
RAID 5



Benefits / Drawbacks

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

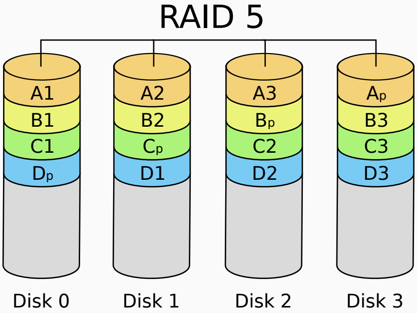
RAID 5



Benefits / Drawbacks

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

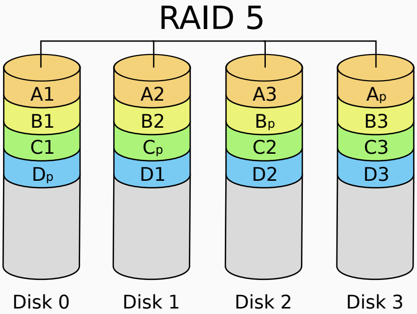
RAID 5



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

RAID

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

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

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Each RAID uses 4 disks for actual data storage.

How many disks do you need?

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

RAID

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How many disks do you need?

- SLED: **1**
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- RAID 1: **8**
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RAID

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How many disks do you need?

- SLED: **1**
- RAID 0: **4**
- RAID 1: **8**
- RAID 4: **5**
- RAID 5: **5**

RAID

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

- SLED: 1 read + 1 write

RAID

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RAID

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

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

RAID

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

RAID

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- SLED: 1 read + 1 write
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- RAID 4: 2 read (data + old parity) + 2 write (data + new parity)
- RAID 5: 2 read (data + old parity) + 2 write (data + new parity)

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

- You accidentally delete a file. ***GONE***
- 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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- The poor intern connects to the production database. (Or here) ***GONE***
- A crypto-locker takes out your computer.

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. ***GONE*** *(probably)*
- The poor intern connects to the production database. (Or here) ***GONE***
- A crypto-locker takes out your computer. Believe it or not, ~~***JAIL***~~ ***GONE***

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. ***GONE*** *(probably)*
- The poor intern connects to the production database. (Or here) ***GONE***
- A crypto-locker takes out your computer. Believe it or not, *~~JAIL~~ GONE*

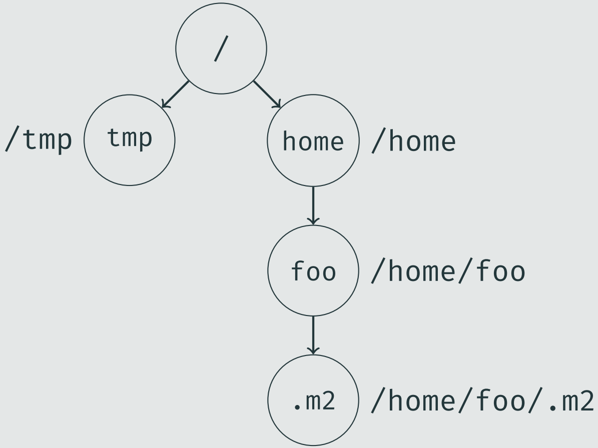
So what do we learn?

RAID IS NO SUBSTITUTE FOR A BACKUP

Files And Directories

Files And Directories

Paths (Linux)



Reading A File

What are the two basic access methods (patterns) for reading a file?

- Sequential Access

  Accessed in order, reading sequential bytes. Writes append at the end.

- Random Access

  Reading and writing at arbitrary positions, programmer needs to specify where to write/read

Which Library Functions and System Calls do we have to access files?

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Flushing dirty buffers

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Closing a file

`fclose` / `close`

Reading from a file

`fread` / `read`

Writing to a file

`fwrite` / `write`

Flushing dirty buffers

The library functions sometimes buffer to reduce the amount of syscalls.

`fflush` flushes those buffers.

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What happens when you move the cursor behind the end of the file?

It creates a hole filled with zeros! Such a file is called a *sparse* file and some file systems might not store empty regions.

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`mmap` the file (works quite well, might cause page faults. Probably faster for large files than read/write calls)

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What system calls do you need to list files in a Linux directory?

1. `opendir`
2. `readdir`: Returns a `dirent` with a *relative path*
3. `closedir`

Open Files

Kernel Data Structures For Open Files

What structures does the kernel use for open files?

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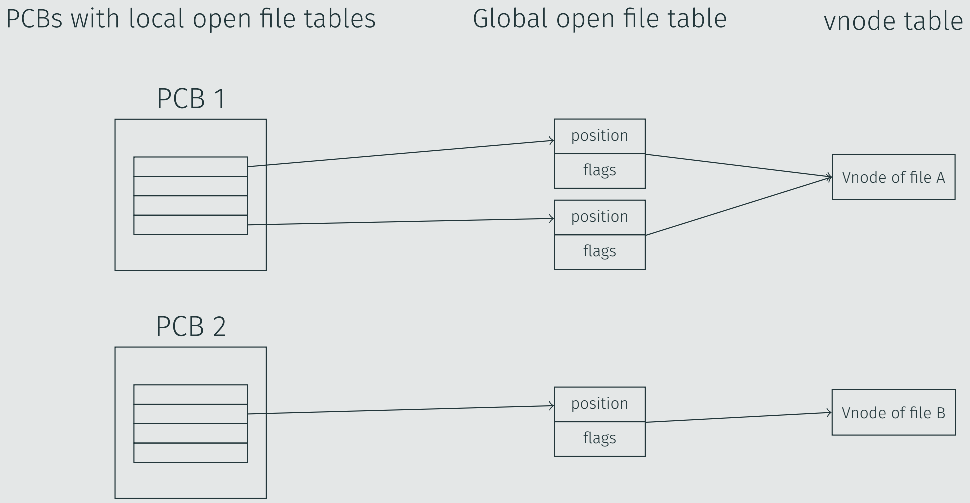
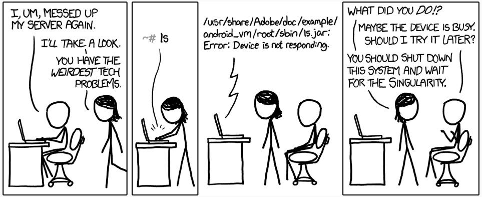


Ende


I, UM, MESSED UP MY SERVER AGAIN.
I'LL TAKE A LOOK.
YOU HAVE THE WEIRDEST TECH PROBLEMS.
~# ls
/usr/share/Adobe/doc/example/android_vm/root/sbin/ls.jar: Error: Device is not responding.
WHAT DID YOU DO!?
MAYBE THE DEVICE IS BUSY. SHOULD I TRY IT LATER?
YOU SHOULD SHUT DOWN THIS SYSTEM AND WAIT FOR THE SINGULARITY.

XKCD 1084 - Server Problem

FRAGEN?

https://forms.gle/9CwJSKidKibubran9

Bis nächste Woche