QUICK REVIEW

S_c → STORAGE CAPACITY N → NUMBER OF DISKS $1/MTTF$ = FAILURE RATE

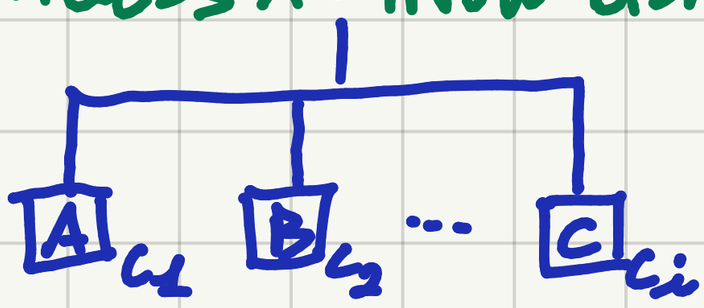
S → TRANSFER RATE SEQUENTIAL WORKLOAD R → RANDOM TRANSFER RATE

MTTDL → MEAN TIME TO DATA LOSS MTTF → MEAN TIME TO FAILURE

D → LATENCY TO ACCESS A SINGLE DISK MTBF → MEAN TIME BETWEEN FAILURE

MTR → MEAN TIME TO RECOVER

a) RAID 0



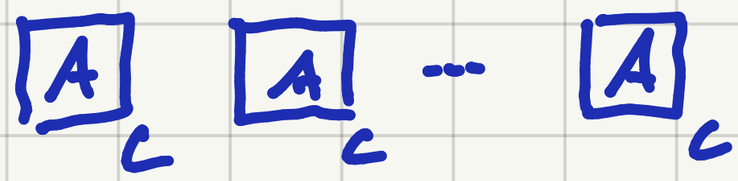
$S_C = \sum_i C_i$ SUM OF ALL DISKS CAPACITY. IF C_i IS THE SAME $\forall i$,

$S_c = N \cdot C$ SEQUENTIAL READ/WRITE $N \cdot S$

RANDOM READ/WRITE $N \cdot R$ READ/WRITE D

RELIABILITY = 0 ONE DISK FAIL ⇒ EVERYTHING FAILS MTTDL = MTTF

b) RAID 1

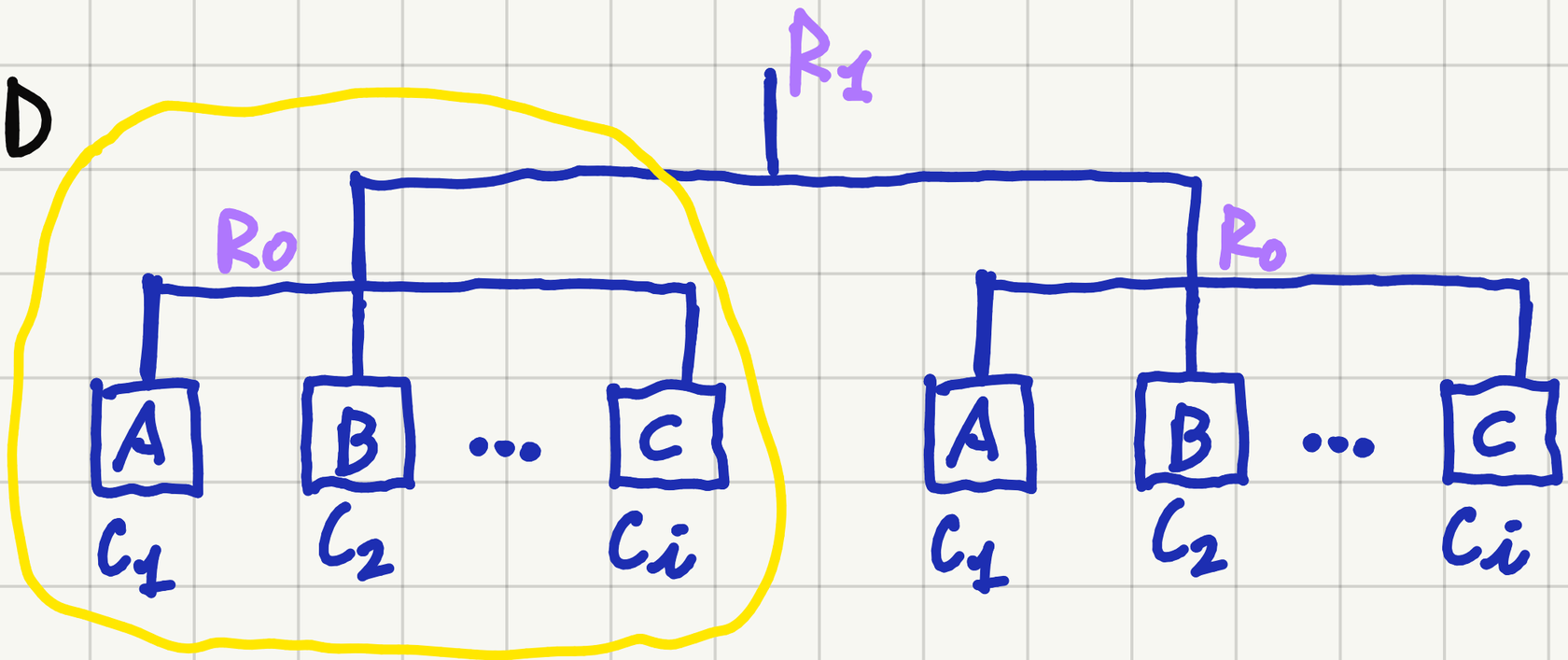


$S_c = C$ RELIABILITY = 1 (AT MOST $\frac{N}{2}$) RANDOM READ $N \cdot R$

SEQUENTIAL READ/WRITE $\frac{N}{2} \cdot S$ RANDOM WRITE $\frac{N}{2} \cdot R$

READ/WRITE D

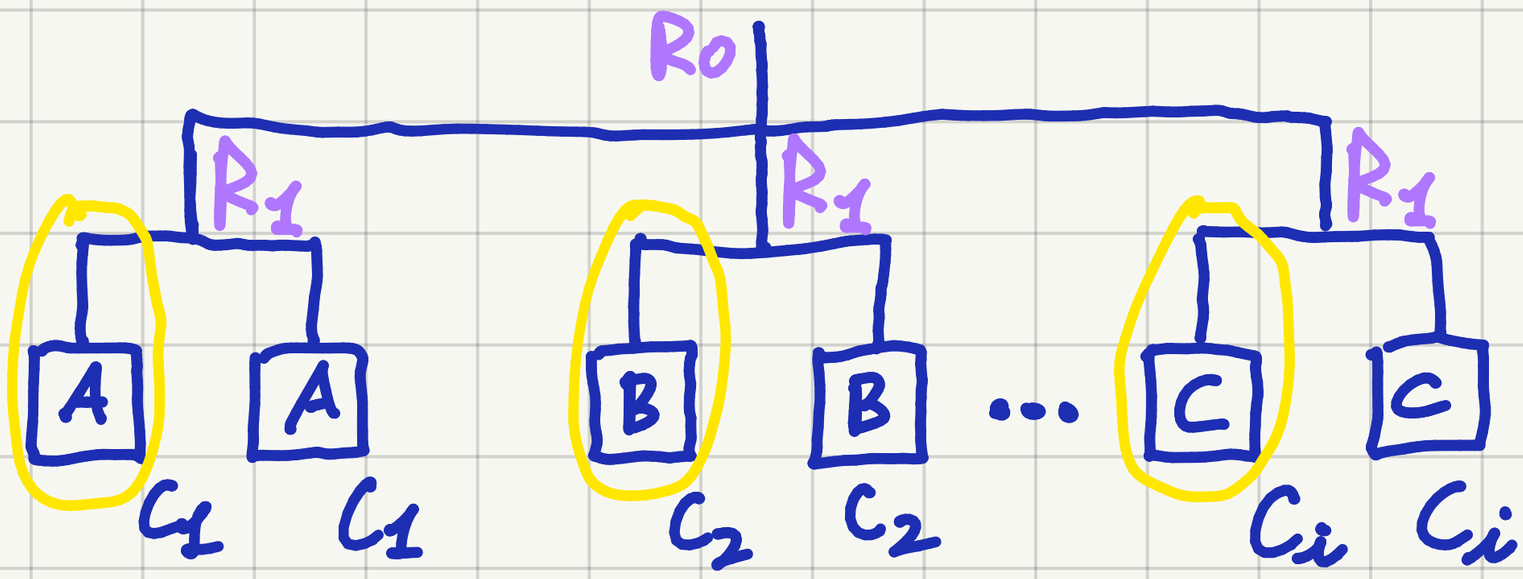
c) RAID 0+1



$S_c = \frac{1}{2}(\sum_i C_i)$ IF C_i IS THE SAME $\forall i$, $S_c = \frac{N}{2} C$

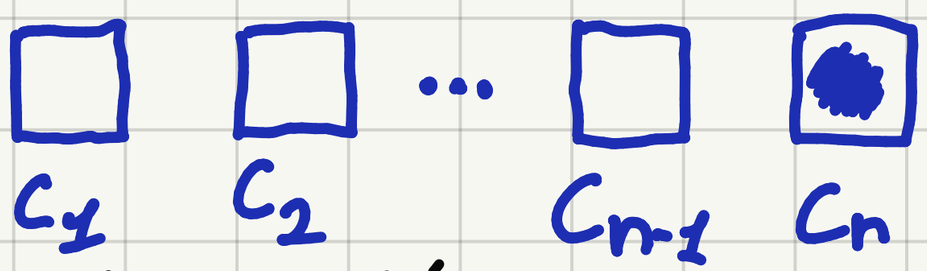
d) RAID 1+0

$$S_c = \frac{1}{2}\left(\sum_i C_i\right)$$



IF C_i IS THE SAME $\forall i$, $S_c = \frac{N}{2} C$

e) RAID 4



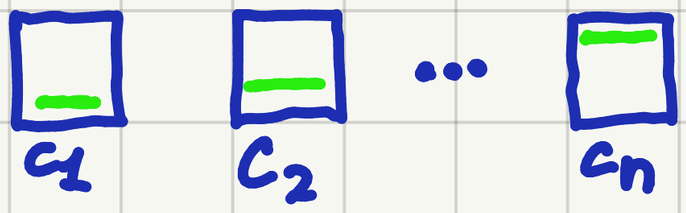
$$S_c = \sum_{i=1}^{N-1} C_i$$ IF C_i IS THE SAME $\forall i$, $S_c = (N-1)C$

RELIABILITY: 1 FAILURE AT MOST

SEQUENTIAL READ/WRITE $(N-1)\cdot S$ READ D

RANDOM READ $(N-1)\cdot R$ RANDOM WRITE $\frac{R}{2}$ WRITE 2D

f) RAID 5



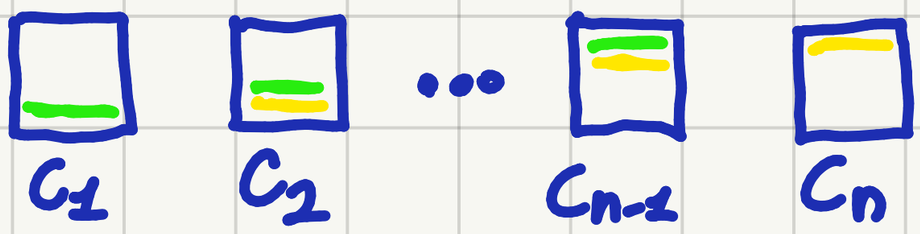
$$S_c = \sum_{i=1}^{N-1} C_i$$ IF C_i IS THE SAME $\forall i$, $S_c = (N-1)C$

RELIABILITY: 1 FAILURE AT MOST

SEQUENTIAL READ/WRITE $(N-1)\cdot S$ READ D

RANDOM READ $N\cdot R$ RANDOM WRITE $\frac{N}{4}\cdot R$ WRITE 2D

g) RAID 6



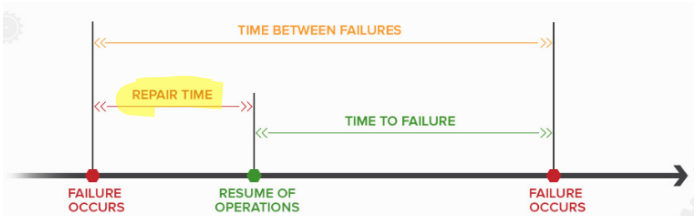
$$S_c = \sum_{i=1}^{N-2} C_i$$ IF C_i IS THE SAME $\forall i$, $S_c = (N-2)\cdot C$

RAID Preliminaries

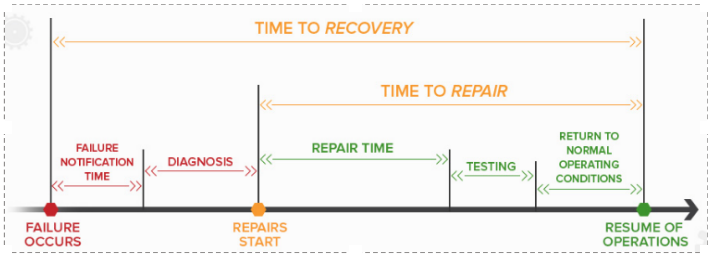
giovedì 19 marzo 2020 10:05

Definitions:

- **RAID** - Redundant Array of Independent Disks
- **MTTDL** –Mean Time To Data Loss
  - Mean time until drive failures cause data loss in the array
- **MTBF** – Mean Time Between Failures
  - is the mean time between hard disk failures.
- **MTTF** – Mean Time To Failure
  - mean time before a disk has a failure
  - 1/MTTF is called Failure Rate



- **MTTR** – Mean Time To Recover (or Repair)
  - Mean time to rebuild redundancy in the array.



Ex_01 – RAID Capacity

giovedì 19 marzo 2020 10:56

Consider to have 6 disks, each one with a capacity of 1TB.
What will be to total storage capacity of the system if they are in the following configurations?

a. RAID 0

b. RAID 1

c. RAID 0+1

d. RAID 1+0

e. RAID 5

f. RAID 6

$C_1 = 1Tb$ $N = 6$ S_c FOR THE VARIOUS CASE?

a) RAID 0

$$S_c = N \cdot C_1 = 6 \cdot 1Tb = 6Tb$$

b) RAID 1

$$S_c = 1Tb$$

c) RAID 0+1

$$S_c = \frac{N}{2} \cdot C_1 = \frac{6}{2} \cdot 1Tb = 3Tb$$

d) RAID 1+0

$$S_c = \frac{N}{2} \cdot C_1 = \frac{6}{2} \cdot 1Tb = 3Tb$$

e) RAID 5

$$S_c = (N-1) \cdot C_1 = 5Tb$$

f) RAID 6

$$S_c = (N-2) \cdot C_1 = 4Tb$$

Ex_02 – RAID 0

mercoledì 4 marzo 2020 11:46

Consider the following RAID 0 setup:

- n = 5 disks
- MTTR = 8 hours
- MTTF(one disk) = 1600 day

The MTTDL will be:

n=5 DISKS MTTR=8h MTTF(ONE DISK)=1600 DAYS MTTDL?

! SOMETIMES, MTTDL IS CALLED $MTTF_{RAID\ 0}$

$$MTTDL = \frac{MTTF}{n} = \frac{1600\ DAYS}{5} = 320\ DAYS$$

NOTICE THAT MTTR IS AN USELESS INFORMATION

Ex_03 - RAID1

mercoledì 4 marzo 2020 11:33

Consider the following RAID 1 setup:

- n = 2 disks
- MTTR = 8 days
- MTTF(one disk) = 1800 day

The MTTDL will be:

$n = 2$ DISKS MTTR = 8 DAYS MTTF(ONE DISK) = 1800 DAYS MTTDL?

$$P(\text{FAIL RAID 1}) = P(1^{ST}\ \text{FAIL}) \cdot P(2^{ND}\ \text{FAIL DURING REPAIR})$$

$$P(1^{ST}\ \text{FAIL}) = \frac{n}{MTTF} = \frac{2}{MTTF} \qquad P(2^{ND}\ \text{FAIL DURING REPAIR}) = \frac{1}{MTTF} \cdot MTTR = \frac{MTTR}{MTTF}$$

$$P(\text{FAIL RAID 1}) = \frac{2MTTR}{MTTF^2}$$

$$MTTDL = \frac{1}{P(\text{FAIL RAID 1})} = \frac{MTTF^2}{2 \cdot MTTR} = \frac{1800^2 \cdot DAYS^1}{16\ \cancel{DAYS}} = 202500\ DAYS$$

Ex_04 – RAID 1+0

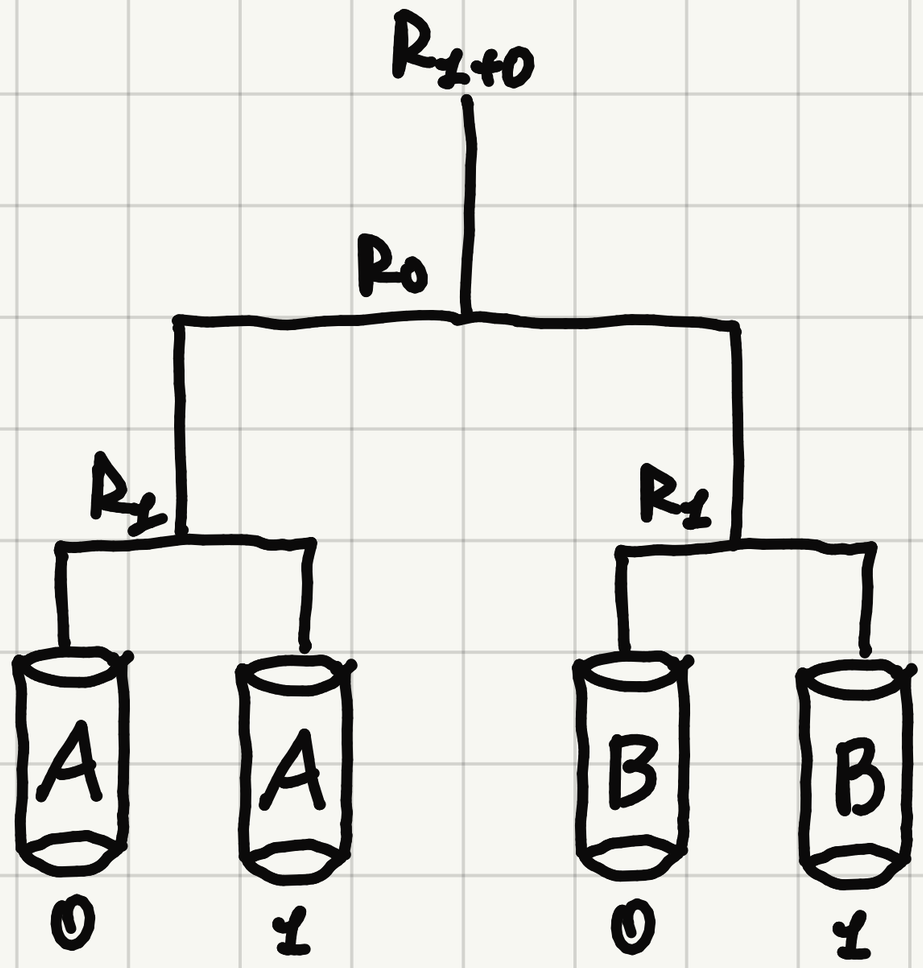
mercoledì 4 marzo 2020 11:45

Consider 2 groups (RAID 0) of 2 disks each (RAID 1), for a total of 4 disks in configuration RAID 1+0:

- MTTR = 3 days
- MTTF(one disk) = 1400 day

The MTTDL will be:

N=4 MTTR=3 DAYS MTTF(ONE DISK)=1400 DAYS MTTDL?



P(FAIL RAID 10) = P(1ST FAIL) · P(2ND FAIL DURING REPAIR)

$$P(1^{ST}\ FAIL) = \frac{N}{MTTF} = \frac{4}{MTTF}$$

RAID 1-0 STRUCTURE

$$P(2^{ND}\ FAIL\ DURING\ REPAIR) = \frac{1}{MTTF} \cdot MTTR = \frac{MTTR}{MTTF}$$

$$P(FAIL\ RAID\ 1+0) = \frac{4 \cdot MTTR}{MTTF^2}$$

$$MTTDL = \frac{1}{P(FAIL\ RAID\ 1)} = \frac{MTTF^2}{4 \cdot MTTR} = \frac{1400^2 \cdot DAYS^2}{12\,DAYS} = 163333\ DAYS$$

Ex_05 – RAID 0+1

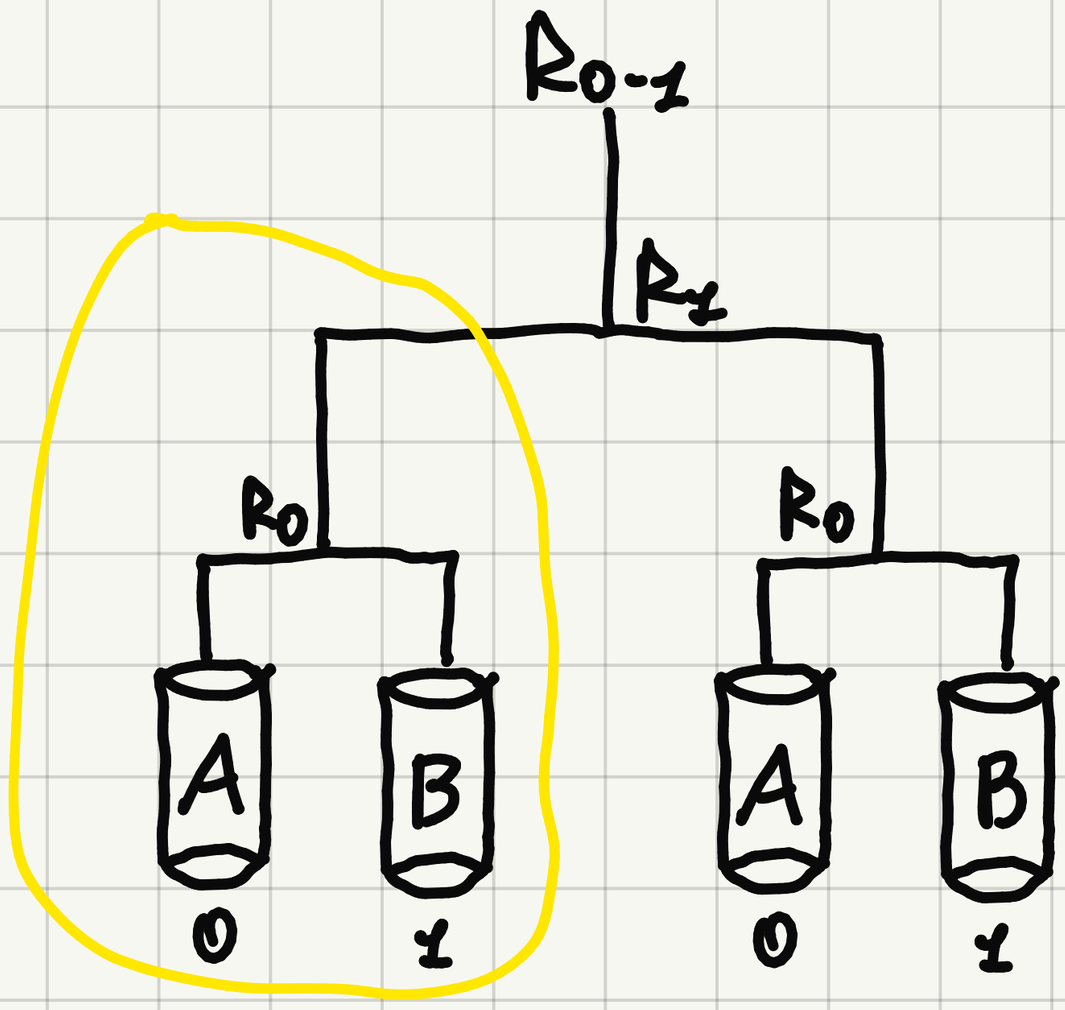
mercoledì 4 marzo 2020 11:33

Consider 2 groups (RAID 1) of 4 disks each (RAID 0), for a total of 8 disks in configuration RAID 0+1:

- MTTR $\simeq$ 4 days
- MTTF(one disk) $\simeq$ 2200 days

The MTTDL will be:

N=8 MTTR=4 DAYS MTTF(ONE DISK)=2200DAYS MTTDL?



P(FAIL 01) = P(1ST FAIL) · P(2ND FAIL DURING REPAIR)

$$P(1^{ST}\ FAIL) = \frac{N/2}{MTTF} \qquad P(^{2ND}\ FAIL) = \frac{N}{MTTF} \cdot MTTR$$

$$P(FAIL\ 01) = \frac{N^2}{2} \cdot \frac{MTTR}{MTTF^2}$$

$$MTTDL = \frac{1}{P(FAIL\ 01)} = \frac{2\,MTTF^2}{N^2 \cdot MTTR} = \frac{2 \cdot 2200^2}{8^2 \cdot 4} = 37813\ DAYS$$

Quiz_2 - RAID 0 + 1

mercoledì 4 marzo 2020 18:31

A system administrator has decided to use a stock of disks characterized by:

MTTF = 800 days

MTTR = 20 days

The target lifetime of the system is 3 years;

The maximum number of disks that could be used in RAID 01 to have a MTTDL larger than the system lifetime is:

1. No more than 58 disks
2. No more than 7 disks
3. At least 8 disks
4. No more than 6 disks
5. None of the other options

MTTF = 800 DAYS MTTR = 20 DAYS MTTDL = 3 YEARS

$$P(\text{FAIL 01}) = P(1^{ST}\ \text{FAIL}) \cdot P(2^{ND}\ \text{FAIL DURING REPAIR})$$

$$P(1^{ST}\ \text{FAIL}) = \frac{N/2}{MTTF} \qquad P(^{2ND}\ \text{FAIL}) = \frac{N}{MTTF} \cdot MTTR$$

$$P(\text{FAIL 01}) = \frac{N^2}{2} \cdot \frac{MTTR}{MTTF^2}$$

$$MTTDL = \frac{1}{P(\text{FAIL 01})} = \frac{2\,MTTF^2}{N^2 \cdot MTTR} = \frac{2 \cdot 800^2}{N^2 \cdot 20} = 3 \cdot 365$$

$$\Rightarrow N = \sqrt{\frac{2 \cdot 800^2}{20 \cdot 3 \cdot 365}} = 7{,}6 \Rightarrow \quad 4)\ N \leq 6$$

Ex_06 – RAID 5

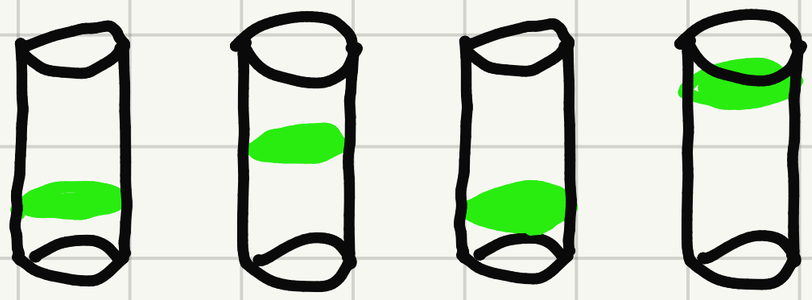
mercoledì 4 marzo 2020 11:10

Consider the following RAID 5 setup:

- n = 4 disks
- MTTR = 3 days
- MTTF(one disk) = 1000 day

The MTTDL will be:

N=4 MTTR=3 DAYS MTTF(ONE DISK)=1000 DAYS MTTDL?



P(FAIL 5) = P(1ST FAIL) · P(2ND FAIL DURING REPAIR)

$$= \frac{N}{MTTF} \cdot \frac{N-1}{MTTF} \cdot MTTR = \frac{N(N-1)MTTR}{MTTF^2}$$

$$MTTDL = \frac{1}{P(FAIL\ 5)} = \frac{MTTF^2}{N(N-1)MTTR} = \frac{1000^2}{4 \cdot 3 \cdot 3} = 27778 \text{ DAYS}$$

Ex_07 – RAID 6

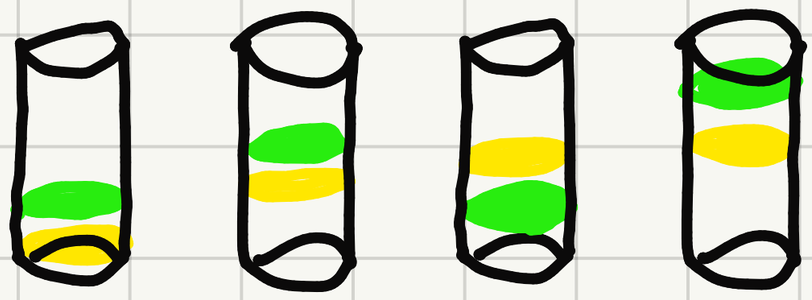
mercoledì 4 marzo 2020 11:11

Consider the following RAID 6 setup:

- n = 5 disks
- MTTR = 2 days
- MTTF(one disk) = 1100 day

The MTTDL will be:

N=5 MTTR=2 DAYS MTTF(ONE DISK)=1100 DAYS MTTDL?



$$P(\text{FAIL } 6) = P(1^{ST}\text{ FAIL}) \cdot P(2^{ND}\text{ FAIL}) \cdot P(3^{RD}\text{ FAIL})$$

$$= \frac{N}{MTTF} \cdot \frac{N-1}{MTTF} MTTR \cdot \frac{N-2}{MTTF} \frac{MTTR}{2} = \frac{N(N-1)(N-2)MTTR^2}{MTTF^3}$$

$$MTTDL = \frac{1}{P(\text{FAIL } 6)} = \frac{2 \cdot MTTF^3}{N(N-1)(N-2)MTTR^2} = \frac{2 \cdot 1100^3}{5 \cdot 4 \cdot 3 \cdot 2^2} = 55458334 \text{ DAYS}$$

Storage Capacity

giovedì 6 maggio 2021 11:40

A Raid6 system uses eight 3TB drives to store data and the required parity bits. How many identical drives would be needed to assemble a RAID1+0 system of equivalent capacity? For the RAID1 configuration consider a single replica of data blocks.

RAID 6 $N=8$ $C_1 = 3Tb$ S_c? IF RAID 1+0, N FOR SAME S_c?

$S_c = (N-2) \cdot C_1 = 18Tb$

$S_c^{1+0} = \frac{N}{2} \cdot C_1 = 18Tb \Rightarrow N = \frac{36}{3} = 12$

Design Choice

giovedì 6 maggio 2021 11:41

You have been assigned from your boss to configure a storage system with 8 disks considering the maximum capacity and a constraint of MTTDL > 8 years. If the MTTF of each disk is 2 years and the MTTR is 3 days, what type of configuration are you going to select:

- RAID 0
- RAID 0+1
- RAID 1+0
- RAID 5
- RAID 6

N=8 MTTF ONE DISK=) 2 YEARS MTTDL > 8 YEARS MTTR = 3 DAYS

$$MTTDL = \frac{1}{P(FAIL)} > 8 \cdot 365 = 2920$$

RAID 0) $MTTDL = \frac{MTTF}{2} = \frac{2}{8}$ YEARS NO

RAID 0+1) $MTTDL = \frac{2MTTF^2}{N^2 MTTR} = \frac{2 \cdot (2 \cdot 365)^2}{8^2 \cdot 3} = 5551$ DAYS ✓

RAID 1+0) $MTTDL = \frac{MTTF^2}{N \cdot MTTR} = \frac{(2 \cdot 365)^2}{8 \cdot 3} = 22204$ DAYS ✓

RAID 5) $MTTDL = \frac{MTTF^2}{N(N-1)MTTR} = \frac{(2 \cdot 365)^2}{8 \cdot 7 \cdot 3} = 3172$ DAYS ✓

RAID 6) $MTTDL = \frac{2MTTF^3}{N(N-1)(N-2)MTTR^2} = \frac{(2 \cdot 365)^2}{8 \cdot 7 \cdot 6 \cdot 3^2} = 70468$ DAYS ✓

RAID 5

SUMMARIZE

$$MTTDL = \frac{1}{P(FAIL)}$$

$P(FAIL\ RAID\ 0) = \frac{N}{MTTF}$! MTTR IS NOT INVOLVED

$P(FAIL\ RAID\ 1) = P(FAIL\ 1+0) = \frac{N \cdot MTTR}{MTTF^2}$

$P(FAIL\ RAID\ 0+1) = \frac{N^2}{2} \cdot \frac{MTTR}{MTTF^2}$

$P(FAIL\ RAID\ 5) = \frac{N(N-1)MTTR}{MTTF^2}$

$P(FAIL\ RAID\ 6) = \frac{N(N-1)(N-2)MTTR^2}{2MTTF^3}$