2022-2 – Laboratório de Arquitetura de Computadores
Como aumentar o desempenho de acesso aos discos

https://youtu.be/B1MGsgsr9GE
Western Digital Vídeo

Memórias Externas
RAID Architecture

Frase do dia:
"O que sabemos é uma gota; o que ignoramos é um oceano."
Sir Isaac Newton

IDENTIKIT E DADOS PESSOAIS

Nome Isaac
Sobrenome Newton
Título Sir
Nascido 4 Janeiro 1643 em Woolsthorpe-by-ColsterworthLincolnshire
Falecido 31 Março 1727 em Kensington, Londra
Gênero masculino
Nacionalidade Inglesa
Profissão matemático, físico
Signo do zodíaco Capricórnio

USCS
UNIVERSIDADE MUNICIPAL DE SÃO CAETANO DO SUL

Avisos: CC-03AN – Datas Importantes

- **Avaliação N1: 20/10/2022 – 21h10**

- **Avaliação N2:**

- **Apresentação dos Grupos: 17/11/2022**
- **Avaliação Integrada (AI) parte da N2: 21 a 23/11/2022**
- **Avaliação Processual (AP) – 100% - Fechamento 30/11/2022**
  - **40% - Seminário sobre TI – Formulário Grupos e Temas 02/10/2022**
  - **60% - Atividades**
    - **In class**
    - **Formulários**

- **Prova N3: 15/12/2022 – 21h10**

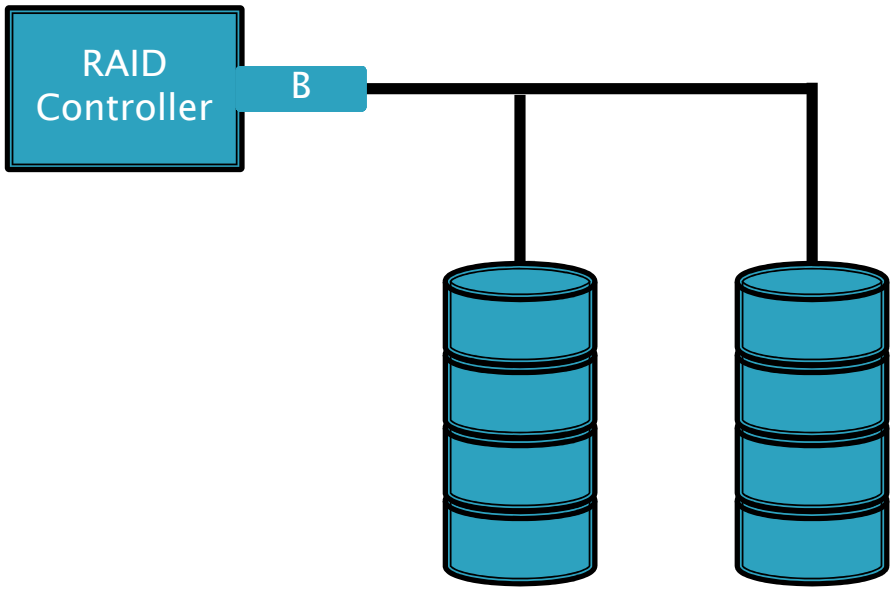
Introduction

- RAID stands for Redundant Array of Independent Disks
- A system of arranging multiple disks for redundancy (or performance)
- Term first coined in 1987 at Berkley
- Idea has been around since the mid 70's
- RAID is now an umbrella term for various disk arrangements
  - Not necessarily redundant

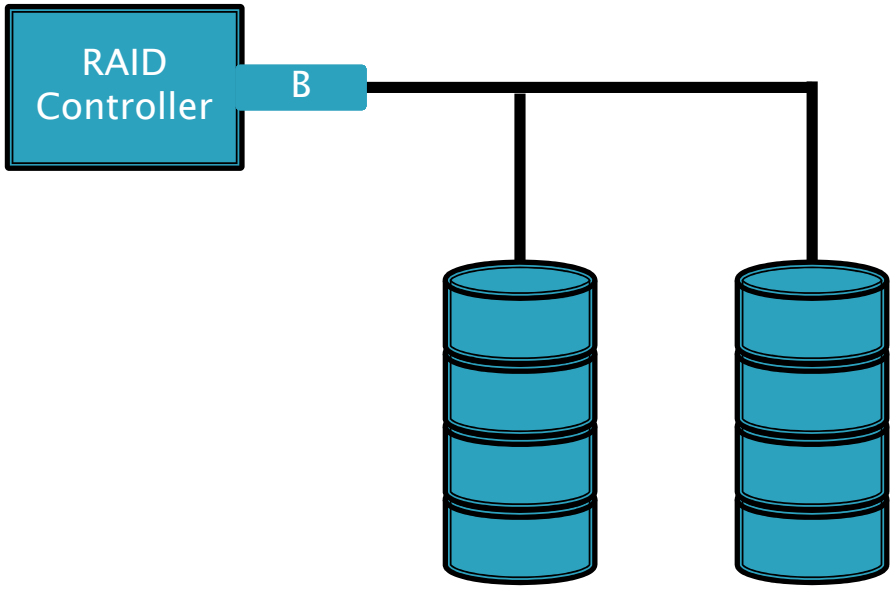
RAID 0

- Also known as "Striping"
- Data is striped across the disks in the array
- Each subsequent block is written to a different disk

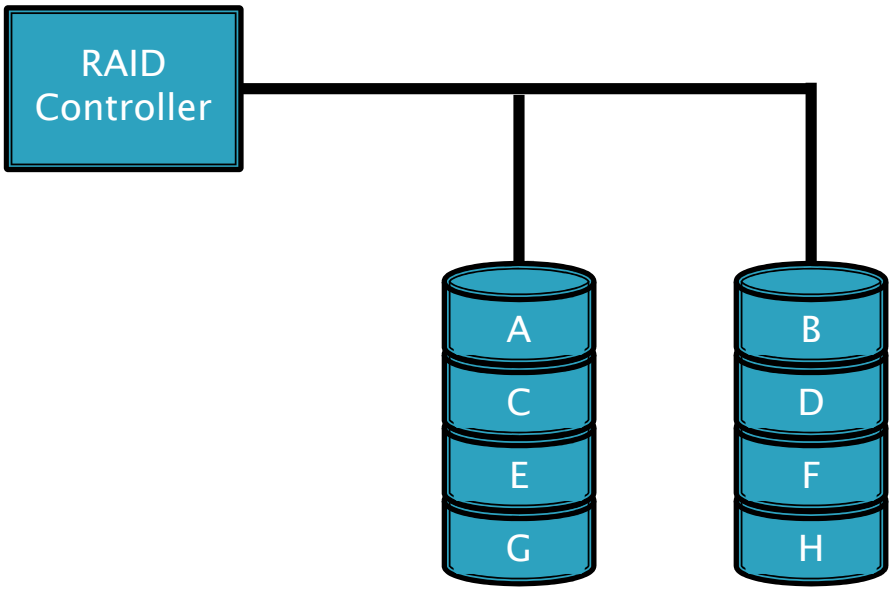
RAID 0 Writes



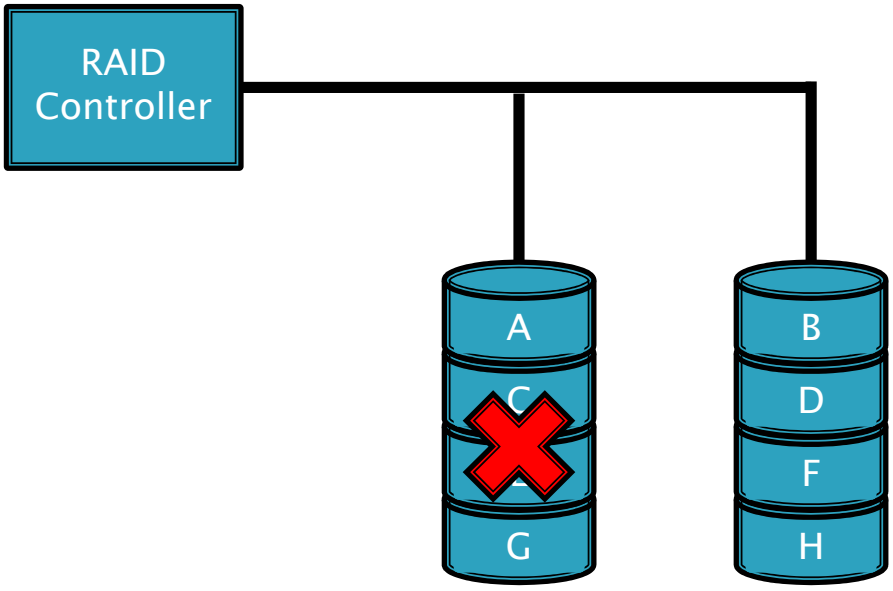
RAID 0 Writes



RAID 0 Reads



RAID 0 Recovery



RAID 0 Pros

- Best use of space
  - Every byte of the disks can be accessed in the array
- Very fast reads and writes
  - The more disks you add to the array, the faster it goes
- Simple design and operation
  - No parity calculation

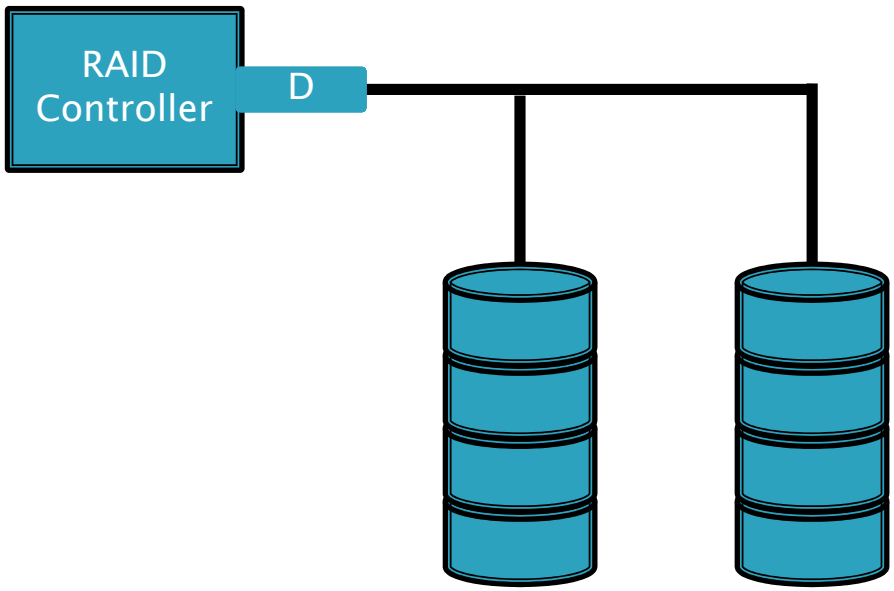
RAID 0 Cons

- No redundancy
- Not for use in mission critical systems
- One disk failure means all your data is unrecoverable

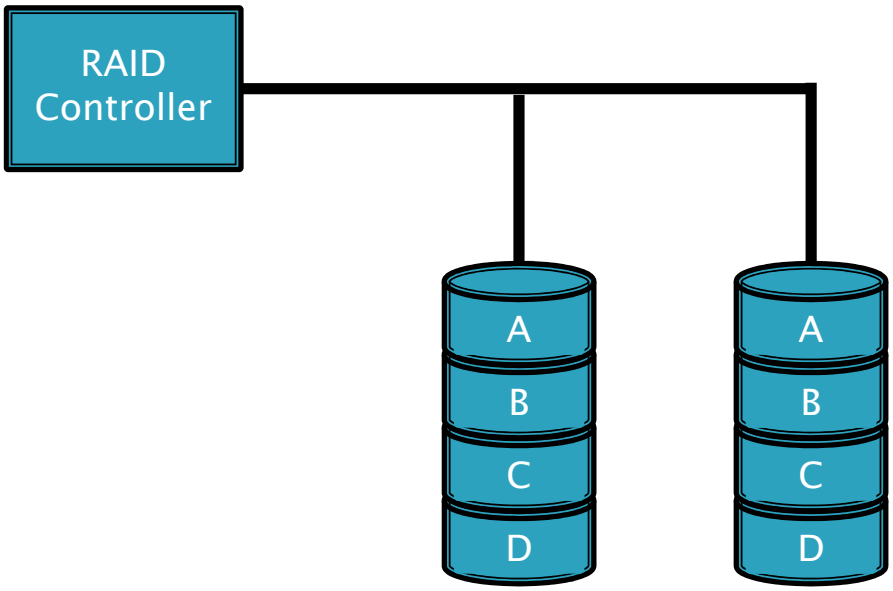
RAID 1

- Known as “Mirroring”
- Data is written to two disks concurrently
- The first type of RAID developed

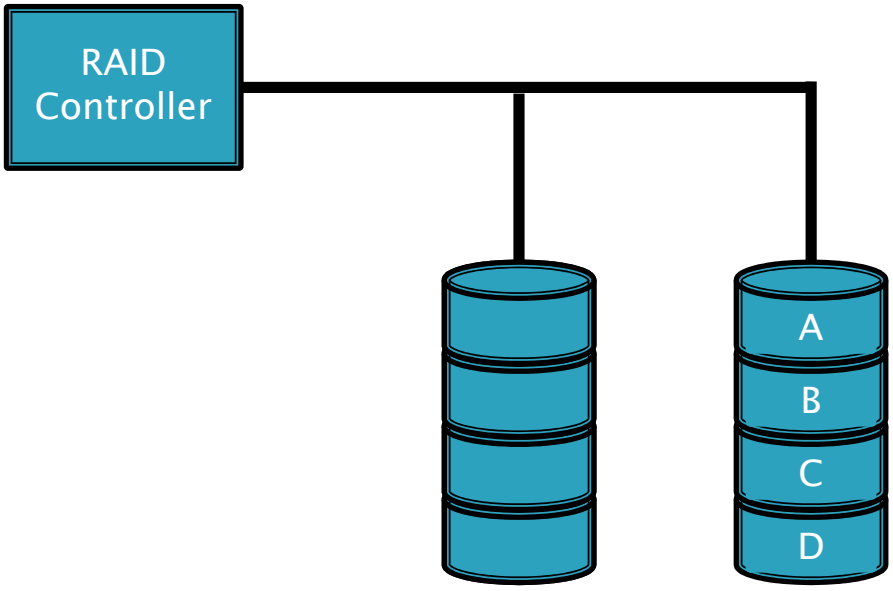
RAID 1 Writing



RAID 1 Reading



RAID 1 Recovery



RAID 1 Pros

- Good redundancy
  - Two copies of every block
- Fast reads
  - Can read 2 blocks at once (more if more disks)
- Writes are acceptable
- No intense calculation on rebuild, just copy

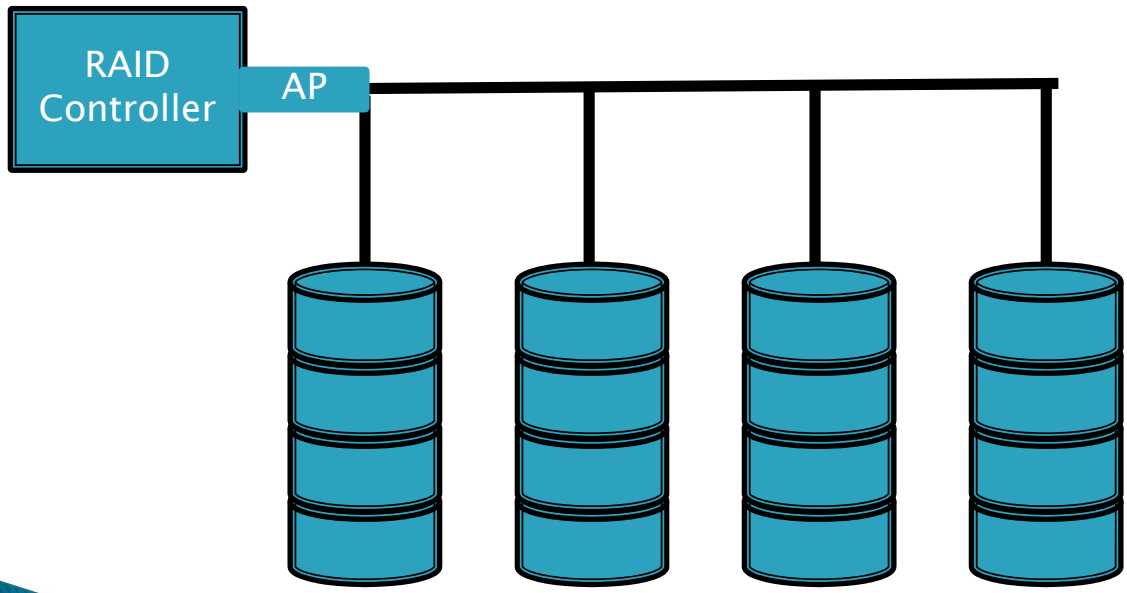
RAID 1 Cons

- SPACE!!
- Using 2 disks gives you 1/2 the space, using 3 gives 1/3 etc…
- Writes are not as fast as other RAID types
- Very expensive

RAID 4

- Striping with a dedicated parity disk
- Blocks are written to each subsequent disk
- Each block of the parity disk is the XOR value of the corresponding blocks on the data disks
- Not used often in the real world

RAID 4 Writing



RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	

RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	1

RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	10

RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	100

RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	1001

RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	10010

RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	100101

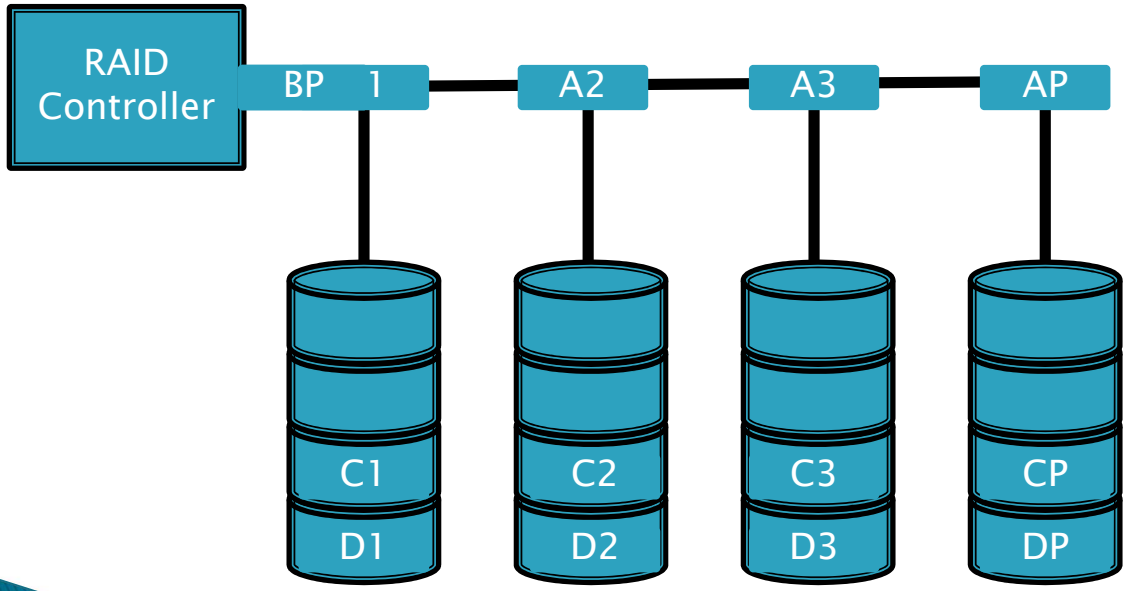
RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	1001011

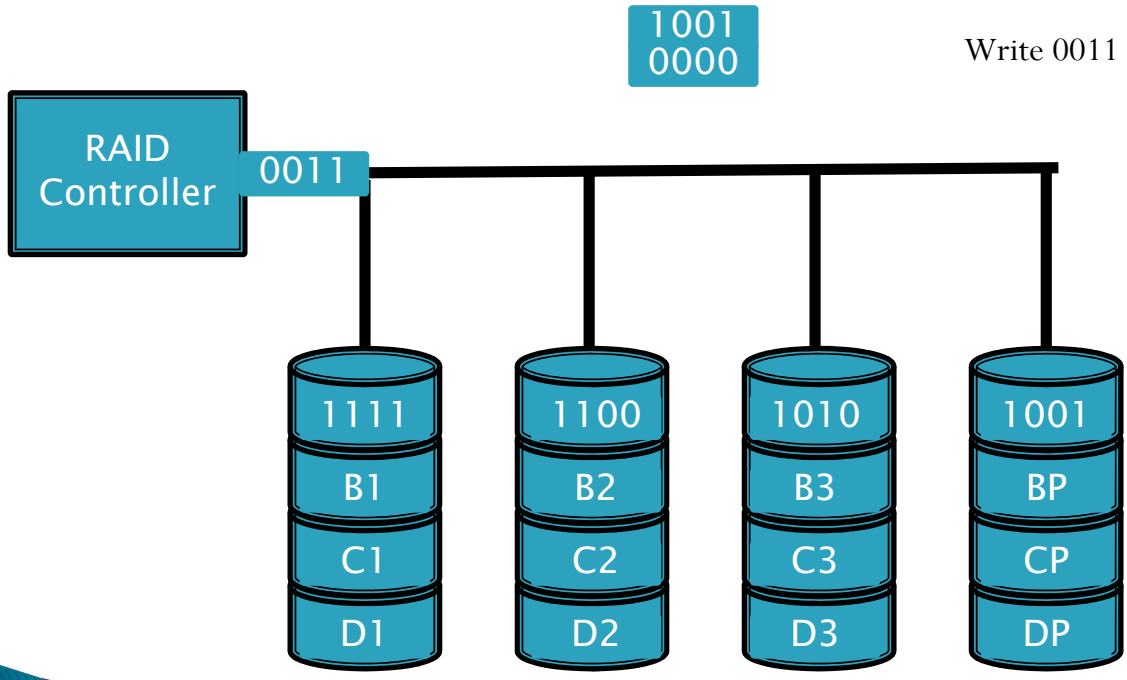
RAID 4 Writing

Block	Data
A1	11110000
A2	11001100
A3	10101010
AP	10010110

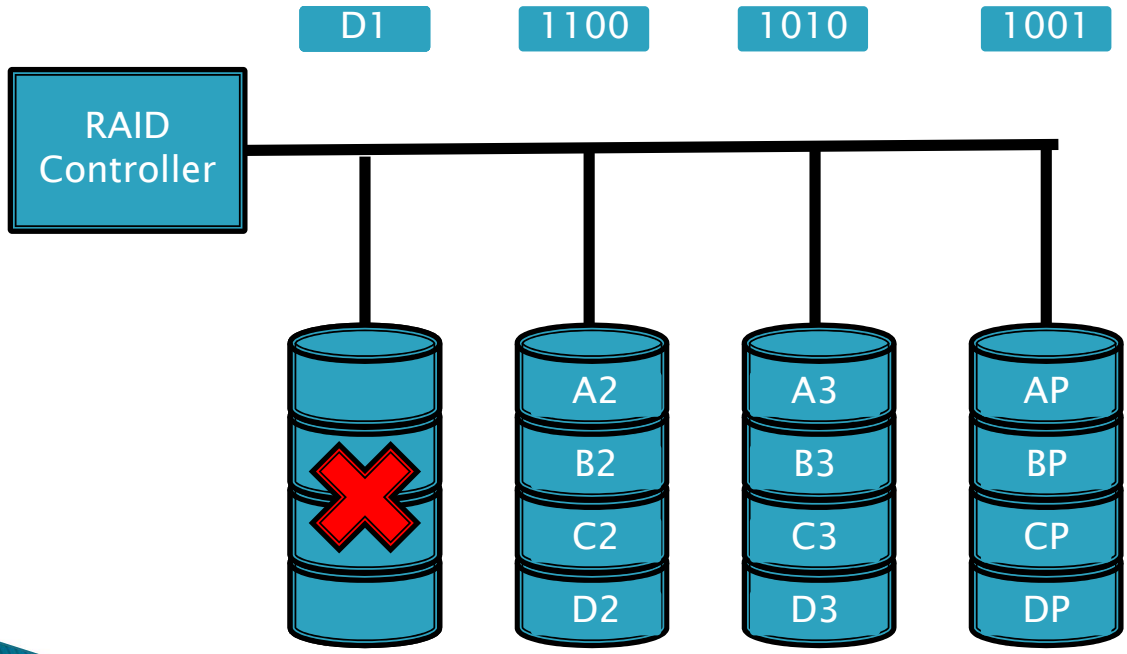
RAID 4 Writing



RAID 4 Modifying

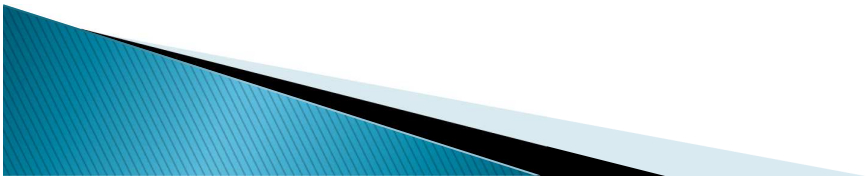


RAID 4 Recovery



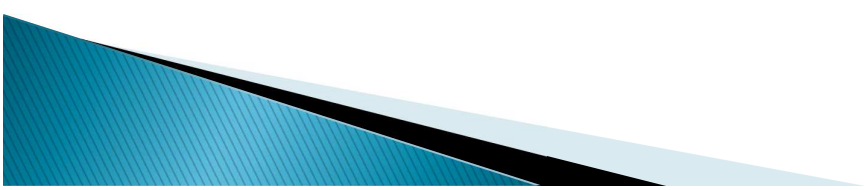
RAID 4 Pros

- High read rate
- Low ratio of error correction space
  - Any number of data disks only require 1 parity disk. 4 disks gives 3/4 usable space 5 gives 4/5
- Can recover from single disk failures



RAID 4 Cons

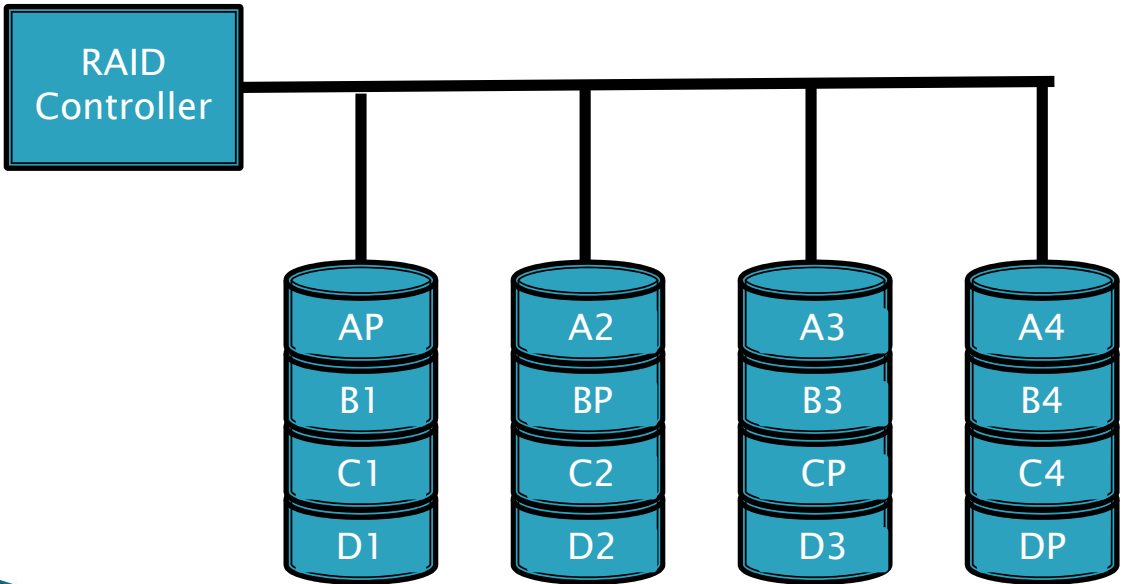
- Very slow writes
  - Every write requires 2 reads and 2 writes
  - Every write requires accessing the single parity disk
- Recovery is processor intensive
- Parity bit cannot detect multi-bit error



RAID 5

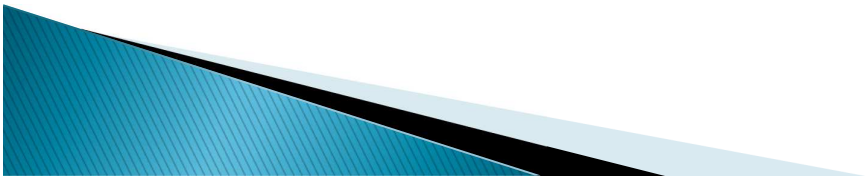
- Striped disks with interleaved parity
- Much like RAID 4 except that parity blocks are spread over every disk

RAID 5



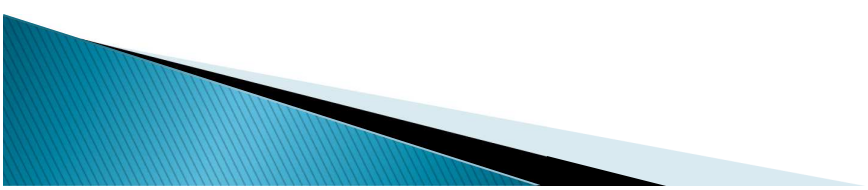
RAID 5 Pros

- Read rates the same as RAID 4
- Because parity bits are distributed, every write does not need to access a single disk
  - Writes are marginally better than RAID 4
- Like RAID 4, you need relatively little parity which allows larger arrays



RAID 5 Cons

- Re-writing a block still requires 2 reads and 2 writes
  - Interleaving mitigates the penalty
- Rebuilding the array takes a long time
- Can only tolerate one disk failure



RAID 2

- Striped set with dual distributed parity
- Defined as any form of RAID that can recover from two concurrent disk failures
- Different implementations
  - Double parity, P+Q, Reed-Solomon Codes
- Essentially RAID 5 with an extra parity disk

RAID 2 Error Correction Using Hamming Codes (Double parity)

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

Hamming Code

Data

Disk	Contents
1	11110000
2	????????
3	00111000
4	01000001
5	????????
6	10111110
7	10001001

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

Hamming Code

Data

Disk	Contents
1	11110000
2	????????
3	00111000
4	01000001
5	????????
6	10111110
7	10001001

No Good! Disk 2 has failed.

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

Data

Disk	Contents
1	11110000
2	????????
3	00111000
4	01000001
5	????????
6	10111110
7	10001001

Great. We can recover disk 2 by using disks 1, 4, and 6. XOR them all and we get…

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

Hamming Code

Data

Disk	Contents
1	11110000
2	00001111
3	00111000
4	01000001
5	????????
6	10111110
7	10001001

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

Hamming Code

Data

Disk	Contents
1	11110000
2	00001111
3	00111000
4	01000001
5	????????
6	10111110
7	10001001

Now we can see disk 5 is the parity bit for disks 1,2,3. XOR them all and we have recovered from two disk failures.

	Data				Redundant		
Disk	1	2	3	4	5	6	7
	1	1	1	0	1	0	0
	1	1	0	1	0	1	0
	1	0	1	1	0	0	1

Hamming Code

Data

Disk	Contents
1	11110000
2	00001111
3	00111000
4	01000001
5	11000111
6	10111110
7	10001001

RAID 2 Continued

- In the example shown, we have not interleaved the parity information to make it easier to understand
- We can interleave the data in the same way we do in RAID 5 to avoid the bottleneck of writing all the parity to a small subset of disks

RAID 2 Pros

- Fast reads
- Very fault tolerant
- As rebuild times increase, having extra fault tolerance is becoming more important
- The parity method described requires 2^k-1 disks with k disks used for parity
- Other methods can require only 2 disks for parity

Raid 2 Cons

- About the same performance write speed as RAID 5. More reads and writes are required, but most can be done concurrently.
- Requires more parity space than RAID 5
  - Still less than RAID 1
- Very computationally expensive

RAID 3

- Bit-interleaved parity
- Instead of using several disks to store Hamming code, as in RAID 2, RAID 3 has a single disk check with parity information.
- Performance is similar between RAID 2 and 3

Hybrids

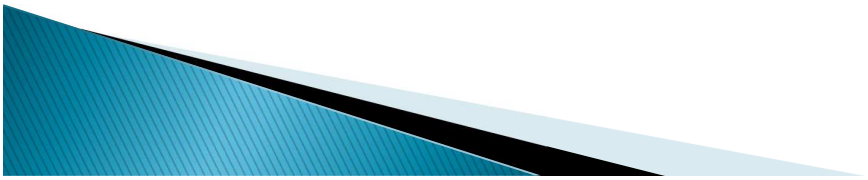
- RAID 1+0
  - Sets of drives in RAID 1 act as the drives for RAID 0
  - Very fast reads
  - Faster writes than RAID 5
  - Redundant yet none of the overhead that comes with RAID 5 or 6
  - In certain cases can handle multiple failures
  - Very expensive

Hybrids Cont.

- Others
  - 5+0
  - 0+1
  - Hot Spares
  - Intel Matrix Raid

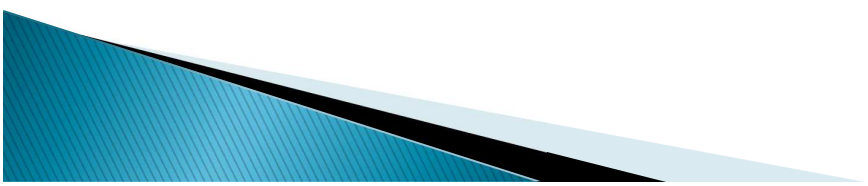
Software RAID (Fake RAID)

- Software controllers offload their error correction calculations to the CPU
- Cheap
- Included on nearly every modern motherboard
- Difficult to boot from



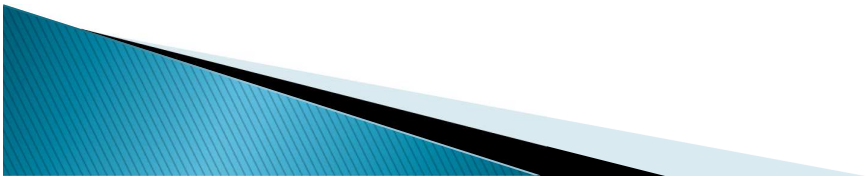
Hardware RAID

- No CPU overhead
- Can include battery backed write cache
- Can appear as a single disk to the BIOS
- Often very expensive
  - (Some cost more than the hard drives used to build the array)
- Proprietary (if your controller card fails, other manufacturers cards wont be able to read the array)



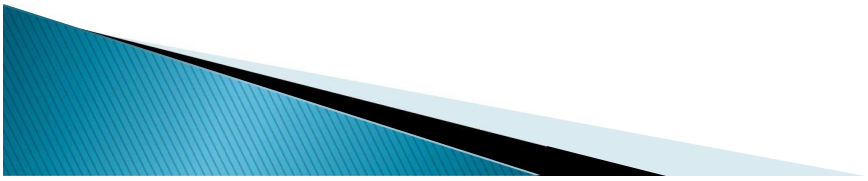
Problems Inherent in all RAIDs

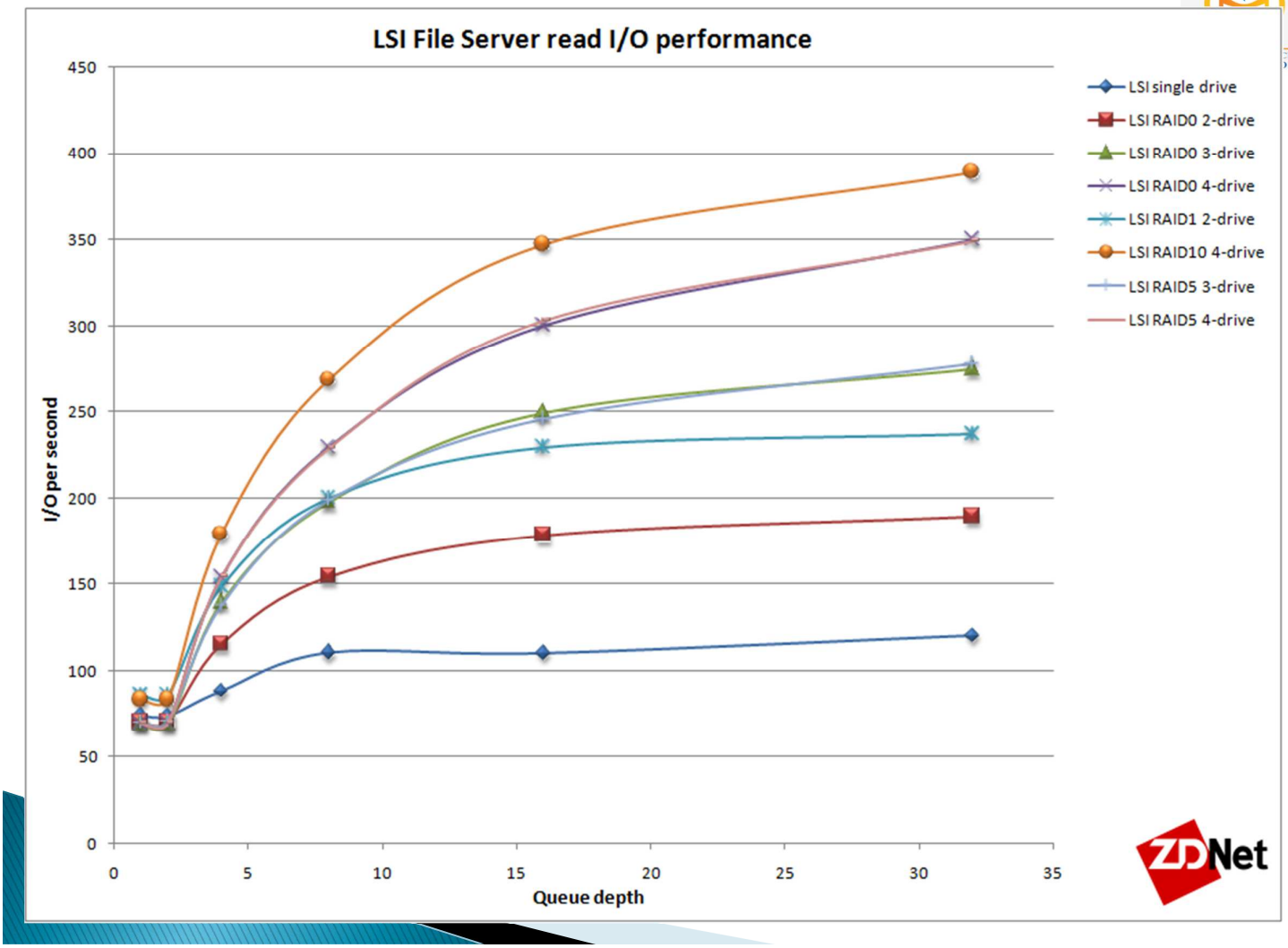
- Correlated Failures
  - Identical disks produced from the same assembly line and run for the exact same amount of time tend to fail together
- Write Atomicity
  - What happens when there is a system crash between a block being written and its associated parity block?

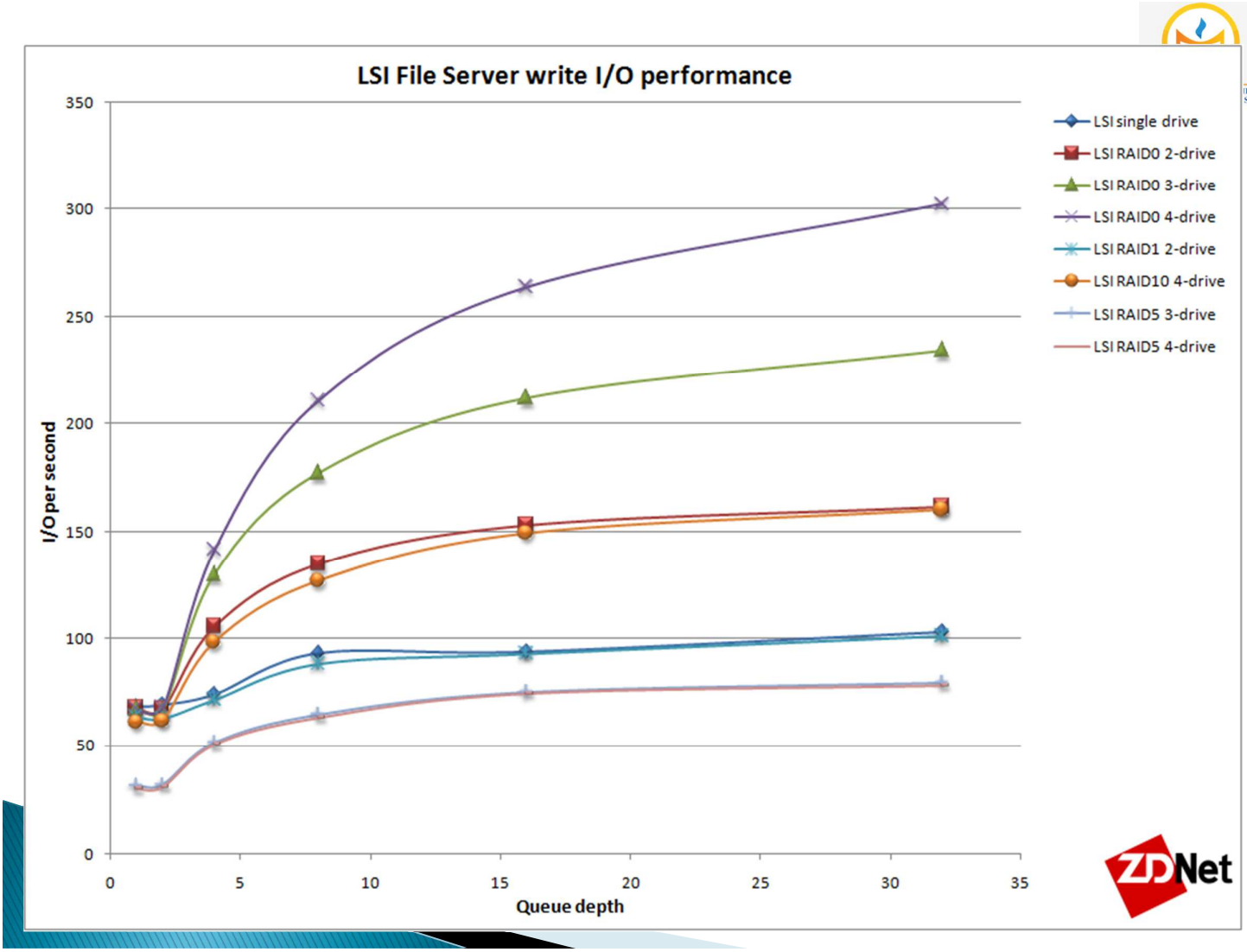


Problems Cont.

- RAID does not protect from bad data overwriting your good data
  - Viruses
  - User Error
- RAID solves the problem of uptime and availability, not data integrity.




LSI File Server read I/O performance
I/O per second
Queue depth
LSI single drive
LSI RAID0 2-drive
LSI RAID0 3-drive
LSI RAID0 4-drive
LSI RAID1 2-drive
LSI RAID10 4-drive
LSI RAID5 3-drive
LSI RAID5 4-drive
ZDNet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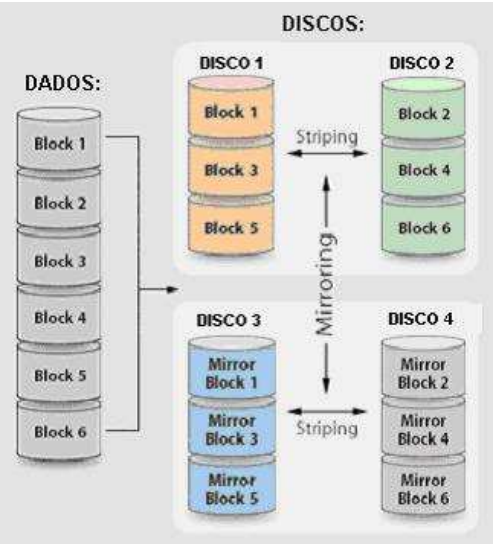
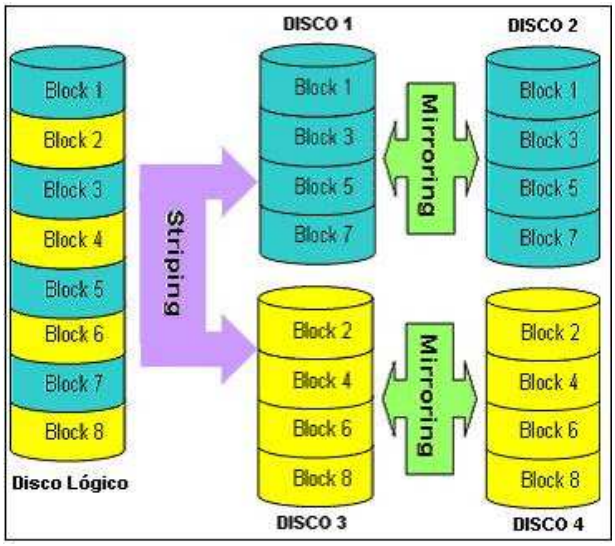
LSI RAID0 4-drive
LSI RAID1 2-drive
LSI RAID10 4-drive
LSI RAID5 3-drive
LSI RAID5 4-drive
ZDNet

Applications

- RAID 0
  - Photoshop scratch disk
  - Video editing workstation
- RAID 5/6
  - File server
  - Web server with static content
- RAID 1+0
  - Database server

Hybrid 0+1 and 1+ 0 How is the better?





Source

- Course Text 1 Instructor's Support Materials
- http://www.zdnet.com/
- Western Digital Vídeo
- https://youtu.be/B1MGsgsr9GE

Checklist

- What is mirroring?
- What is striping?
- What is a parity bit?
- How do we use Hamming code to allow identification of a single error?
- List 5 levels of RAID
- What is Hybrid, Software, Hardware RAID?

The end!

Valeu galera!