

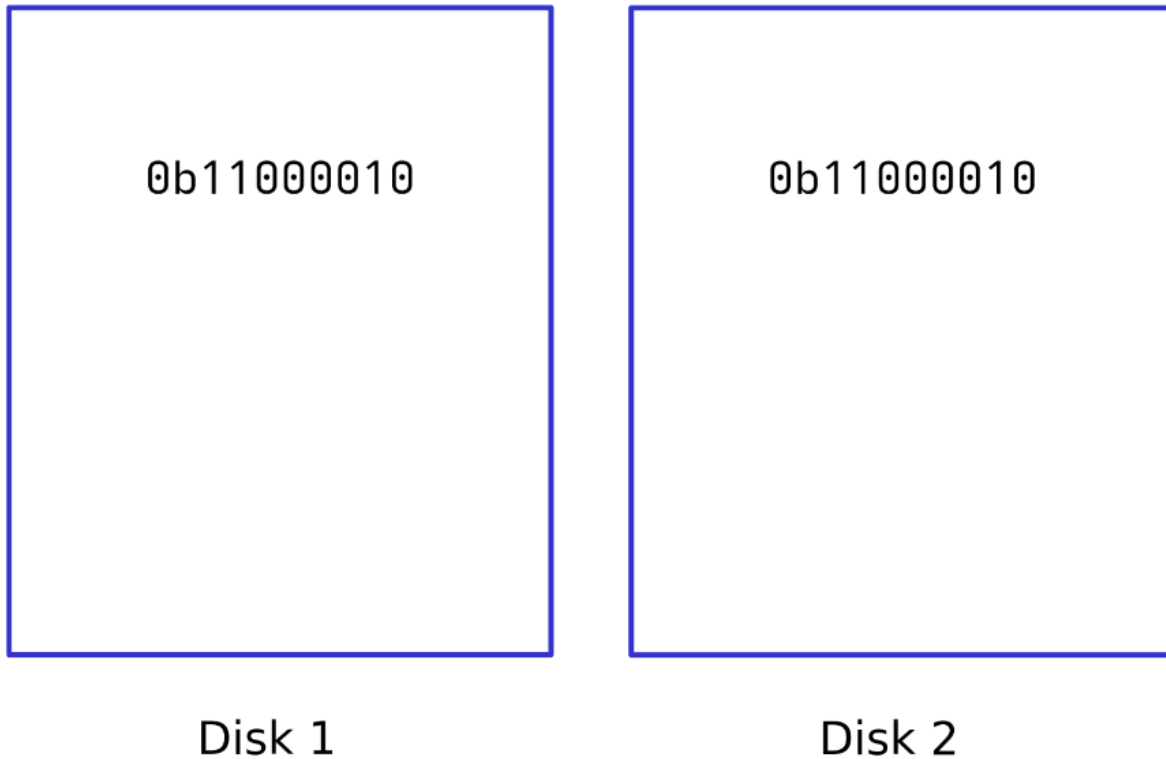
The problem

- You have files that you don't want to lose
- You have a disk to store the files (NVMe, Hard Drives, USB storage sticks, SD cards, etc)
- You want your files to be okay even if a program or person accidentally deletes or messes up the files
- You want your files to be okay even if the disk stops functioning
- You have so many files that they can't fit on a single disk
- You want a way to back up your files to a separate computer
- You want a way of checking that your files are still intact

ZFS

- A file system (other examples of file systems include FAT, NTFS, ext4, btrfs)
- Lets you add up the storage from multiple disks to have more space to store files
- Lets you store the same files on multiple disks so that if one of them stops functioning, you can still access your files (redundancy)
- Never gives you corrupted files when reading (checksums)

Mirrors

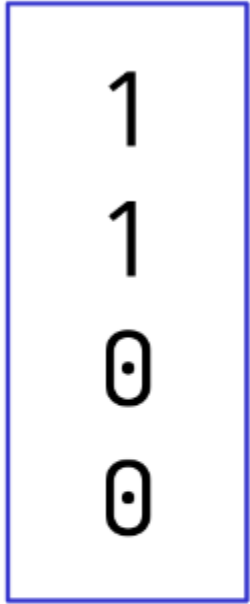


- All disks in a mirror store exactly the same data
- Mirrors have 2+ disks
- As long as one of the disks in the mirror is working and not corrupted, you can access your files
- Your usable capacity is the capacity of 1 disk
- Adding more disks to the mirror does not increase the total capacity

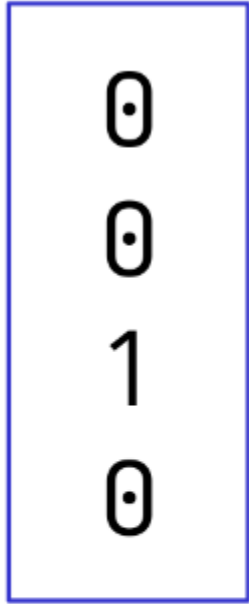
Mirrors - Check your understanding

- If you have a mirror of 2 disks which can store 1TB each, what is the total capacity?
- If you have a mirror of 3 disks which can store 4TB each, what is the total capacity?
- If you have a 1TB disk and a 2TB disk, how much capacity can you use in a mirror configuration?

raidz1



Disk 0
(bits 0-3)



Disk 1
(bits 4-7)



Disk 2
(parity bits)

raidz1

- Consists of 3+ disks of equal size
- 1 disk is used for parity
- The total amount of usable capacity is $(\text{the number of disks} - 1) * (\text{the capacity of a disk})$
- If any 1 disk gets corrupted, your files are still intact
- This is possible using XOR
- If 1 disk gets corrupted and a 1 more gets corrupted before you can replace the first one, you lose your files

`raidz1` - check your understanding

- In a `raidz1` composed of 3 disks that can each store 1TB, what is the total capacity?
- In a `raidz1` composed of 5 disks that can each store 8TB, what is the total capacity?
- Assuming you have 3+ disks, what has more redundancy, a mirror or `raidz1` configuration?
- Assuming you have 3+ disks, what has more total capacity, a mirror or `raidz1` ?

raidz2

- Similar to `raidz1`
- 2 parity disks
- Up to 2 disks can get corrupted and your files will still be intact

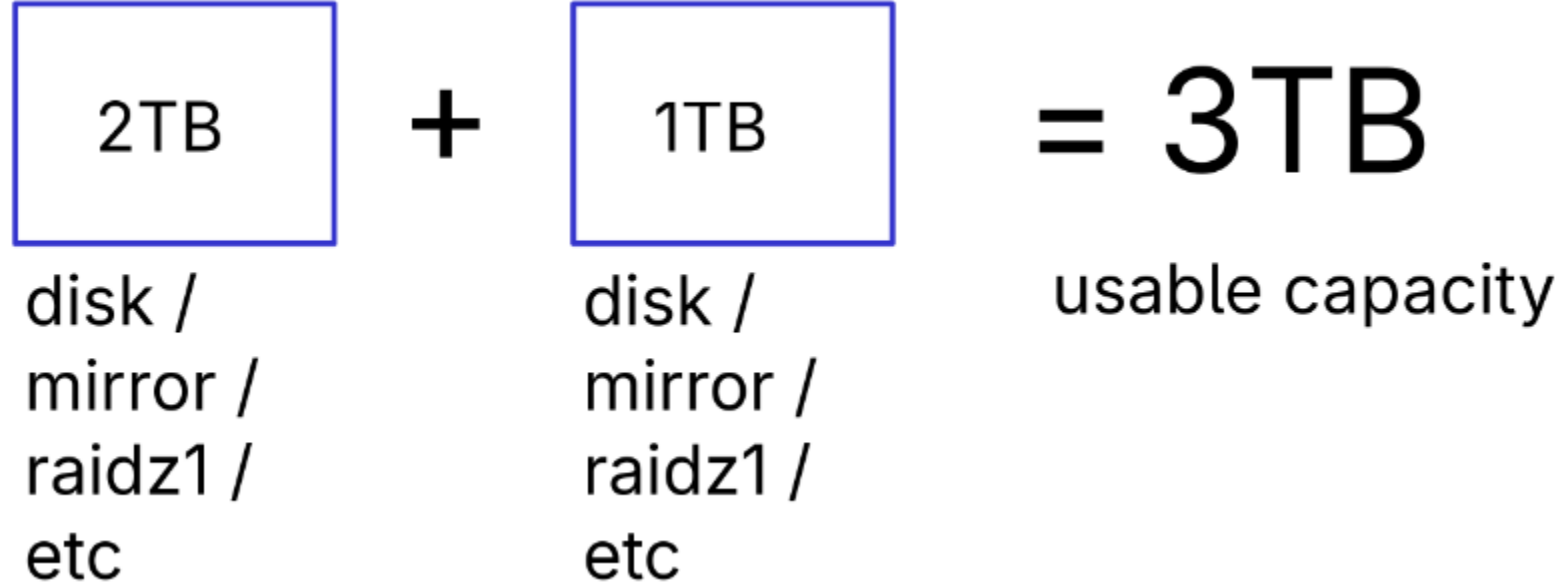
`raidz2` - check your understanding

- What is the total capacity of a `raidz2` composed of 6 drives that each store 20TB?
- How do `mirror`, `raidz1`, and `raidz2` compare to each other? What are the strengths, weaknesses, and trade-offs?
- In what scenarios would you use `raidz2` rather than `raidz1` ?

raidz3

It's what you would think it is.

Summing Capacities (vdev s)



- Each group of disks is called a vdev
- You can combine multiple vdev s to combine their capacity
- Useful for simply combining the capacities of multiple disks without any redundancy

vdev states

State	Description
ONLINE	All disks are working
DEGRADED	One or more disks is not working, but the vdev is still functional because of redundancy
FAULTED	The vdev is not functional

- If a single vdev in a group of vdev s gets FAULTED , you cannot access your files.

zpool s

- A `zpool` consists of multiple `vdev` s
- It has a name set by the user and a random numeric id

Datasets

- A file system backed by a `zpool`
- Has its own mount point, settings, and permissions
- A `zpool` can have multiple datasets
- The smallest unit of backup-able data
- If you have a lot of files, it's recommended to organize them into multiple datasets so that it's easier to move them around different `zpool` s
- A dataset is identified by `<zpool>/<dataset>` . So a an example dataset would be `my-zpool/my-dataset` .

Snapshots



- Let you create a restore point in a dataset
- Taking snapshots is pretty fast and doesn't block other file system operations
- You can rollback to a snapshot to go back to how all the files in the dataset were at the time when the snapshot was taken
- Linear, no branches like Git
- Identified as `<zpool>/<dataset>@<snapshot>`

Backing up snapshots

- `zfs send` and `zfs receive`
- Encrypted
- Incremental
- Two-machine backup system
- `zfs send` to file

Scrubbing

- `zpool scrub`
- Reads all of your files and makes sure they are not corrupted
- Checksums
- Repairs corrupted files if possible

Maintenance Commands

- Often used when disks need to be physically attached and detached
- `zpool replace`
- `zpool offline`
- `zpool online`

Resilvering

- Initializes / updates a disk
- Automatically starts `zpool replace` and `zpool online`

Installing ZFS

- Install OpenZFS
- Officially supports Linux and FreeBSD
- Kernel module (due to licensing)
- Super easy to install on Ubuntu and NixOS

Getting started

- [OpenZFS Documentation](#)
- [Arch Wiki](#)
- [Ubuntu ZFS Tutorials](#)
- [NixOS Wiki](#)
- [2.5 Admins Episode 256: Why ZFS](#)

