ZFS
The Last Word in Filesystem

tzute

What is RAID?

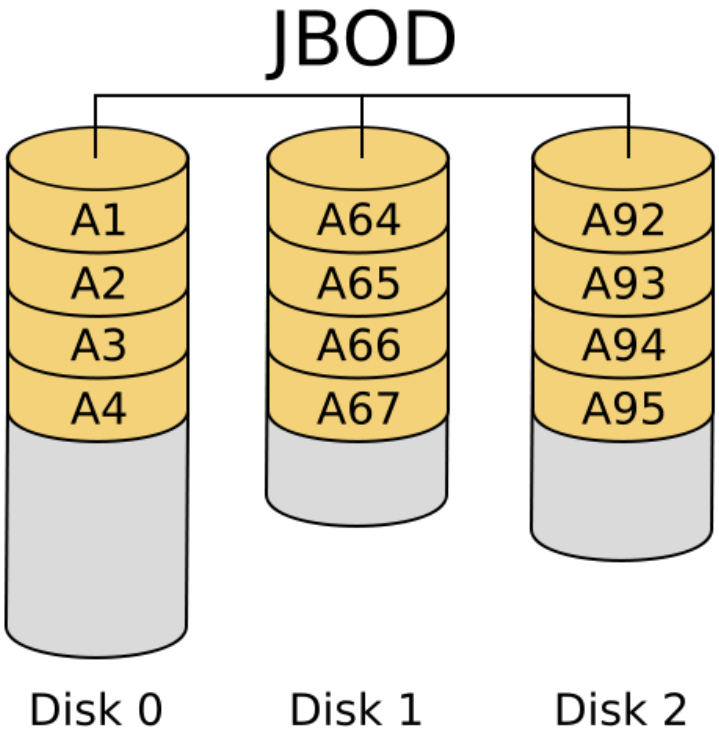
RAID

- Redundant Array of Independent Disks
- A group of drives glue into one

Common RAID types

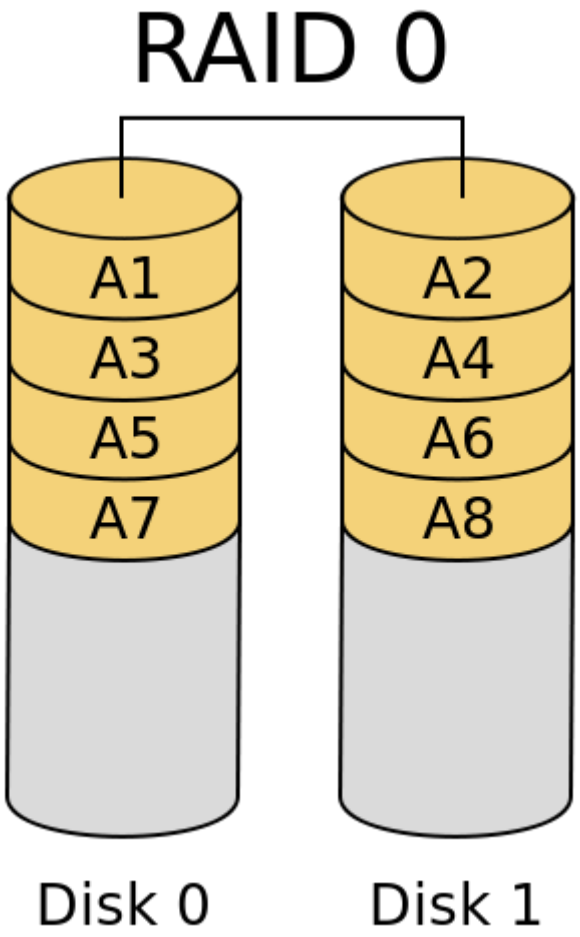
- JBOD
- RAID 0
- RAID 1
- RAID 5
- RAID 6
- RAID 10
- RAID 50
- RAID 60

JBOD (Just a Bunch Of Disks)



https://zh.wikipedia.org/zh-tw/RAID

RAID 0 (Stripe)



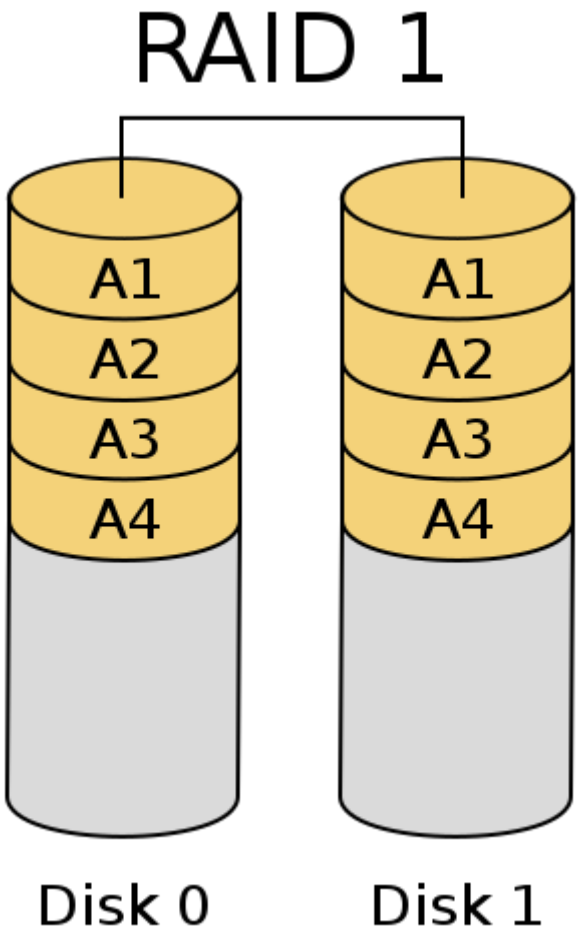
https://zh.wikipedia.org/zh-tw/RAID

RAID 0 (Stripe)

- Striping data onto multiple devices
- High write/read speed

- Data corrupt if ANY of the device fail

RAID 1 (Mirror)

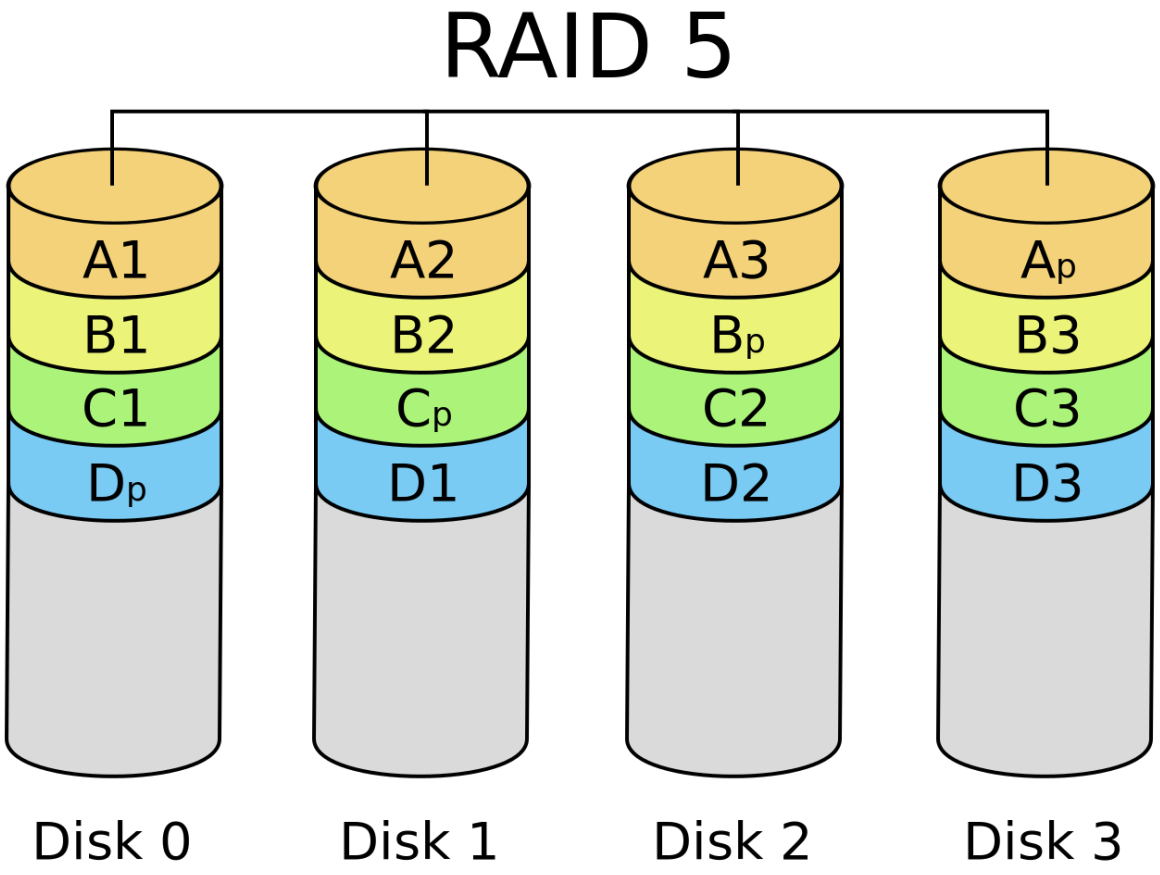


https://zh.wikipedia.org/zh-tw/RAID

RAID 1 (Mirror)

- Devices contain identical data
- 100% redundancy
- Fast read

RAID 5

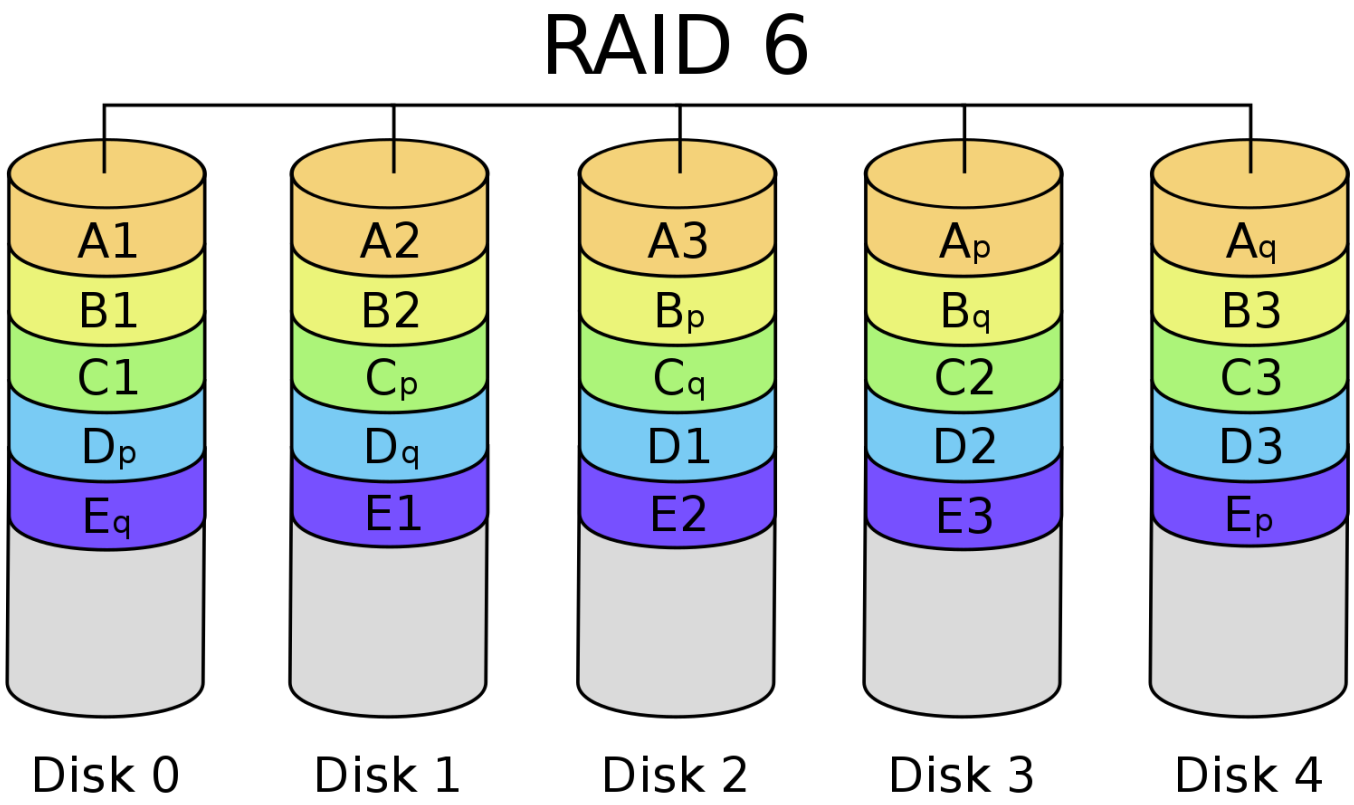


https://zh.wikipedia.org/zh-tw/RAID

RAID 5

- Slower than RAID 0 / RAID 1
- Higher CPU usage

RAID 6



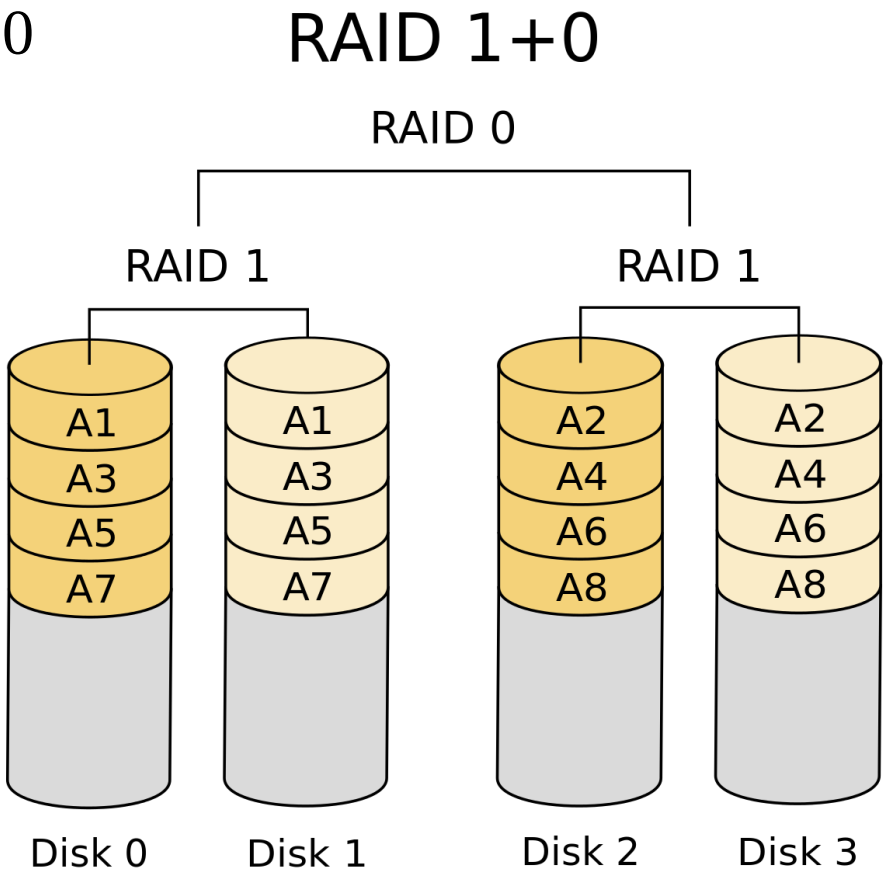
https://zh.wikipedia.org/zh-tw/RAID

RAID 6

- Slower than RAID 5
- Use two different correcting algorithm
- Usually implemented via hardware

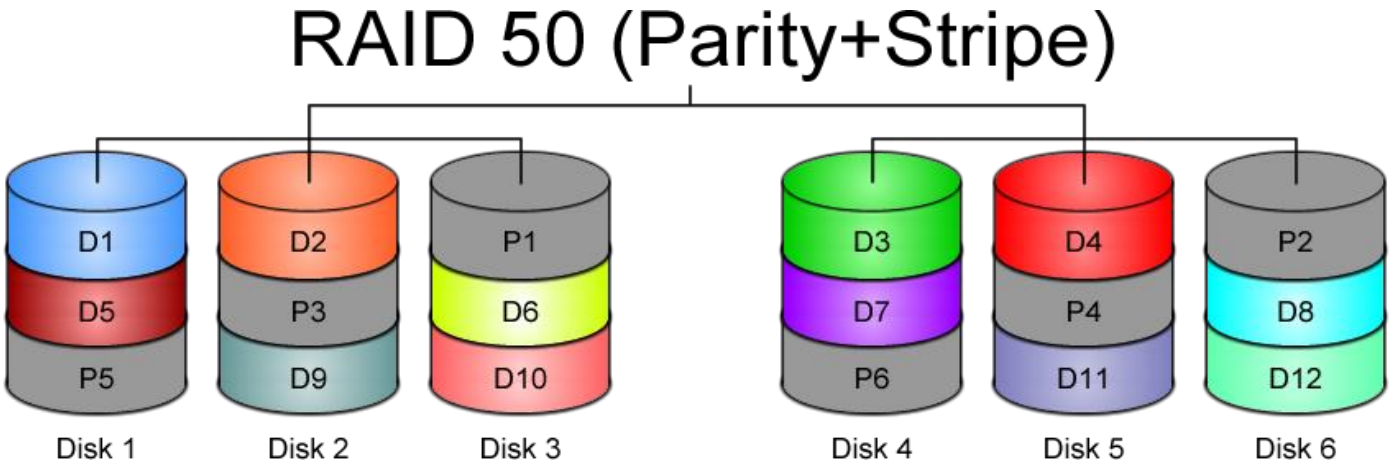
RAID 10

- RAID 1+0



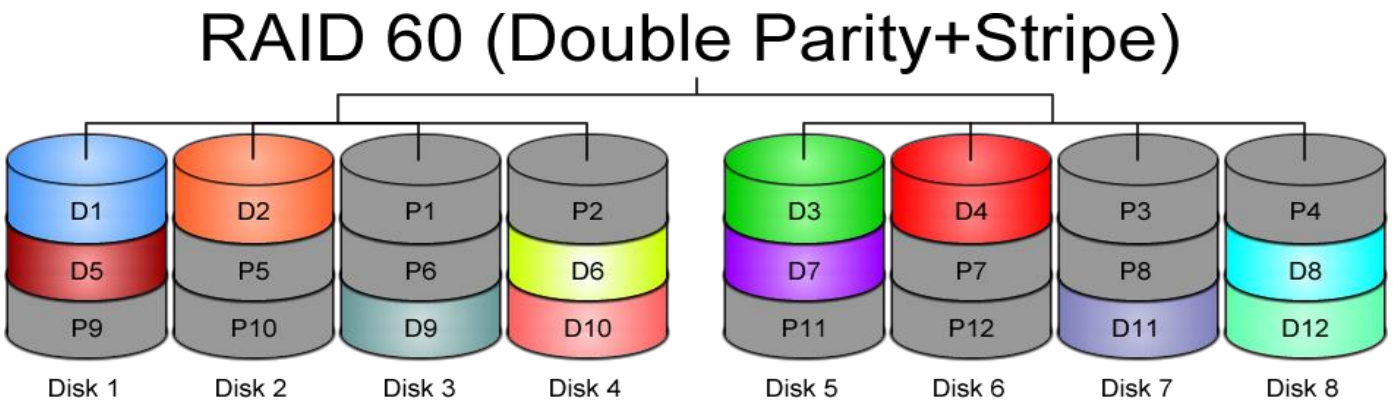
https://zh.wikipedia.org/zh-tw/RAID

RAID 50?



https://www.icc-usa.com/wp-content/themes/icc_solutions/images/raid-calculator/raid-50.png

RAID 60?



https://www.icc-usa.com/wp-content/themes/icc_solutions/images/raid-calculator/raid-60.png

Here comes ZFS

Why ZFS?

- Easy adminstration
- Highly scalable (128 bit)
- Transactional Copy-on-Write
- Fully checksummed
- Revolutionary and modern
- SSD and Memory friendly

ZFS Pools

- ZFS is not just filesystem
- ZFS = filesystem + volume manager

- Work out of the box
- Zuper zimple to create
- Controlled with single command
  - zpool

ZFS Pools Components

- Pool is create from vdevs (Virtual Devices)
- What is vdevs?

- **disk**: A real disk (sda)
- **file**: A file
- **mirror**: Two or more disks mirrored together
- **raidz1/2**: Three or more disks in RAID5/6*
- **spare**: A spare drive
- **log**: A write log device (ZIL SLOG; typically SSD)
- **cache**: A read cache device (L2ARC; typically SSD)

RAID in ZFS

- ***Dynamic* Stripe**: Intelligent RAID 0
- **Mirror**: RAID 1
- **Raidz1**: Improved from RAID5 (parity)
- **Raidz2**: Improved from RAID6 (double parity)
- **Raidz3**: triple parity
- Combined as dynamic stripe

Create a simple zpool

- zpool create mypool /dev/sda /dev/sdb

```
Dynamic Stripe (RAID 0)
        |- /dev/sda
        |- /dev/sdb
```

- zpool create mypool
  - mirror /dev/sda /dev/sdb
  - mirror /dev/sdc /dev/sdd
- What is this?

WT* is this

```
zpool create mypool
        mirror /dev/sda /dev/sdb
        mirror /dev/sdc /dev/sdd
                raidz /dev/sde /dev/sdf /dev/sdg
                        log mirror /dev/sdh /dev/sdi
                                cache /dev/sdj /dev/sdk
                                 spare /dev/sdl /dev/sdm
```

Zpool command

zpool list

list all the zpool

zpool status [pool name]

show status of zpool

zpool export/import [pool name]

export or import given pool

zpool set/get <properties/all>

set or show zpool properties

zpool online/offline <pool name> <vdev>

set an device in zpool to online/offline state

zpool attach/detach <pool name> <device> <new device>

attach a new device to an zpool/detach a device from zpool

zpool replace <pool name> <old device> <new device>

replace old device with new device

zpool scrub

try to discover silent error or hardware failure

zpool history [pool name]

show all the history of zpool

zpool add <pool name> <vdev>

add additional capacity into pool

zpool create/destroy

create/destory zpool

Zpool properties

Each pool has customizable properties

NAME	PROPERTY	VALUE	SOURCE
zroot	size	460G	-
zroot	capacity	4%	-
zroot	altroot	-	default
zroot	health	ONLINE	-
zroot	guid	13063928643765267585	default
zroot	version	-	default
zroot	bootfs	zroot/ROOT/default	local
zroot	delegation	on	default
zroot	autoreplace	off	default
zroot	cachefile	-	default
zroot	failmode	wait	default
zroot	listsnapshots	off	default

Zpool Sizing

- ZFS reserve 1/64 of pool capacity for safe-guard to protect CoW

- RAIDZ1 Space = Total Drive Capacity -1 Drive
- RAIDZ2 Space = Total Drive Capacity -2 Drives
- RAIDZ3 Space = Total Drive Capacity -3 Drives
- Dynamic Stripe of 4* 100GB= 400 / 1.016= ~390GB
- RAIDZ1 of 4* 100GB = 300GB - 1/64th= ~295GB
- RAIDZ2 of 4* 100GB = 200GB - 1/64th= ~195GB
- RAIDZ2 of 10* 100GB = 800GB - 1/64th= ~780GB

http://cuddletech.com/blog/pivot/entry.php?id=1013

ZFS Dataset

ZFS Datasets

- Two forms:
  - filesystem: just like traditional filesystem
  - volume: block device
- Nested
- Each dataset has associated properties that can be inherited by sub-filesystems
- Controlled with single command
  - zfs

Filesystem Datasets

- Create new dataset with
  - zfs create <pool name>/<dataset name>
- New dataset inherits properties of parent dataset

Volumn Datasets (ZVols)

- Block storage
- Located at /dev/zvol/<pool name>/<dataset>
- Used for iSCSI and other non-zfs local filesystem
- Support “thin provisioning”

Dataset properties

```
NAME   PROPERTY              VALUE                  SOURCE
zroot  type                  filesystem             -
zroot  creation              Mon Jul 21 23:13 2014  -
zroot  used                  22.6G                  -
zroot  available             423G                   -
zroot  referenced            144K                   -
zroot  compressratio         1.07x                  -
zroot  mounted               no                     -
zroot  quota                 none                   default
zroot  reservation           none                   default
zroot  recordsize            128K                   default
zroot  mountpoint            none                   local
zroot  sharenfs              off                    default
```

zfs command

zfs set/get <prop. / all> <dataset>

set properties of datasets

zfs create <dataset>

create new dataset

zfs destroy

destroy datasets/snapshots/clones..

zfs snapshot

create snapshots

zfs rollback

rollback to given snapshot

zfs promote

promote clone to the orgin of filesystem

zfs send/receive

send/receive data stream of snapshot with pipe

Snapshot

- Natural benefit of ZFS's Copy-On-Write design
- Create a point-in-time "copy" of a dataset
- Used for file recovery or full dataset rollback
- Denoted by @ symbol

Create snapshot

- # zfs snapshot tank/something@2015-01-02
  - Done in seconds
  - No additional disk space consume

Rollback

- # zfs rollback zroot/something@2015-01-02
  - IRREVERSIBLY revert dataset to previous state
  - All more current snapshot will be destroyed

Recover single file?

- hidden ".zfs" directory in dataset mount point
- set snapdir to visible

Clone

- "copy" a separate dataset from a snapshot
- caveat! still dependent on source snapshot

Promotion

- Reverse parent/child relationship of cloned dataset and referenced snapshot
- So that the referenced snapshot can be destroyed or reverted

Replication

- # zfs send tank/somethin@123 | zfs recv ….
  - dataset can be piped over network
  - dataset can also be received from pipe

Performance Tuning

General tuning tips

- System memory
- Access time
- Dataset compression
- Deduplication
- ZFS send and receive

Random Access Memory

- ZFS performance depends on the amount of system
  - recommended minimum: 1GB
  - 4GB is ok
  - 8GB and more is good

Dataset compression

- Save space
- Increase cpu usage
- Increase data throughput

Deduplication

- requires even more memory
- increases cpu usage

ZFS send/recv

- using buffer for large streams
  - misc/buffer
  - misc/mbuffer (network capable)

Database tuning

- For PostgreSQL and MySQL users recommend using a different recordsize than default 128k.

- PostgreSQL: 8k
- MySQL MyISAM storage: 8k
- MySQL InnoDB storage: 16k

File Servers

- Disable access time
- keep number of snapshots low
- dedup only of you have lots of RAM
- for heavy write workloads move ZIL to separate SSD drives
- optionally disable ZIL for datasets (beware consequences)

Webservers

- Disable redundant data caching
  - Apache
    - EnableMMAP Off
    - EnableSendfile Off
  - Nginx
    - Sendfile off
  - Lighttpd
    - server.network-backend="writev"

Cache and Prefetch

ARC

Adaptive Replacement Cache

- Resides in system RAM
  - major speedup to ZFS
  - the size is auto-tuned

Default:

- arc max: memory size - 1GB
- metadata limit: ¼ of arc_max
- arc min: ½ of arc_meta_limit (but at least 16MB)

Tuning ARC

- Disable ARC on per-dataset level
- maximum can be limited
- increasing arc_meta_limit may help if working with many files

- # sysctl kstat.zfs.misc.arcstats.size
- # sysctl vfs.zfs.arc_meta_used
- # sysctl vfs.zfs.arc_meta_limit

- http://www.krausam.de/?p=70

L2ARC

- L2 Adaptive Replacement Cache
  - is designed to run on fast block devices (SSD)
  - helps primarily read-intensive workloads
  - each device can be attached to only one ZFS pool

- # zpool add <pool name> cache <vdevs>
- # zpool add remove <pool name> <vdevs>

Tuning L2ARC

enable prefetch for streaming or serving of large files

configurable on per-dataset basis

turbo warmup phase may require tuning (e.g. set to 16MB)

vfs.zfs.l2arc_noprefetch

vfs.zfs.l2arc_write_max

vfs.zfs.l2arc_write_boost

ZIL

- ZFS Intent Log
  - guarantees data consistency on fsync() calls
  - replays transaction in case of a panic or power failure
  - use small storage space on each pool by default
- To speed up writes, deploy zil on a separate log device(SSD)
- Per-dataset synchonocity behavior can be configured
  - # zfs set sync=[standard|always|disabled] dataset

File-level Prefetch (zfetch)

- Analyses read patterns of files
- Tries to predict next reads

- Loader tunable to enable/disable zfetch:
  vfs.zfs.prefetch_disable

Device-level Prefetch (vdev prefetch)

- reads data after small reads from pool devices
- useful for drives with higher latency
- consumes constant RAM per vdev
- is disabled by default

- Loader tunable to enable/disable vdev prefetch:
  vfs.zfs.vdev.cache.size=[bytes]

ZFS Statistics Tools

sysctl vfs.zfs

sysctl kstat.zfs

using tools:

- zfs-stats: analyzes settings and counters since boot
- zfsf-mon: real-time statistics with averages

Both tools are available in ports under sysutils/zfs-stats

References

- ZFS tuning in FreeBSD (Martin Matuˇska):
  - Slide
    - http://blog.vx.sk/uploads/conferences/EuroBSDcon2012/zfs-tuning-handout.pdf
  - Video
    - https://www.youtube.com/watch?v=PIpI7Ub6yjo
- Becoming a ZFS Ninja (Ben Rockwood):
  - http://www.cuddletech.com/blog/pivot/entry.php?id=1075
- ZFS Administration:
  - https://pthree.org/2012/12/14/zfs-administration-part-ix-copy-on-write