Porting ZFS file system to FreeBSD

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The beginning...

- ZFS released by SUN under CDDL license
- available in Solaris / OpenSolaris only
- ongoing Linux port for FUSE framework (userland); started as SoC project

Features...

- ZFS has many very interesting features, which make it one of the most wanted file systems

Features...

- dynamic stripping – use the entire bandwidth available,
- RAID-Z (RAID-5 without "write hole" (more like RAID-3 actually)),
- RAID-1,
- 128 bits (POSIX limits FS to 64 bits)... (think about 65 bits)

Features...

- pooled storage
  - no more volumes/partitions
  - does for storage what VM did for memory
- copy-on-write model
- transactional operation
  - always consistent on disk
  - no fsck, no journaling

Features...

- snapshots
  - very cheap, because of COW model
- clones
  - writtable snapshots
- snapshot rollback
  - always consistent on disk
- end-to-end data integrity
  - detects and corrects silent data corruption caused by any defect in disk, cable, controller, driver or firmware

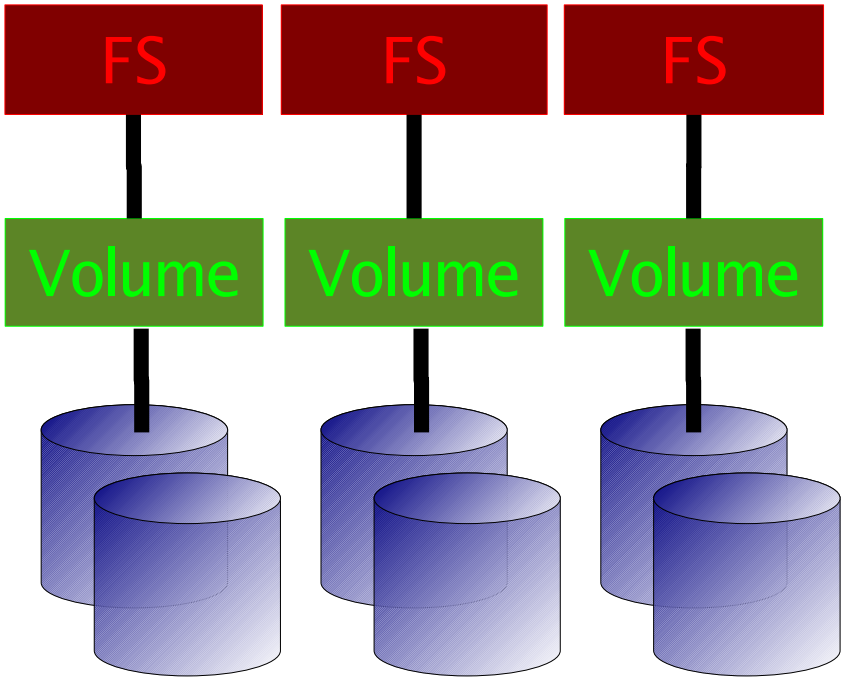
Features...

- built-in compression
  - lzjb, gzip (as a patch)
- self-healing
- endian-independent
  - always write in native endianess
- simplified administration
- per-filesystem encryption
  - soon

FS/Volume model vs. ZFS

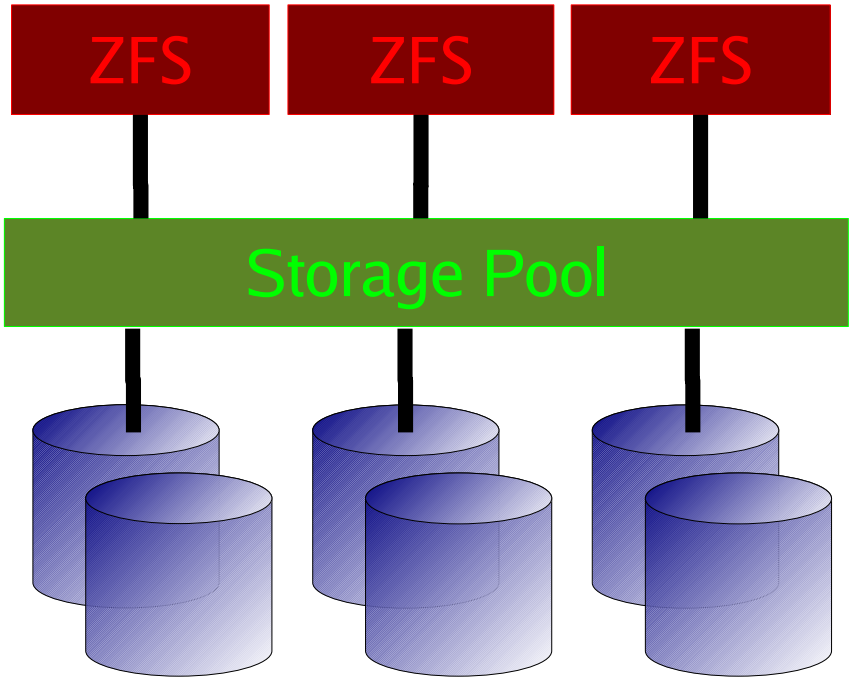
Tranditional Volumes

- abstraction: virtual disk
- volume/partition for each FS
- grow/shrink by hand
- each FS has limited bandwidth
- storage is fragmented



ZFS Pooled Storage

- abstraction: malloc/free
- no partitions to manage
- grow/shrink automatically
- all bandwidth always available
- all storage in the pool is shared



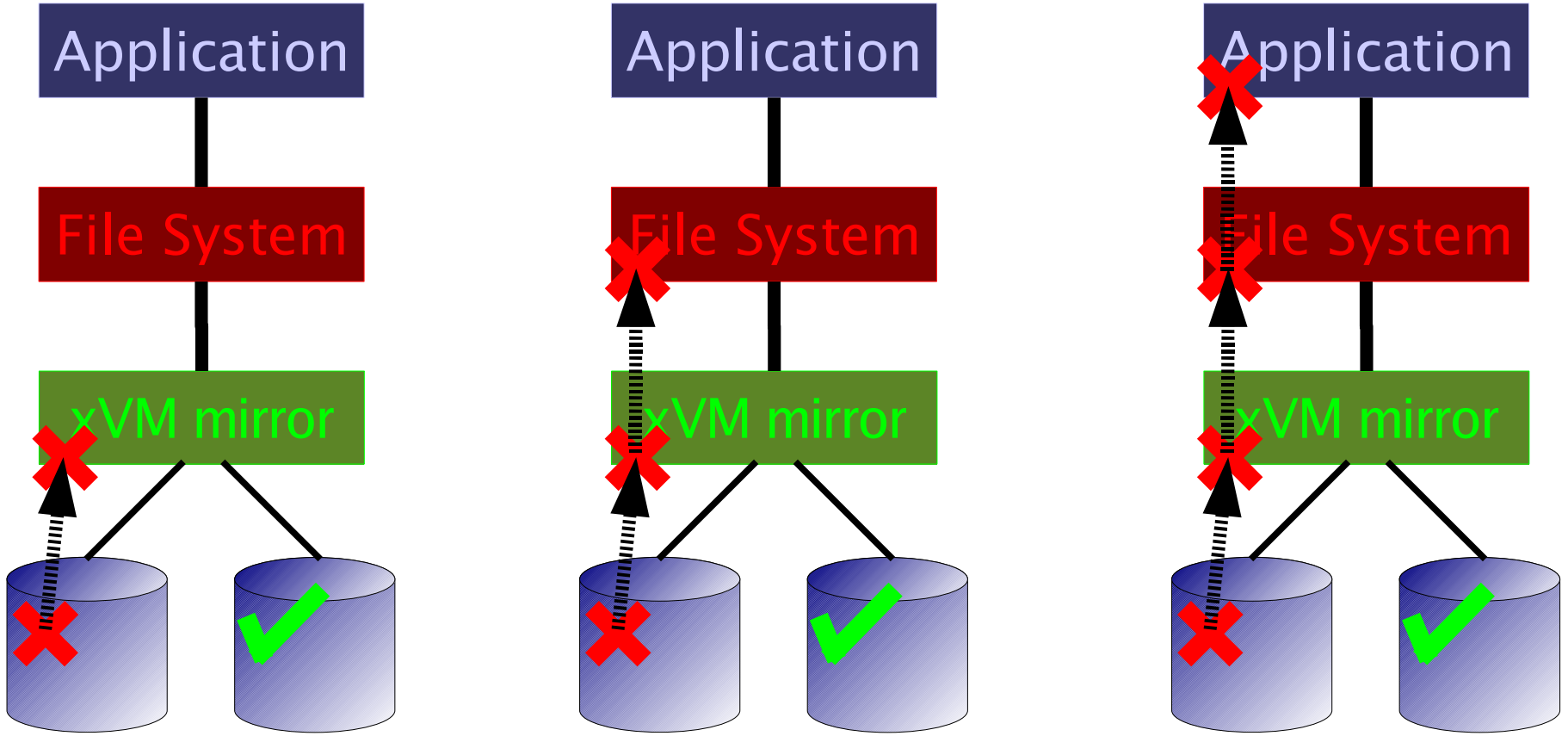
ZFS Self-Healing

Traditional mirroring

1. Application issues a read. Mirror reads the first disk, which has a corrupt block. It can't tell...

2. Volume manager passes the bad block to file system. If it's a metadata block, the system panics. If not...

3. File system returns bad data to the application...

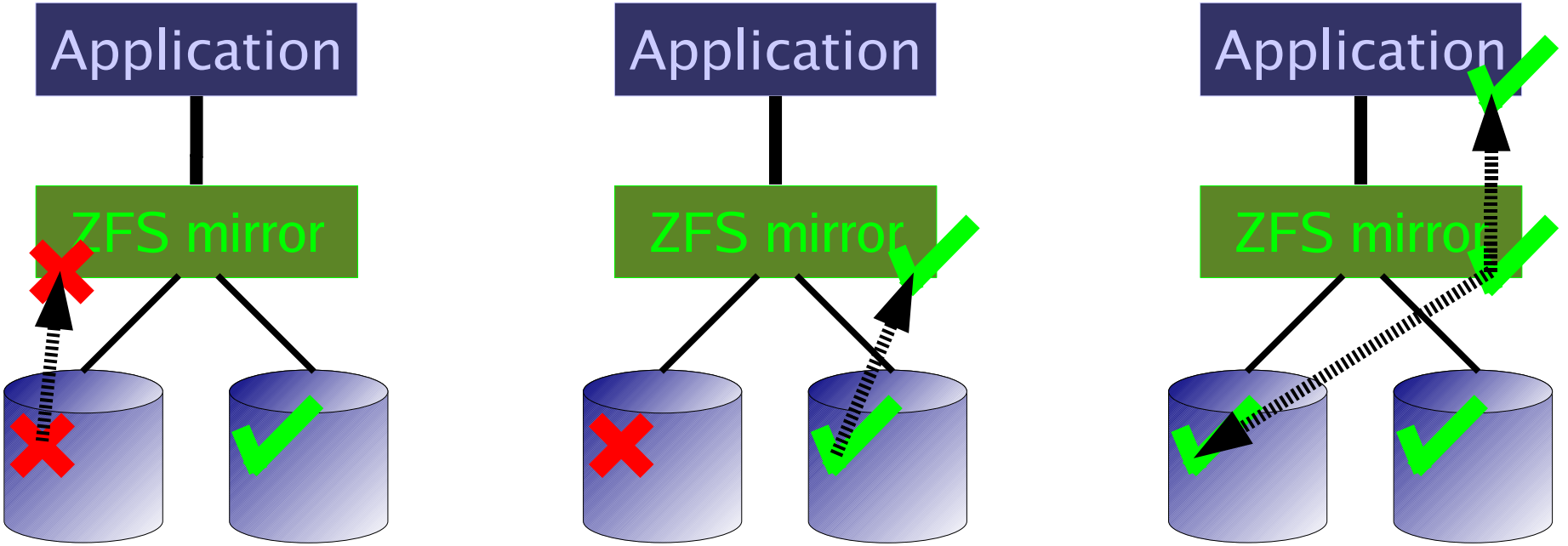


Self-Healing data in ZFS

1. Application issues a read. ZFS mirror tries the first disk. Checksum reveals that the block is corrupt on disk.

2. ZFS tries the second disk. Checksum indicates that the block is good.

3. ZFS returns good data to the application and repairs the damaged block.



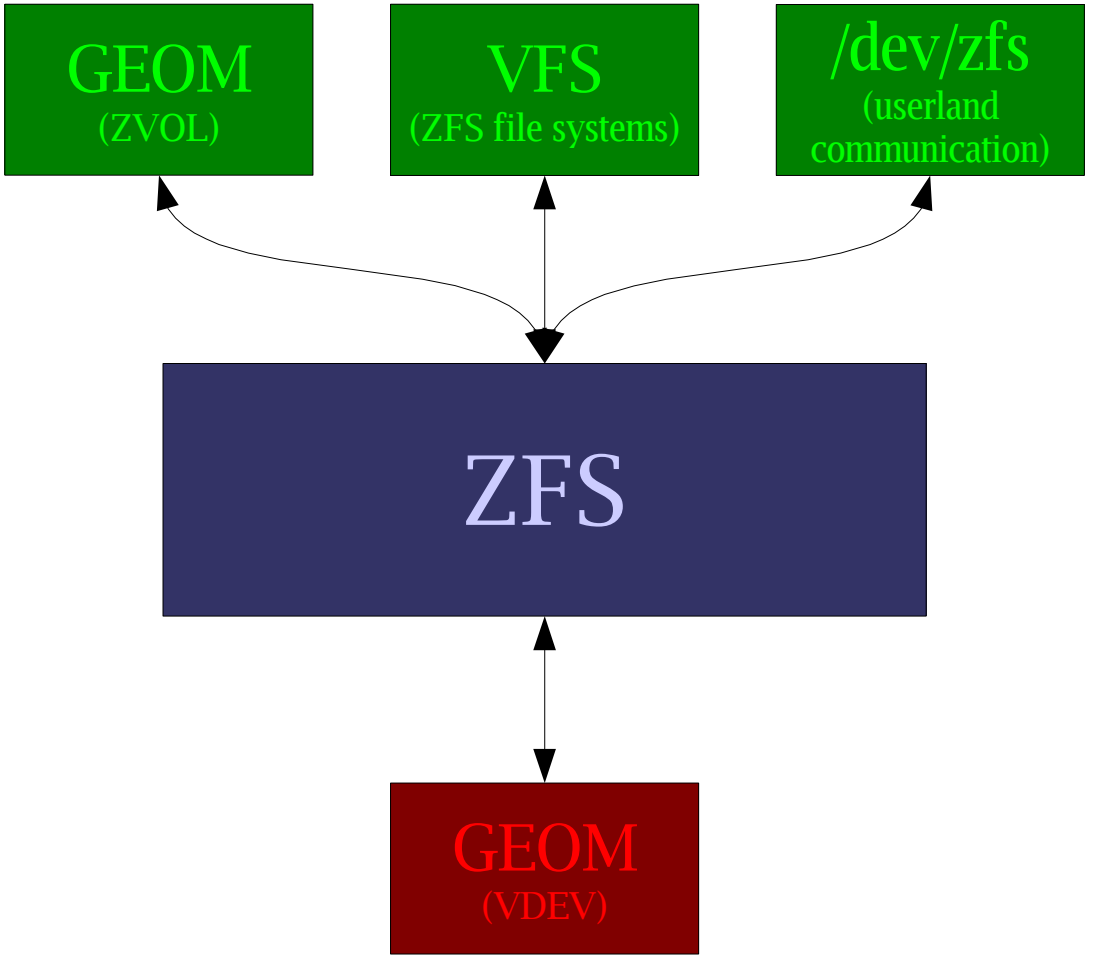
Porting...

- very portable code (started to work after 10 days of porting)
- few ugly Solaris-specific details
- few ugly FreeBSD-specific details (VFS, buffer cache)
- ZPL was hell (ZFS POSIX layer); yes, this is the thing which VFS talks to

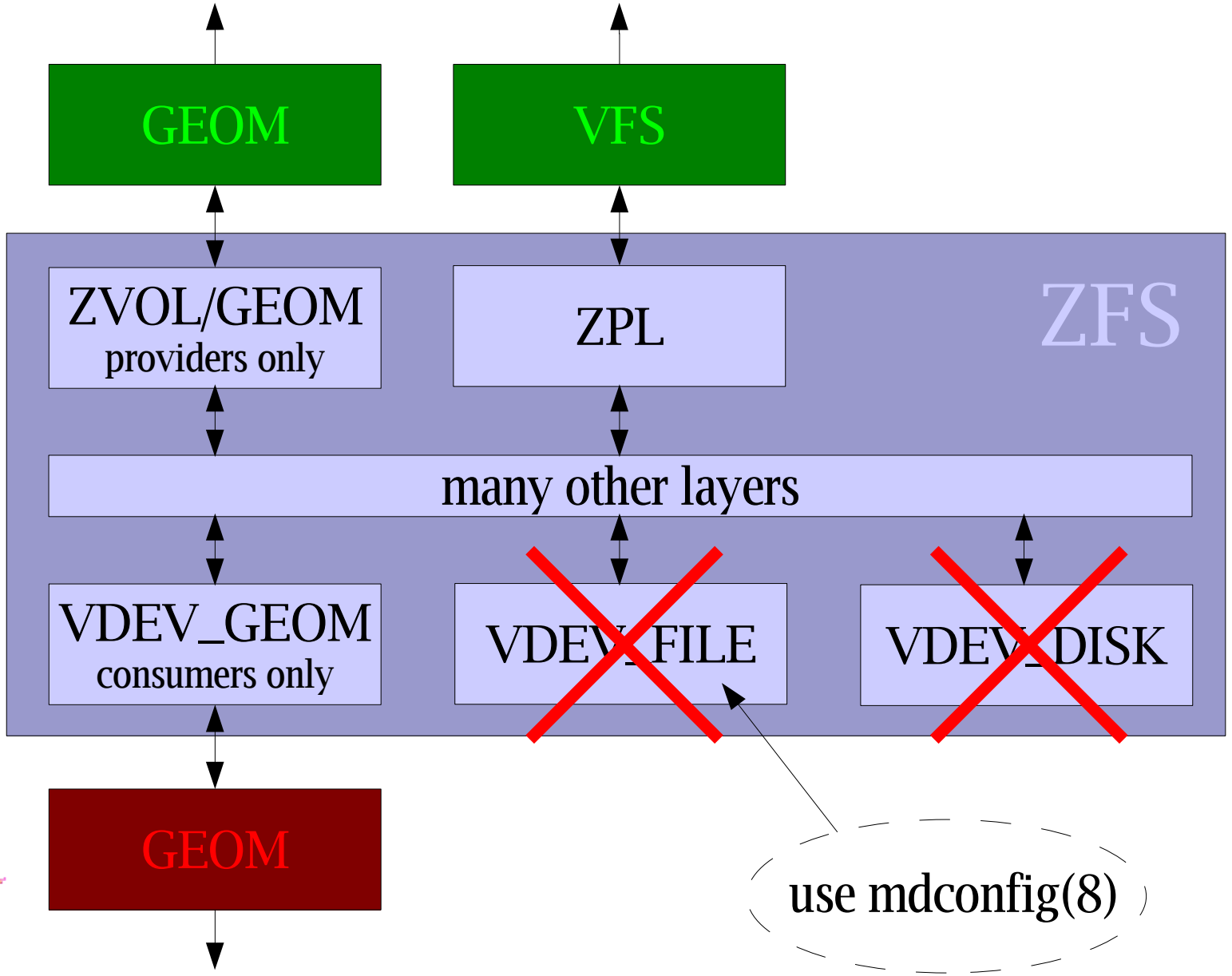
Solaris compatibility layer

contrib/opensolaris/ - userland code taken from OpenSolaris
used by ZFS (ZFS control utilities, libraries, test tools)
compat/opensolaris/ - userland API compatibility layer
(Solaris-specific functions missing in FreeBSD)
cddl/ - Makefiles used to build userland libraries and utilities
sys/contrib/opensolaris/ - kernel code taken from OpenSolaris
used by ZFS
sys/compat/opensolaris/ - kernel API compatiblity layer
sys/modules/zfs/ - Makefile for building ZFS kernel module

ZFS connection points in the kernel



How does it look exactly...



Snapshots

- contains @ in its name:

```
# zfs list
NAME                    USED  AVAIL  REFER  MOUNTPOINT
tank                    50,4M 73,3G  50,3M  /tank
tank@monday             0     -      50,3M  -
tank@tuesday            0     -      50,3M  -
tank/freebsd            24,5K 73,3G  24,5K  /tank/freebsd
tank/freebsd@tuesday    0     -      24,5K  -
```

- mounted on first access under /mountpoint/.zfs/snapshot/<name>
- hard to NFS-export
  - separate file systems have to be visible when its parent is NFS-mounted

NFS is easy

```
# mountd /etc/exports /etc/zfs/exports
# zfs set sharenfs=ro,maproot=0,network=192.168.0.0,mask=255.255.0.0 tank
# cat /etc/zfs/exports
# !!! DO NOT EDIT THIS FILE MANUALLY !!!

/tank    -ro -maproot=0 -network=192.168.0.0 -mask=255.255.0.0
/tank/freebsd   -ro -maproot=0 -network=192.168.0.0 -mask=255.255.0.0
```

- we translate options to exports(5) format and SIGHUP mountd(8) daemon

Missing bits in FreeBSD needed by ZFS

Sleepable mutexes

- no sleeping while holding mutex(9)
- Solaris mutexes implemented on top of sx(9) locks
- condvar(9) version that operates on sx(9) locks

GFS (Generic Pseudo-Filesystem)

- allows to create “virtual” objects (not stored on disk)
- in ZFS we have:

  .zfs/

  .zfs/snapshot

  .zfs/snapshot/<name>/

VPTOFH

- translates vnode to a file handle
- VFS_VPTOFH(9) replaced with VOP_VPTOFH(9) to support NFS exporting of GFS vnodes
- its just better that way, ask Krik for the story:)

lseek(2) SEEK_{DATA,HOLE}

- SEEK_HOLE – returns the offset of the next hole
- SEEK_DATA – returns the offset of the next data
- helpful for backup software
- not ZFS-specific

Testing correctness

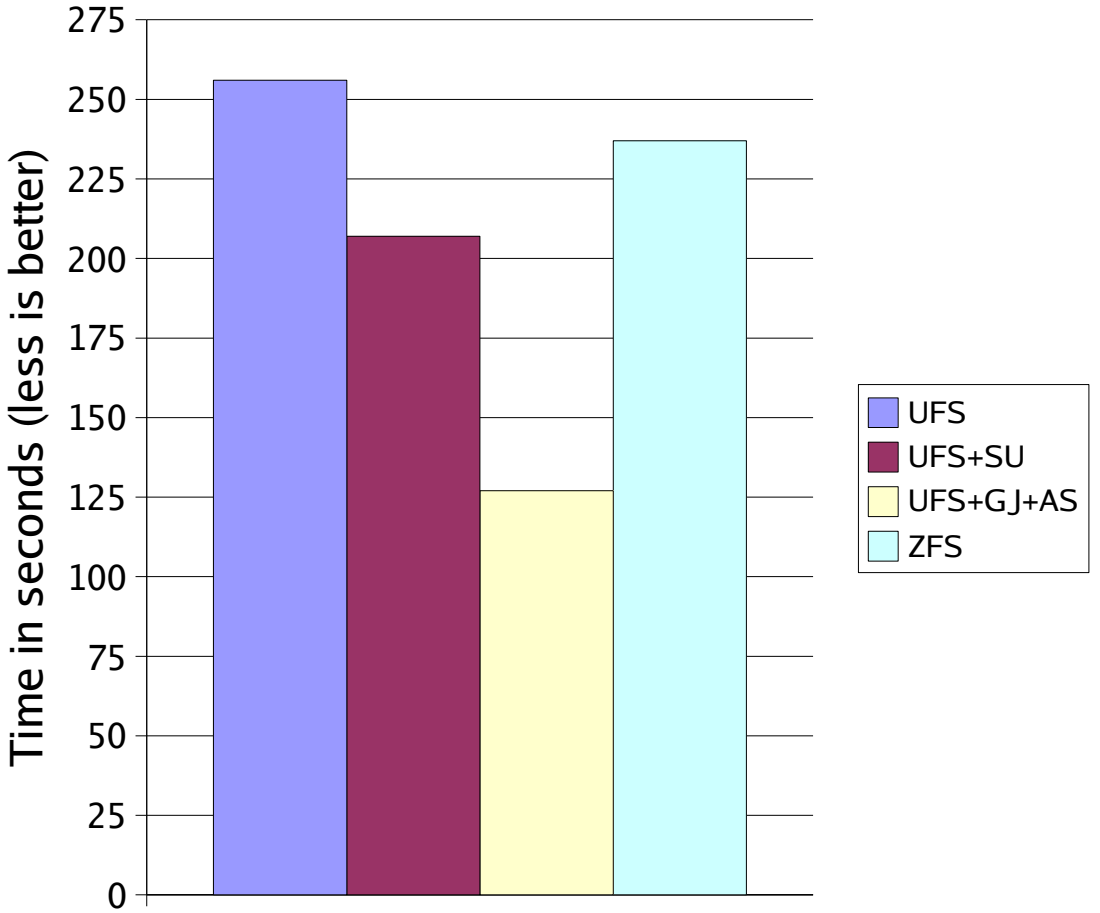
- ztest (libzpool)
  - “a product is only as good as its test suite”
  - runs most of the ZFS code in userland
  - probably more abuse in 20 seconds that you'd see in a lifetime
- fstest regression test suite
  - 3438 tests in 184 files
  - # prove -r /usr/src/tools/regression/fstest/tests
  - tests: chflags(2), chmod(2), chown(2), link(2), mkdir(2), mkfifo(2), open(2), rename(2), rmdir(2), symlink(2), truncate(2), unlink(2)

Performance

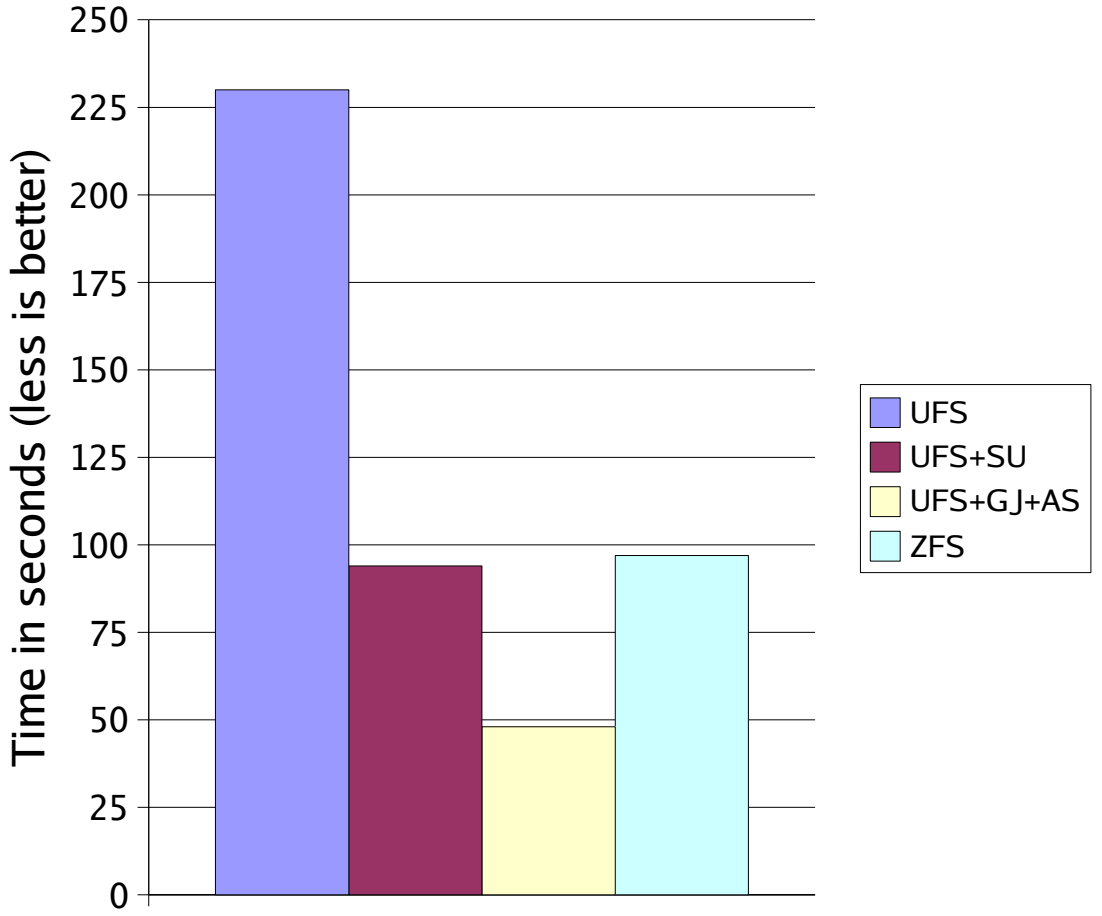
Before showing the numbers...

- a lot to do in this area
  - bypass the buffer cache
  - use new sx(9) locks implementation
  - use name cache
- on the other hand...
  - ZFS on FreeBSD is MPSAFE

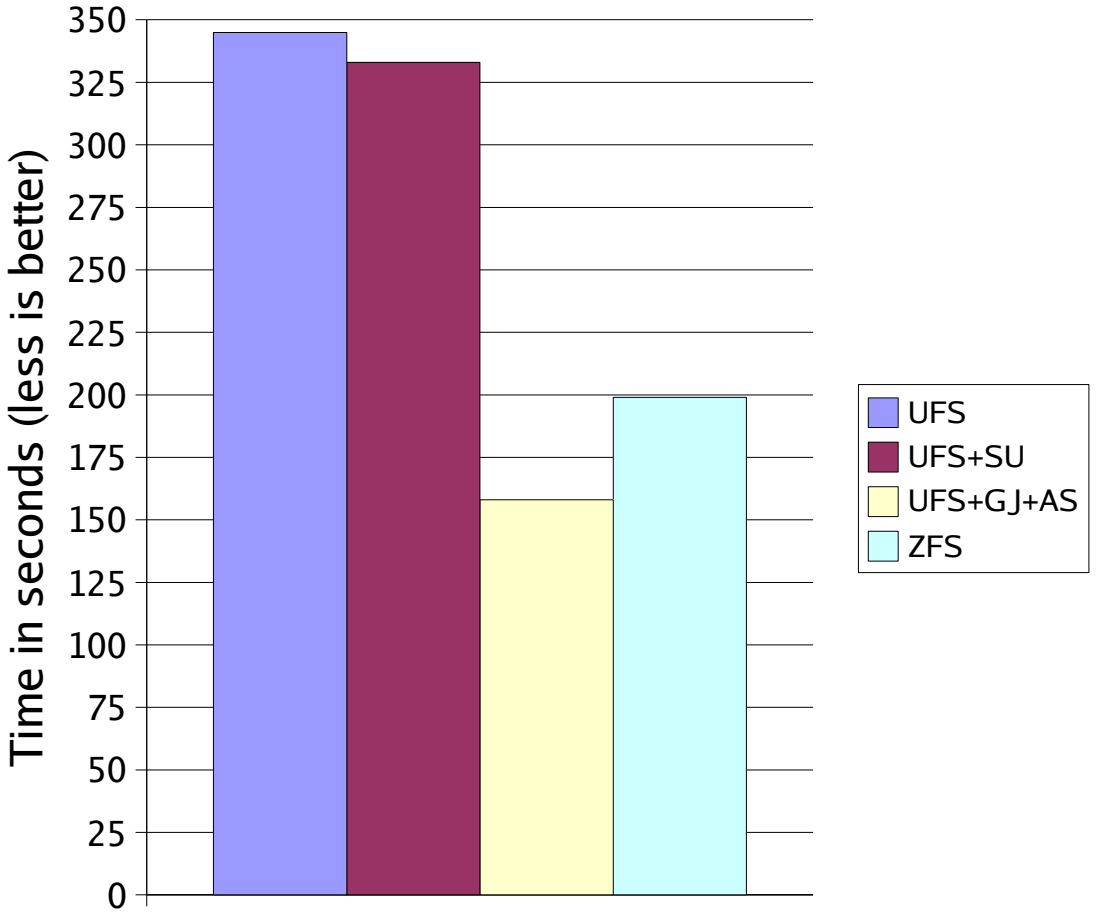
Untaring src.tar four times one by one



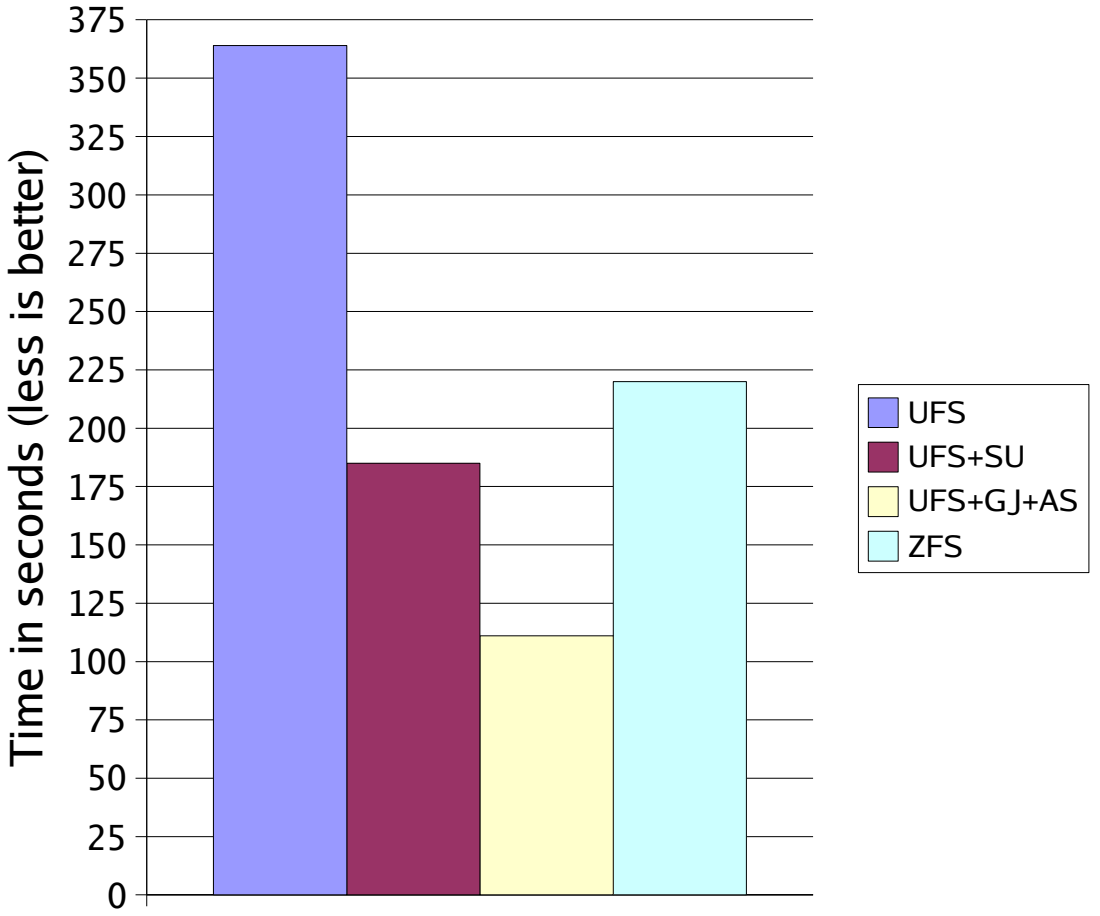
Removing four src directories one by one



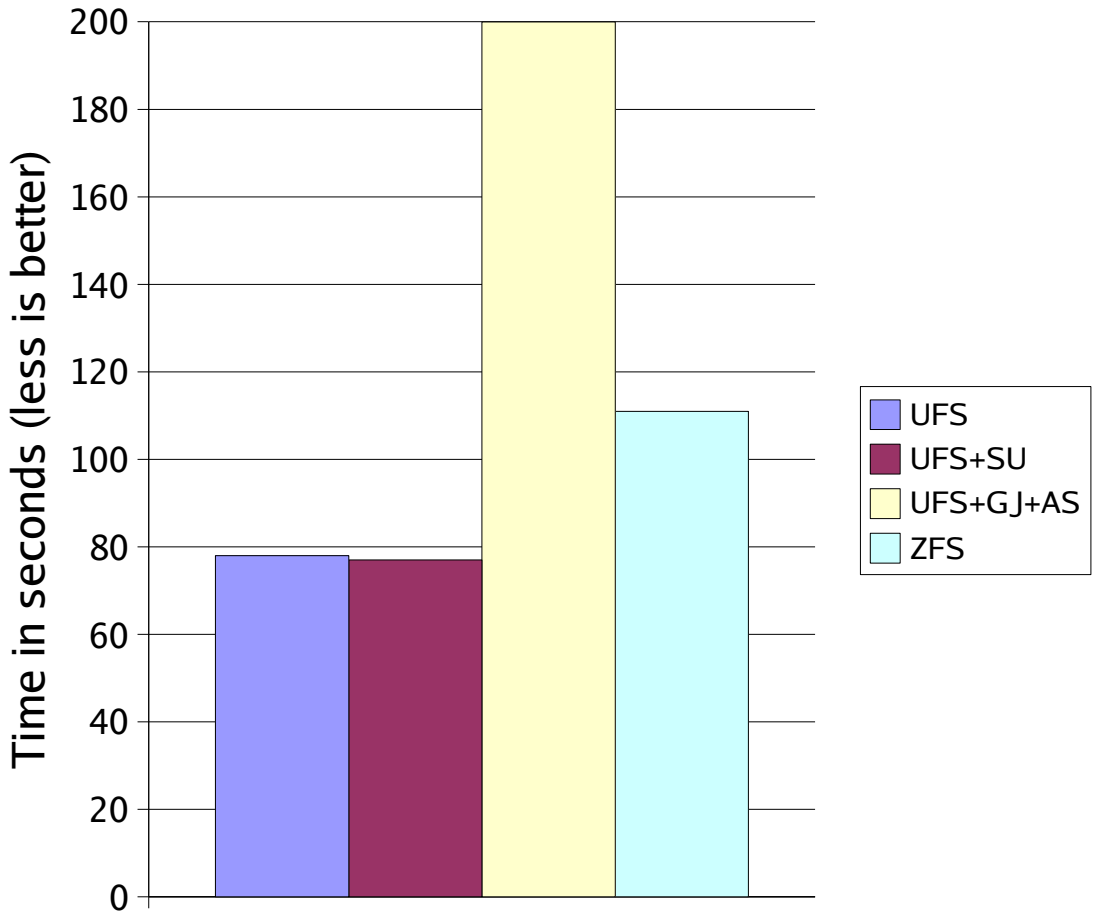
Untaring src.tar four times in parallel



Removing four src directories in parallel



dd if=/dev/zero of=/fs/zero bs=1m count=5000



Future directions

Access Control Lists

- we currently have support for POSIX.1e ACLs
- ZFS natively operates on NFSv4-style ACLs
- not implemented yet in my port

iSCSI support

- iSCSI daemon (target mode) only in the ports collection
- once in the base system, ZFS will start to use it to export ZVOLs just like it exports file system via NFS

Integration with jails

- ZFS nicely integrates with zones on Solaris, so why not to use it with FreeBSD's jails?
- pools can only be managed from outside a jail
- zfs file systems can be managed from within a jail

Integration with jails

```
main# zpool create tank mirror da0 da1
main# zfs create tank/jail
main# jail hostname /jail/root 10.0.0.1 /bin/tcsh
main# zfs jail -i <id> tank/jail

jail# zfs create tank/jail/home
jail# zfs create tank/jail/home/pjd
jail# zfs snapshot tank/jail/home@today
```

Proofs...