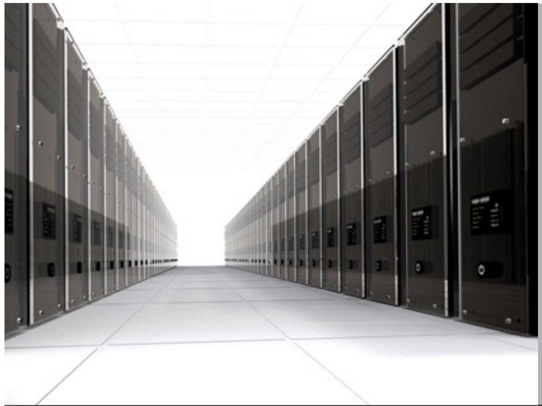

STORAGE CONCEPTS

David López
v 2.5.1
Updated spring 2022

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Magnetic vs. Optical vs. Solid State

Three basic storage technology:
- Magnetic
  - Tapes (1952-Today)
  - Hard Disk (1956-Today)
- Optical
  - Optical Disc Archive (2013 – Today)
- Solid State
  - Solid State Discs – SSD (2006 – Today)

Hard Disk situation

Hard disks are “living dinosaurs”
- According to Moore’s law, the density of microelectronics doubles every 18 months
- In hard disks, this only applies to:
  - Process speed of the controller (which never was much of a problem anyway)
  - Increased speed of read/write operations because more data is packed onto each track
  - Increased capacity of the disk (that means more accesses per second)
- The problem is that it does not affect nor to the rotational speed neither to the actuators moving speed
  - And several actuators on the same rack does not work due to the high density and dilatation

BIG PROBLEM: HDD can store gigantic amounts of data, but the transactions per second are tied to the mechanical internals

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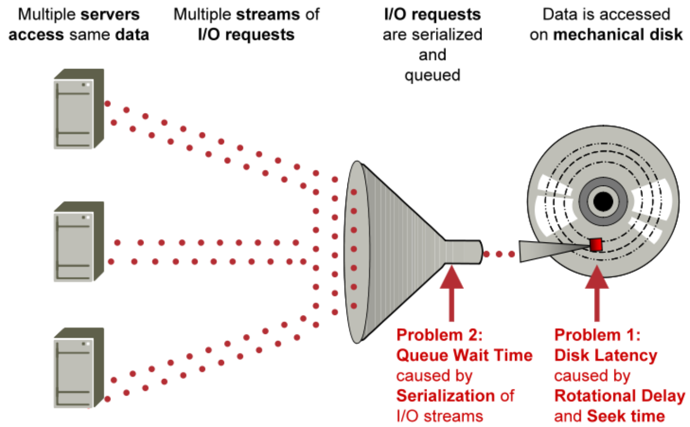
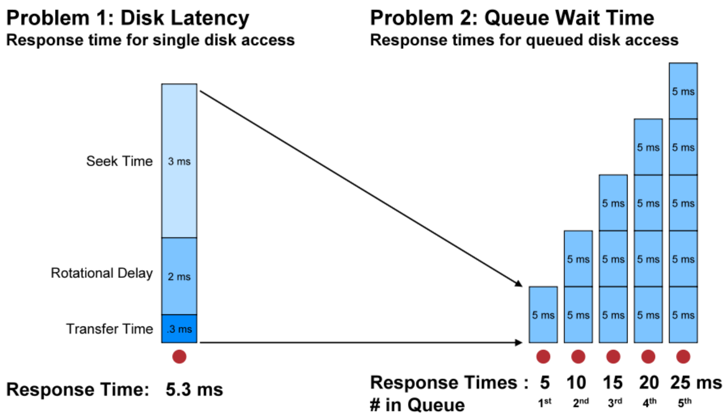
Hard disk problems



http://www.violin-memory.com/assets/Violin-WP-Disk-Storage-Shortfall.pdf?d=1

Disk latency + queue wait time



http://www.violin-memory.com/assets/Violin-WP-Disk-Storage-Shortfall.pdf?d=1

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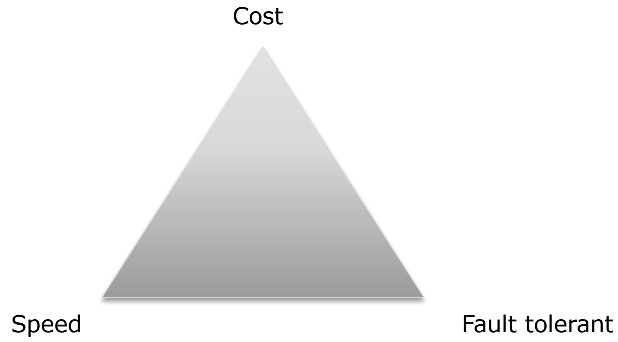
Storage triangle



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LUNs and JBOD

- Divided in **LUN**s (**L**ogical **UN**its)
  - For the host computer, there are not differences between LUNs and physical disks
- Easy to work for the host computer
  - Partitions or (more often) aggregation
  - Saw as an unique disk for backup
- Example a **JBOD** (**J**ust a **B**unch **O**f **D**isks)
  - Example: three 2TB disks
  - Build a 6TB LUN
  - You can have disks of different size (not like RAID)
  - One block following the next on the same disk (not like RAID 0) "Concatenation or SPAN, not stripped"

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JBOD

	Space Efficiency	Fault tolerance	Read Performance	Write Performance
JBOD	1	0	1	1

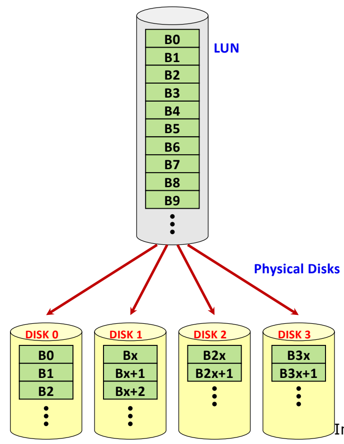

Image by Agustín Fernández (AC)

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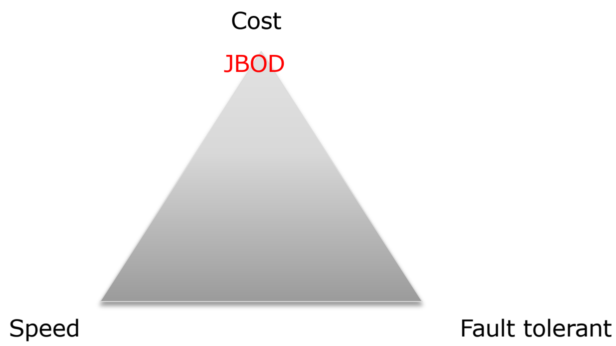
Storage triangle



Avoiding errors: RAID

- RAID offers redundancy, BUT ALSO SPEED (at a certain cost)
- Let's calculate # of parallel R/W in
  - RAID 0
  - RAID 1
  - RAID 5
  - RAID 6
  - RAID 10, 01
  - RAID 51, 15
- Important question: WHAT ABOUT THE STRIPE SIZE?
  - 4KB-128KB?
  - In the activities we will consider 4KB but it is an interesting question

RAID 0 (stripping) & RAID 1 (mirroring)

	Space Efficiency	Fault tolerance	Read Performance	Write Performance
RAID 0	1	0	n to 1	n to 1
RAID 1	1/n	n-1	n (real)	1

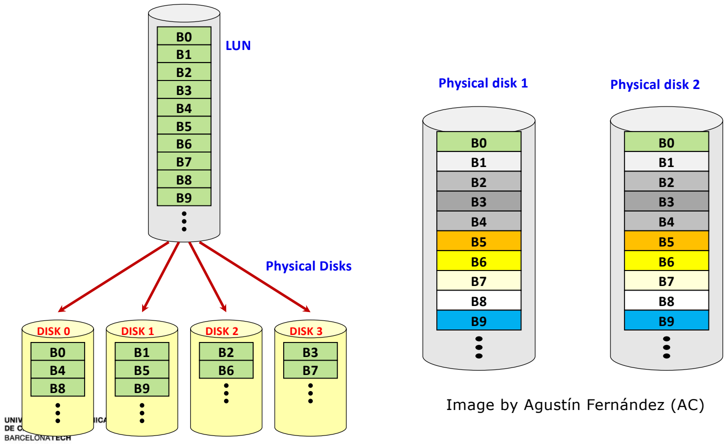
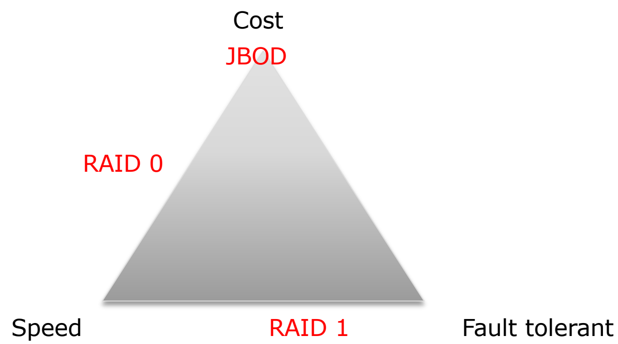
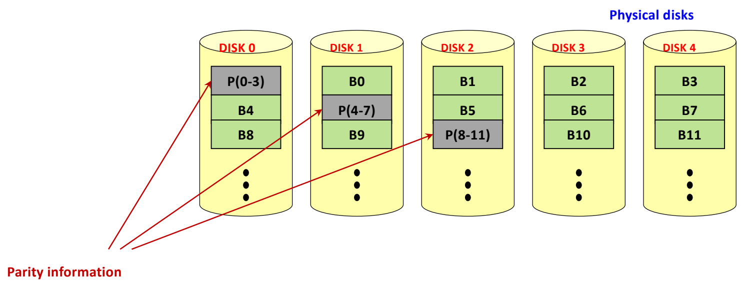


Image by Agustín Fernández (AC)

Storage triangle



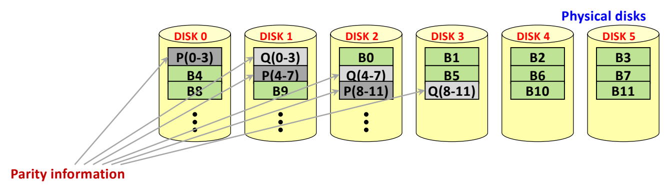
RAID 5: Block-level striping with distributed parity



	Space Efficiency	Fault tolerance	Read Performance	Write Performance
RAID 5	n-1	1	n (n/2)	(n-1) (n/2)

Image by Agustín Fernández (AC)

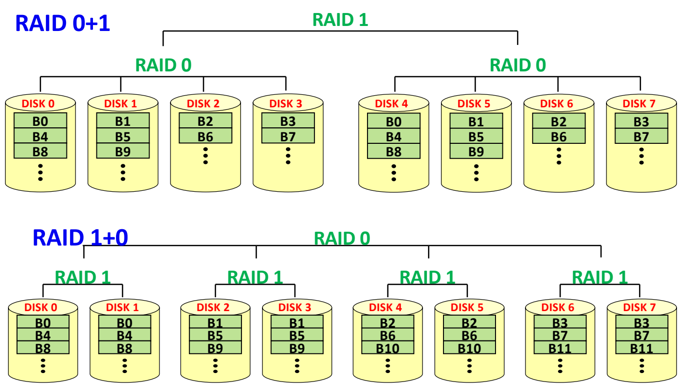
RAID 6: Block-level striping with double distributed parity



	Space Efficiency	Fault tolerance	Read Performance	Write Performance
RAID 6	n-2	2	n (n/3)	(n-2) (n/3)

Image by Agustín Fernández (AC)

RAID 10 & RAID 01



	Space Efficiency	Fault tolerance	Read Performance	Write Performance
RAID 10/01	n/mirrors	n/mirrors	n mirrors	(n/mirrors) 1

Image by Agustín Fernández (AC)

RAID 51 & 15

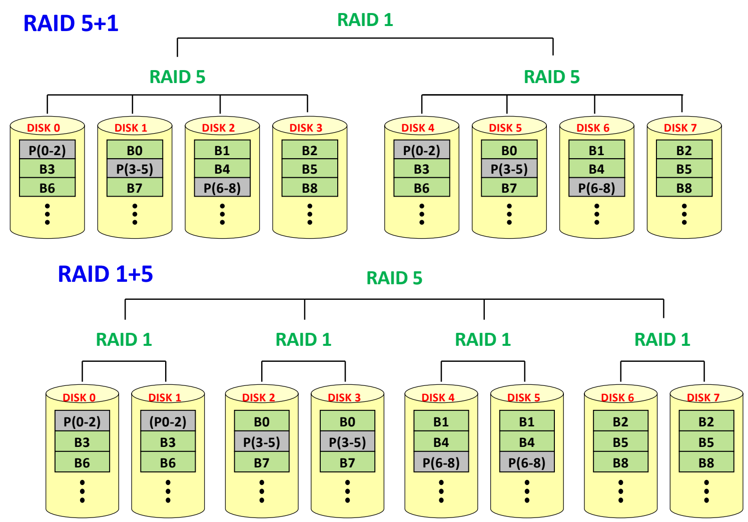
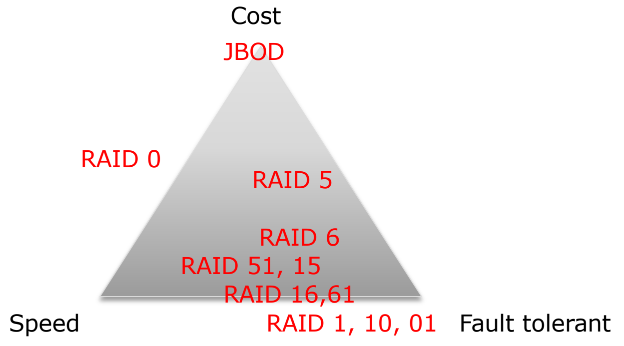


Image by Agustín Fernández (AC)

Storage triangle



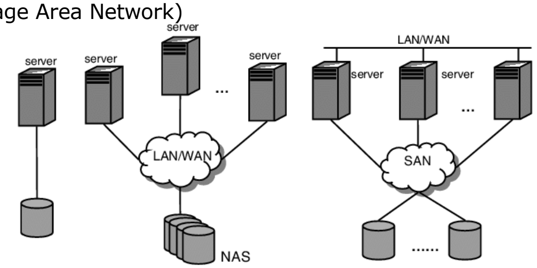
RAID, write penalty & capacity

	RAID 0	RAID 10	RAID 5	RAID 51	RAID 6	RAID 61
Operations per write	1W	2W	2R+2W	(2R+2W) x2	3R+3W	(3R+3W) x2
Write penalty	1	2	4	8	6	12
Capacity	X*C	(X/2)*C	(X-1)*C	((X-1)/2)*C	(X-2)*C	((X-2)/2*C
Minimum number of discs	2	4	3	6	4	8
Required discs (for Y Bytes)	Y/C	2*Y/C	Y/C +1	2*Y/C +1	Y/C +2	2*Y/C +2

Let's assume X discs, homogeneous, each one of capacity C

Avoiding errors: storage networks

- a) DAS (Direct Attached Storage)
- b) NAS (Network Attached Storage)
- c) SAN (Storage Area Network)



(a) DAS (b) NAS (c) SAN

Further reading:
IBM. Demystifying Storage Networking: DAS, SAN, NAS, NAS Gateways, Fibre Channel, and I SCSI. David Sacks
www-03.ibm.com/industries/ca/en/education/k12/technical/whitepapers/storagenetworking.pdf

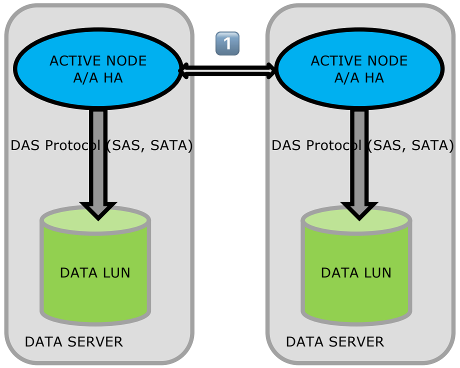
DAS (Direct Attached Storage)

The simplest form

- A single (or multiple) disk drive or tape connected to a computer
- Can have some features like RAID, partitions, …
- Can be accessed by others?
  - Yes. Not directly but through the host computer
  - There is no network device between the data storage device and the computer
- Direct connection, usually using SAS or SATA
  - SAS: Serial Attached SCSI (Small Computer System Interface)
  - SATA: Serial Advanced Technology Attached
- Low cost solution

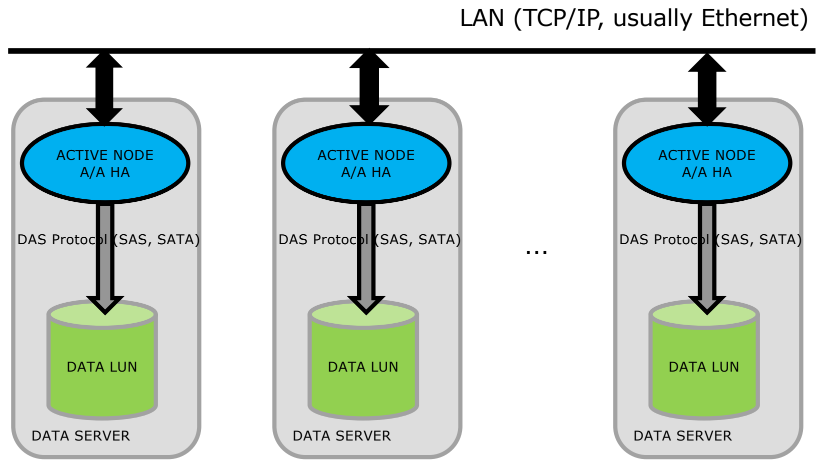
QUITE INUSUAL IN DATA CENTERS

DAS (Direct Attached Storage) idea



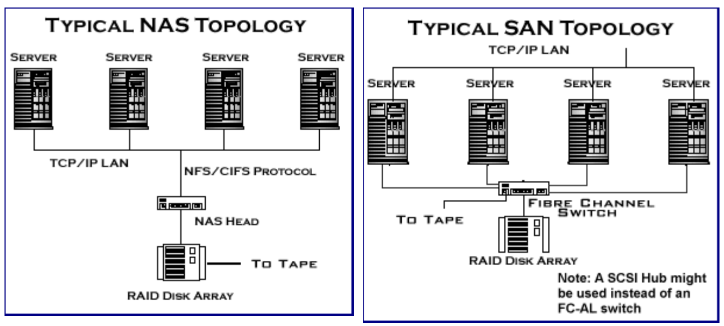
- Both nodes actives (A/A) (not Active/Passive A/P)
- When one node fails, its data are unreachable for the other nodes
- HA (High Availability) requires each piece of data replicated in other nodes (but local disks are cheap)
- Changes are not immediately visible to all nodes.
- Cluster software needed to arbitrate Read & Modify access to replicate data in order to maintain consistency (through Ethernet) 1

DAS (Direct Attached Storage)

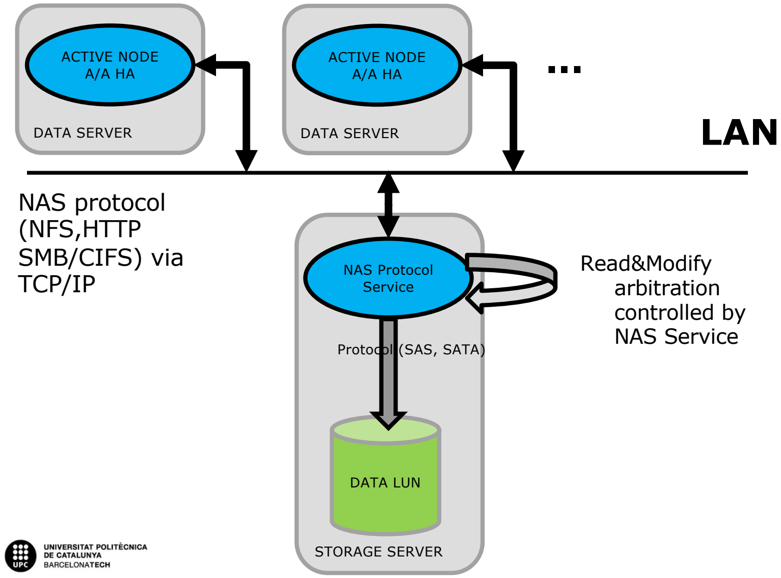


NAS and SAN

Image from NAS-SAN.com



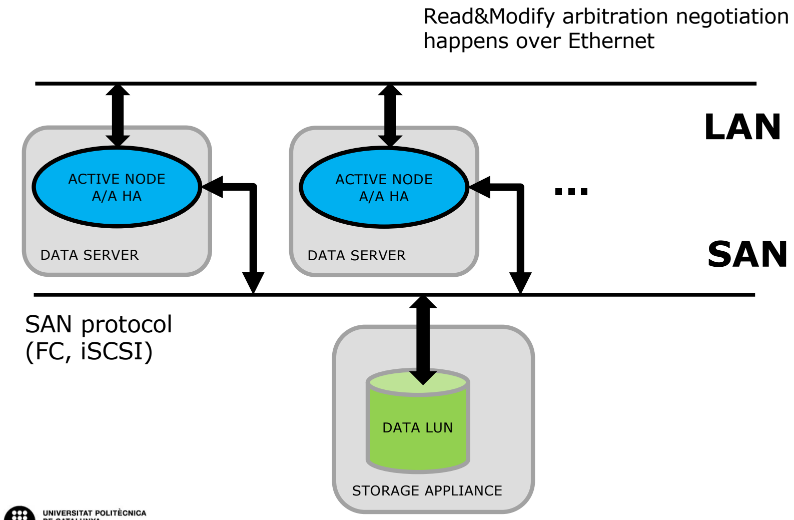
NAS (Network Attached Storage)



NAS (Network Attached Storage) details

- Attached to a TCP/IP network (usually Ethernet)
  - Typically 100 Mbps – 10 Gbps, 2-4μsec latency
- Protocol operates on files (like a network attached file)
- NAS appears to the OS as a shared folder
- NAS is LAN-dependent; if the LAN goes down so does the NAS
- Does not scale very well (in the EBH project we will ignore this)
- One weakness related with its very nature:
  - Ethernet transfer data via packets, that can be sent out-of-order (or even lost), so the file is not available until all packets has arrived
  - No problem with small files, problem with large files (video production or consumption)

SAN (Storage Area Network)



SAN (Storage Area Network) details

- Dedicated high-performance network for block-level storage
  - Typically 2-200 Gbps, <1μsec latency
- Protocol operates on blocks: multiple clients can access files at the same time with very high performance (as it was a local hard disk). Changes are visible by all nodes
- SAN is LAN-independent; if the LAN goes slow does not affect
- More complex to administrate, more expensive
- Not affected by out-or-order

NAS

- Cheaper
- Easy to manage
- Ideal for:
  - File storage and share
  - Small Databases

SAN

- High performance
- Ideal for:
  - High transaction databases
  - E-commerce
  - Video editing or broadcasting
  - If fast backup is required

IOPS (Input / Output Operations Per Second)

- Pronounced *eye-ops*
- Common performance measurement for storage devices
- There are applications to measure it
  - Iometer (Intel)
  - IOzone
  - FIO
- Not easy to define / compare
  - Mix of read / write operations
  - Sequential and random accesses
  - Data block sizes
- Typical values
  - Total IOPS (mix of R/W, Seq/RND)
  - Random read IOPS
  - Random write IOPS
  - Sequential read IOPS
  - Sequential write IOPS
- IOPS * TransferSizeInBytes = MBps

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SSD performance

Many IOPS? Solid State Disks can offer the solution!

- In our project
  - HDD IOPS: 640 – 5210
  - SSD IOPS (RD/WR): 90k/10k – 540k / 205k

And the cost? Fa$t di$k$ co$t money!

- In our project
  - HDD cost: 0,029 /G (8 TB=235€) – 0,15€/G (2.4TB=360€)
  - SSD cost: 0,155 €/GB (2TB=310€) – 0,21€/GB (7,68TB=1545€)

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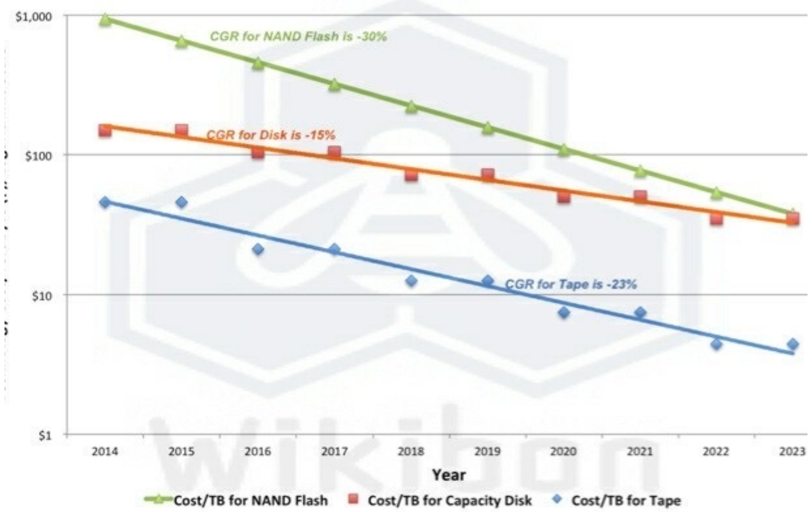
SSD & HDD price forecast



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Consumer vs Enterprise

HDD

Model	Seagate Barracuda ST8000DM0004	Toshiba MG07ACA14TA	Seagate ST10000NM009G	HPE 765466-B21	HPE EG002400JWJNN
Tipus	Consumer	Enterprise	Enterprise	Enterprise	Enterprise
Capacitat (TB)	8	14	10	2	2,4
Consum (W)	6.8	7.8	9.5	7	7.1
Preu (€)	235	520	350	250	360
IOPS R/W	640	800	710	3360	5210
RPM	5400	7200	7200	10000	10000
€ / GB	0,029375	0,037142857	0,035	0,125	0,15

SSD

Model	Samsung 860 EVO	Intel Optane H10	Kingston SEDC100M	WD Gold S768T1D0D	WD Ultrastar DC SN640
Tipus	Consumer	Consumer	Enterprise	Enterprise	Enterprise
Capacitat (TB)	2	1	1,92	7,68	3,8
Consum (W)	2.2	5,8	9	12	8
Preu (€)	310	195	372	1545	750
IOPS R/W	90k / 10k	330K /250k	540K /205K	467k/ 65K	511K / 82K
Tecnologia	3D QLC NAND	3D QLC NAND	3D TLC NAND	3D TLC NAND	3D TLC NAND
€ / GB	0,155	0,195	0,19375	0,201171875	0,197368421

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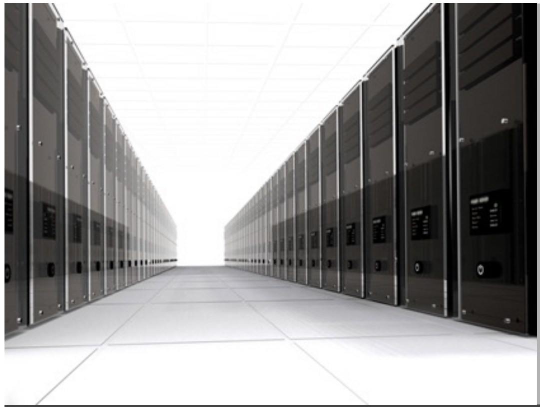

STORAGE

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