Lawrence Livermore National Laboratory

ZFS on Linux for Lustre
LUG11

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ZFS/Lustre History

- 2007
  - Livermore raises ldiskfs scalability/performance concerns
    - Fsck, filesystem size, random IO, data integrity, etc
  - Alternate backend is needed for ***large*** lustre filesystems
  - ZFS identified as technically the best solution
    - Addresses all known ldiskfs limitations
    - Proven production quality implementation
    - Licensing concerns can be addressed
    - Must be ported to Linux
  - CFS/Sun start ZFS/Lustre user space implementation

ZFS/Lustre History

- 2008
  - Livermore starts porting ZFS to the kernel
    - Intended to determine viability of a kernel port
    - No unsurmountable technical issues discovered
    - Initial performance results are encouraging
  - Sun Lustre-osd development
    - Shift in strategy, the Livermore kernel port is adopted
    - Brian joins the Sun Lustre-osd development team
    - Continued Lustre-osd development
  - Licensing concerns unresolved... work continues...

ZFS/Lustre History

- 2009
  - Livermore ZFS development
    - Focus on a production quality ZFS port
    - Built quarter scale prototype ZFS/Lustre filesystem
  - Sun/Oracle Lustre-osd development
    - Oracle acquires Sun
    - Lustre-osd development continues unchanged
    - Zerocopy, grants, large dnodes, quotas, utilities, etc
  - Licensing concerns unresolved... work continues...

ZFS/Lustre History

- 2010
  - Livermore ZFS development
    - Linux integration (utilities, udev, zevents, disk failures)
    - Built a full scale ZFS/Lustre filesystem
  - Oracle Lustre-osd development
    - Announced ZFS/Lustre only available for Solaris
    - Lustre-osd development continues on Linux
    - Oracle cancels Lustre... progress is delayed...
  - Licensing concerns unresolved... work continues at LLNL...

ZFS/Lustre History

- 2011
  - Livermore ZFS development
    - ZFS Posix Layer (ZPL) added
    - Lustre-osd development branch publicly available
  - Whamcloud Lustre-osd development
    - Contracted by Livermore to complete Lustre-osd
    - Most of the original Lustre-osd developers are at Whamcloud
  - Licensing concerns unresolved... work continues...

- Late 2011
  - Livermore plans a ZFS/Lustre filesystem for Sequoia
    - 50 PB capacity, 512 GB/s – 1 TB/s bandwidth

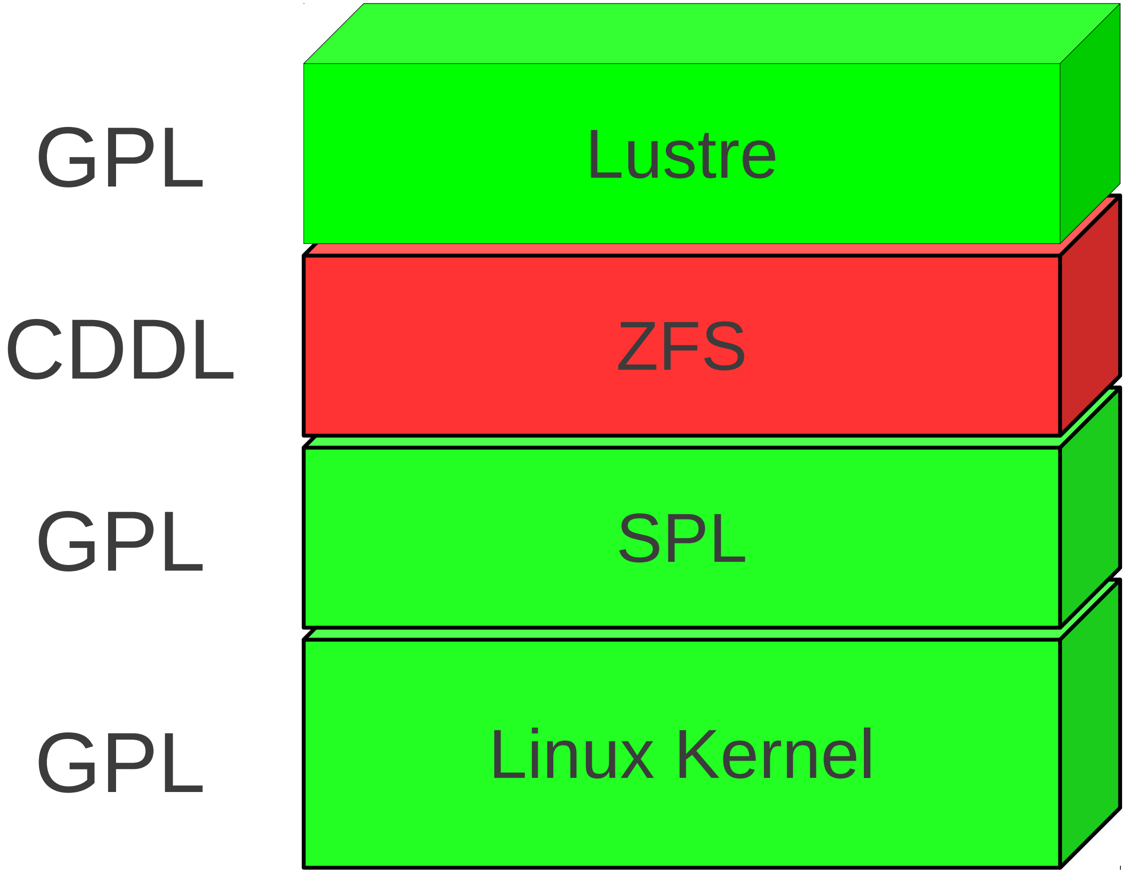
ZFS Overview

- Developed by Sun (now Oracle) on Solaris
- Combined filesystem, logical volume manager, RAID
- Copy-on-write
- Built-in data integrity
- Intelligent online scrubbing and resilvering
- Very large filesystem limits

LLNL's Reasons for porting ZFS

- Lustre servers currently use ext4 (ldiskfs)
  - Random writes bound by disk IOPS rate, not disk bandwidth
  - OST size limits
  - fsck time is unacceptable
  - Expensive hardware required to make disks reliable
- Late 2011 requirement:
  - 50PB, 512GB/s – 1 TB/s
  - At a price we can afford
- COW sequentializes random writes
  - No longer bound by drive IOPS
- Single volume size limit of 16 EiB
- Zero fsck time. On-line data integrity and error handling
- Expensive RAID controllers are unnecessary

Licensing Concerns



CDDL = Common Development and Distribution License
GPL = (Gnu) General Public License

Licensing Concerns

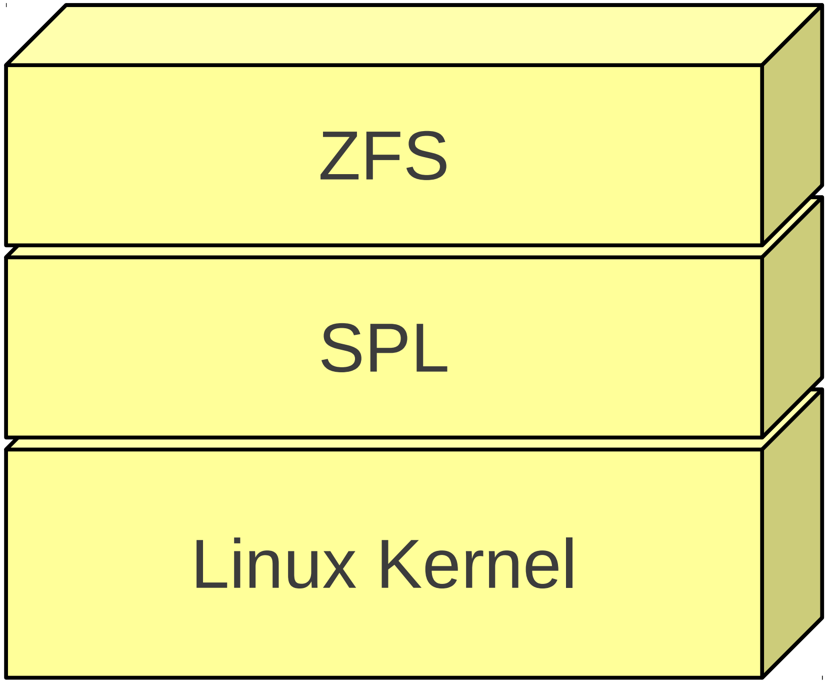
- Distributing Source
  - CDDL is an open source license
  - CDDL provides an explicit patent license
  - ZFS changes contributed as CDDL code
  - ZFS sources kept separate from all GPL code

- Distributing Binaries
  - Linux kernel allows non-GPL third party modules
    - Nvidia, ATI, etc...
  - Linus views the kernel module interface as LGPL
    - ZFS uses no GPL-only symbols
    - Included headers do not make a derived work

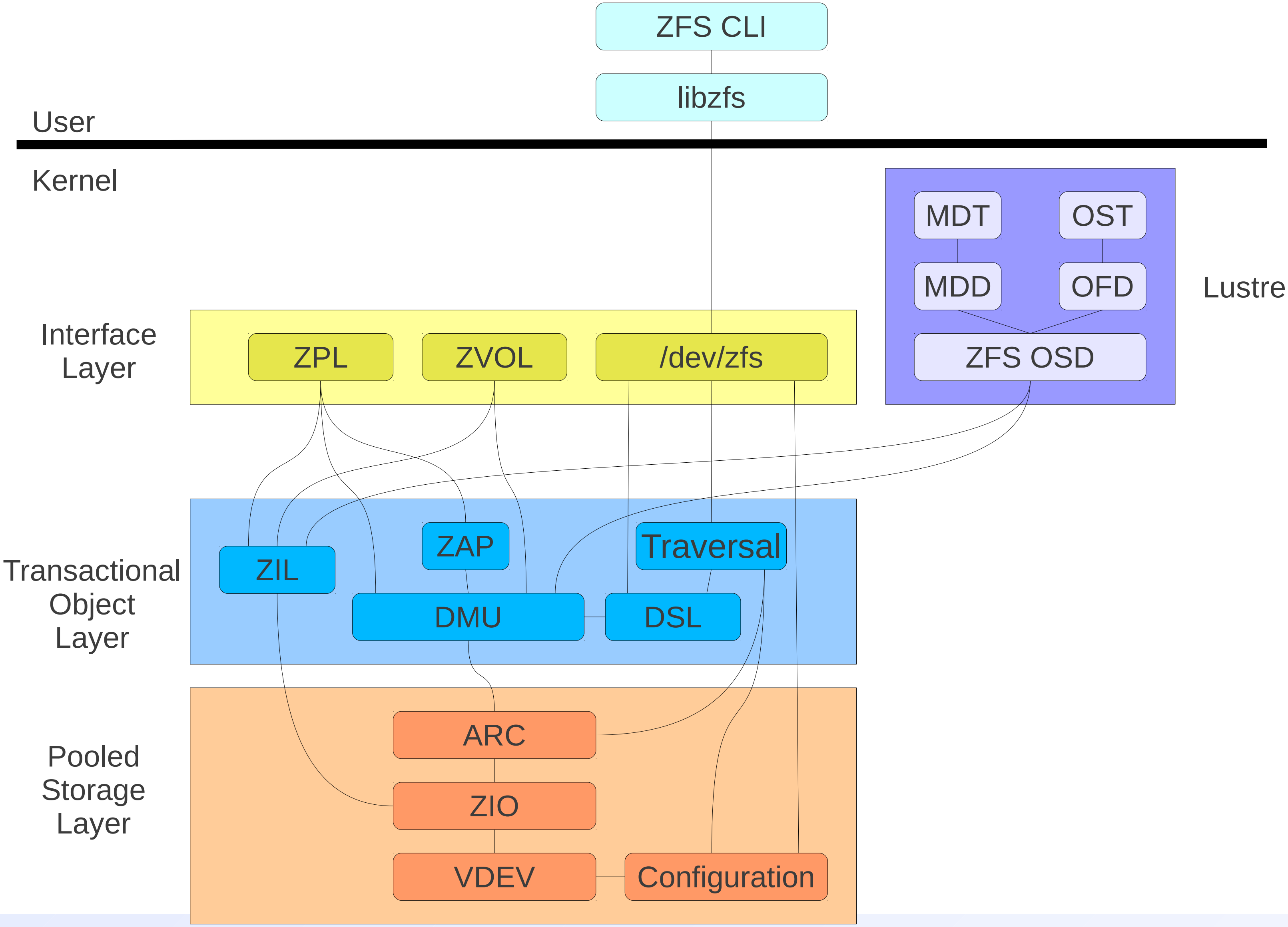
Licensing Concerns

- ZFS is NOT a derived work of Linux
  - “It would be rather preposterous to call the Andrew FileSystem a 'derived work' of Linux, for example, so I think it's perfectly OK to have a AFS module, for example.”
    - Linus Torvalds
  - “Our view is that just using structure definitions, typedefs, enumeration constants, macros with simple bodies, etc., is NOT enough to make a derivative work. It would take a substantial amount of code (coming from inline functions or macros with substantial bodies) to do that.”
    - Richard Stallman (The FSF's view)

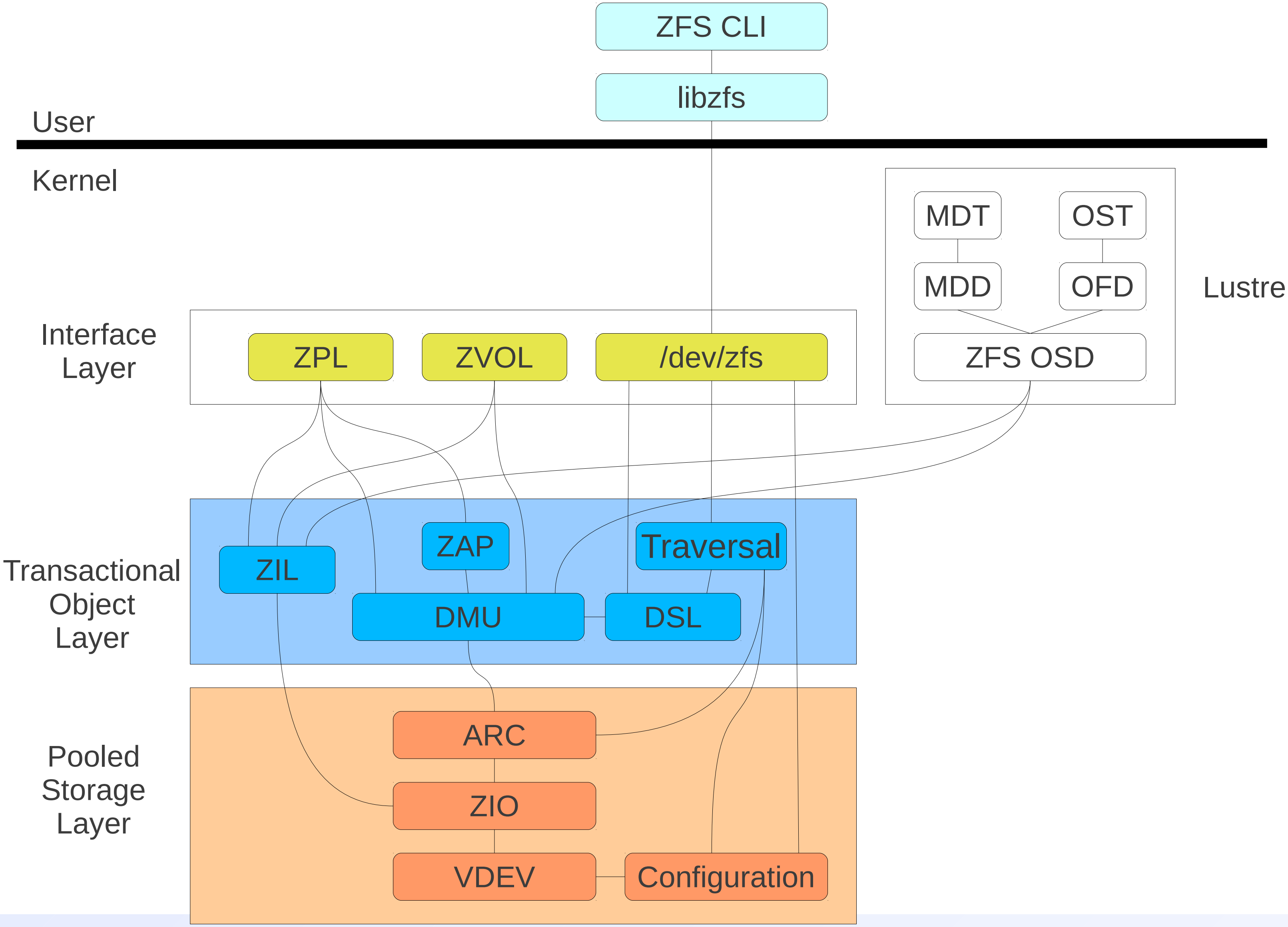
Solaris Porting Layer
Linux/ZFS Glue



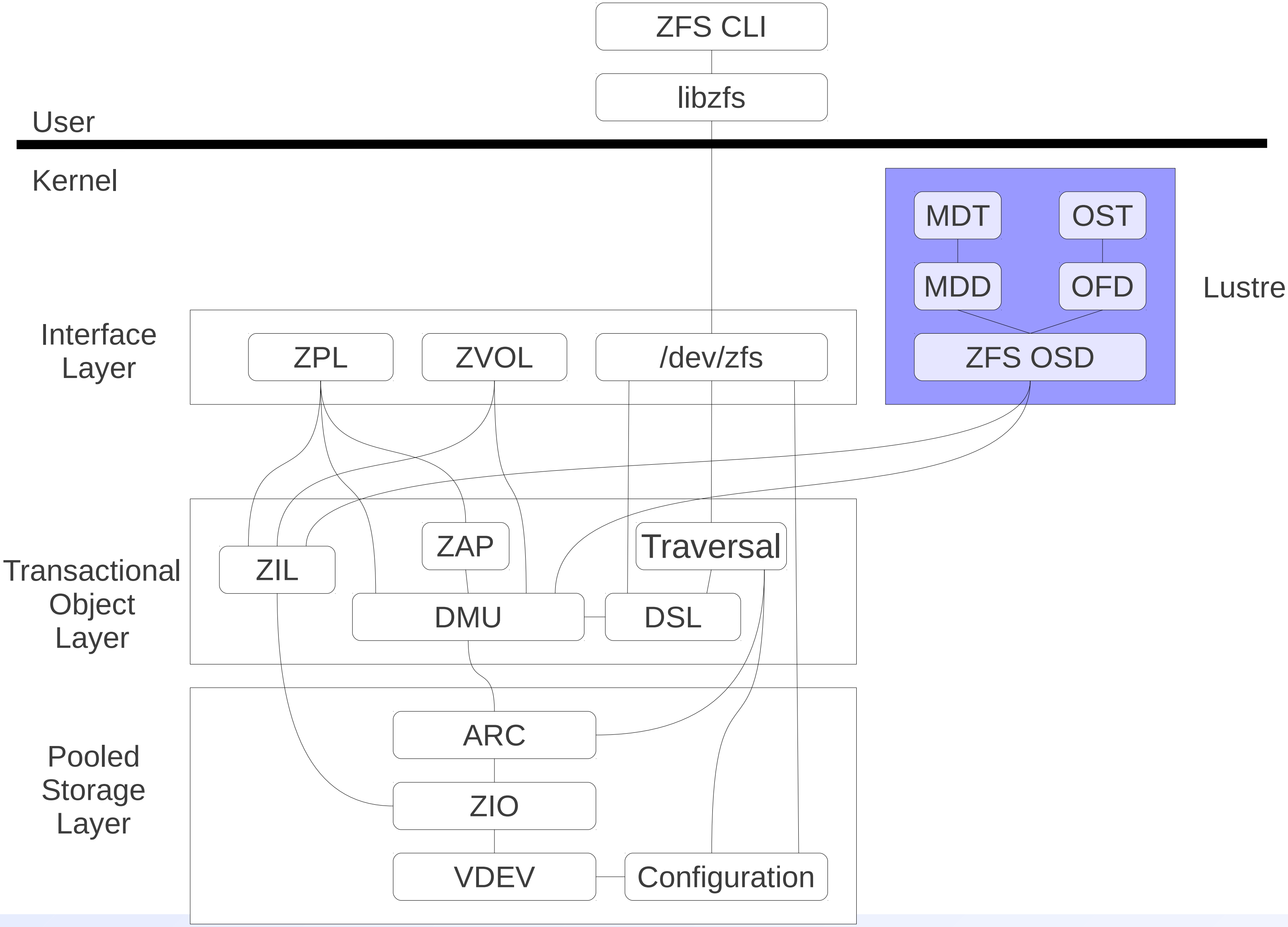
ZFS and Lustre Components



Ported by LLNL

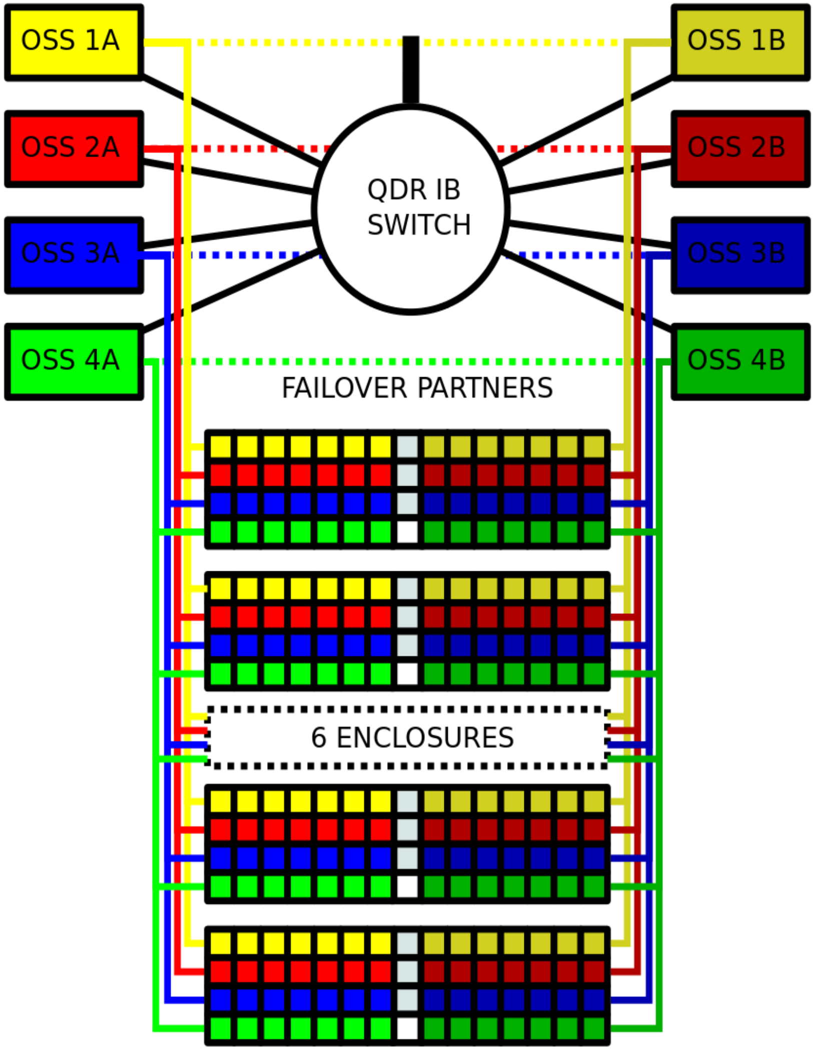


CFS → Sun → Oracle → Whamcloud



ZFS/Lustre Prototype (Zeno)

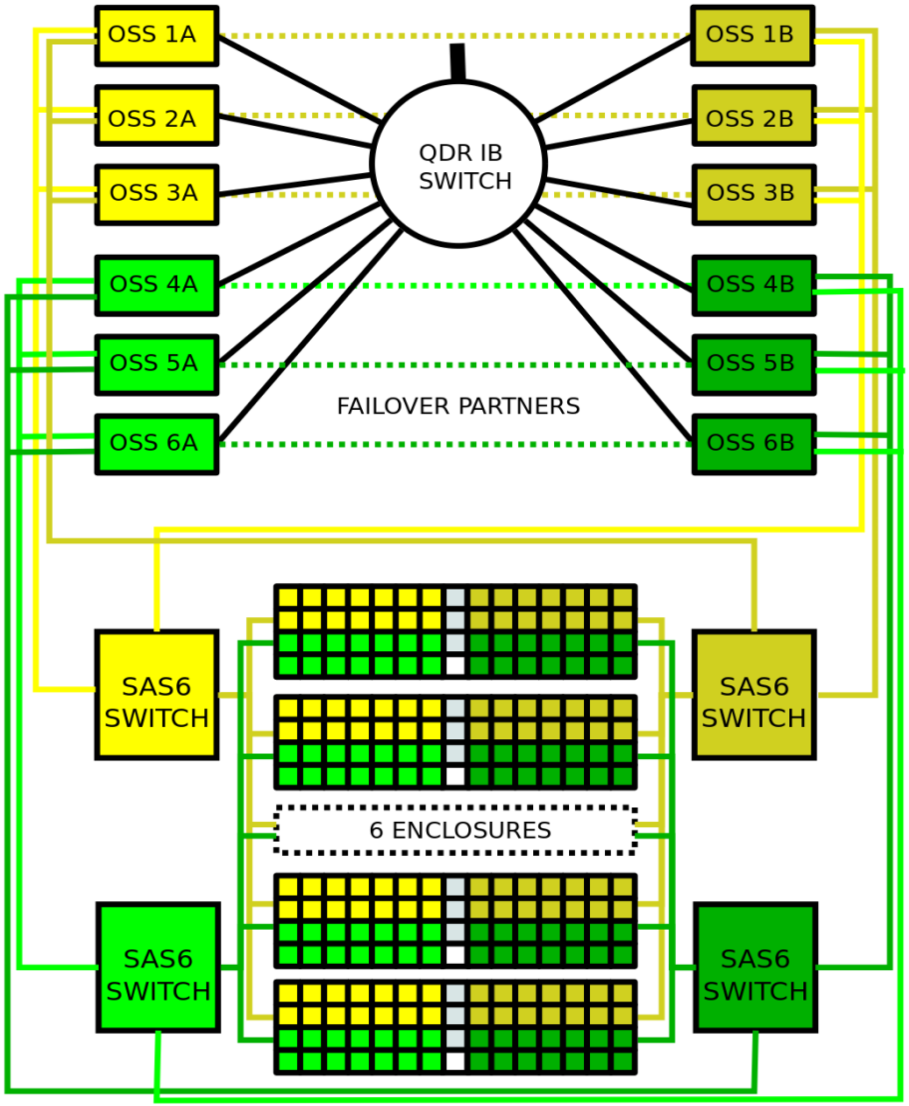
OSS SSU (Zeno)



Component	Bandwidth
QDR IB	25.6 GB/s
Host SAS	96.0 GB/s
JBOD SAS	96.0 GB/s
Disk	56.0 GB/s

- 896 TB / SSU
- 25.6 GB/s
- 70 2TB Disks / Host
  - 7 – 8+2 Raid-Z2 groups
  - 1 – 112 TB OST / Host

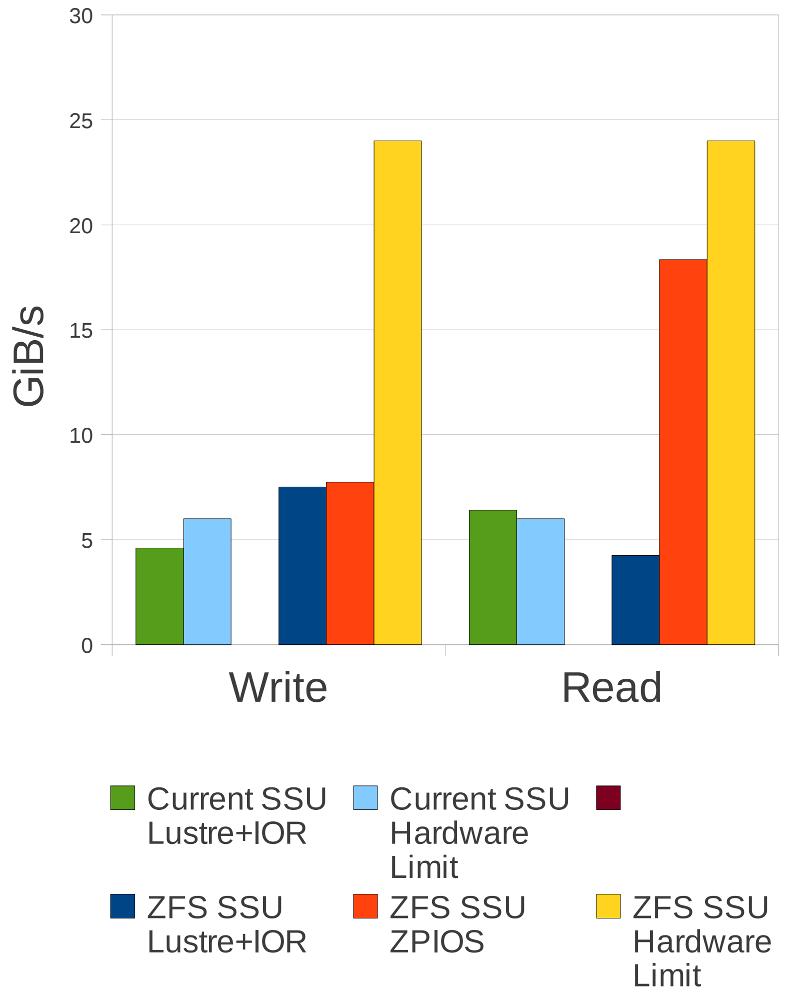
OSS SSU (Zeno3)



Component	Bandwidth
QDR IB	38.4 GB/s
Host SAS	38.4 GB/s
JBOD SAS	96.0 GB/s
Disk	60.0 GB/s

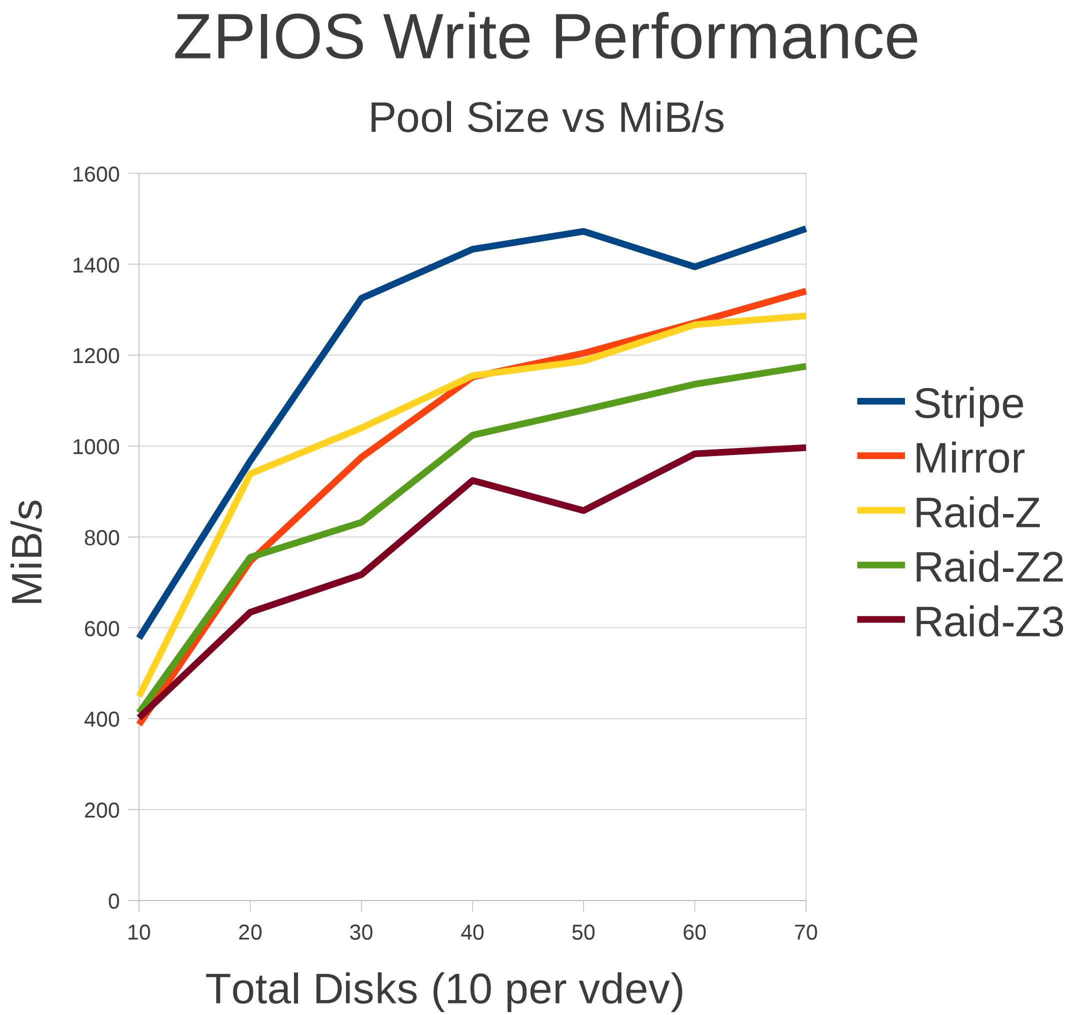
- 960 TB / SSU
- 38.4 GB/s
- 50 2TB Disks / Host
  - 5 – 8+2 Raid-Z2 groups
  - 1 - 80TB OST / Host

ZFS Performance Comparison



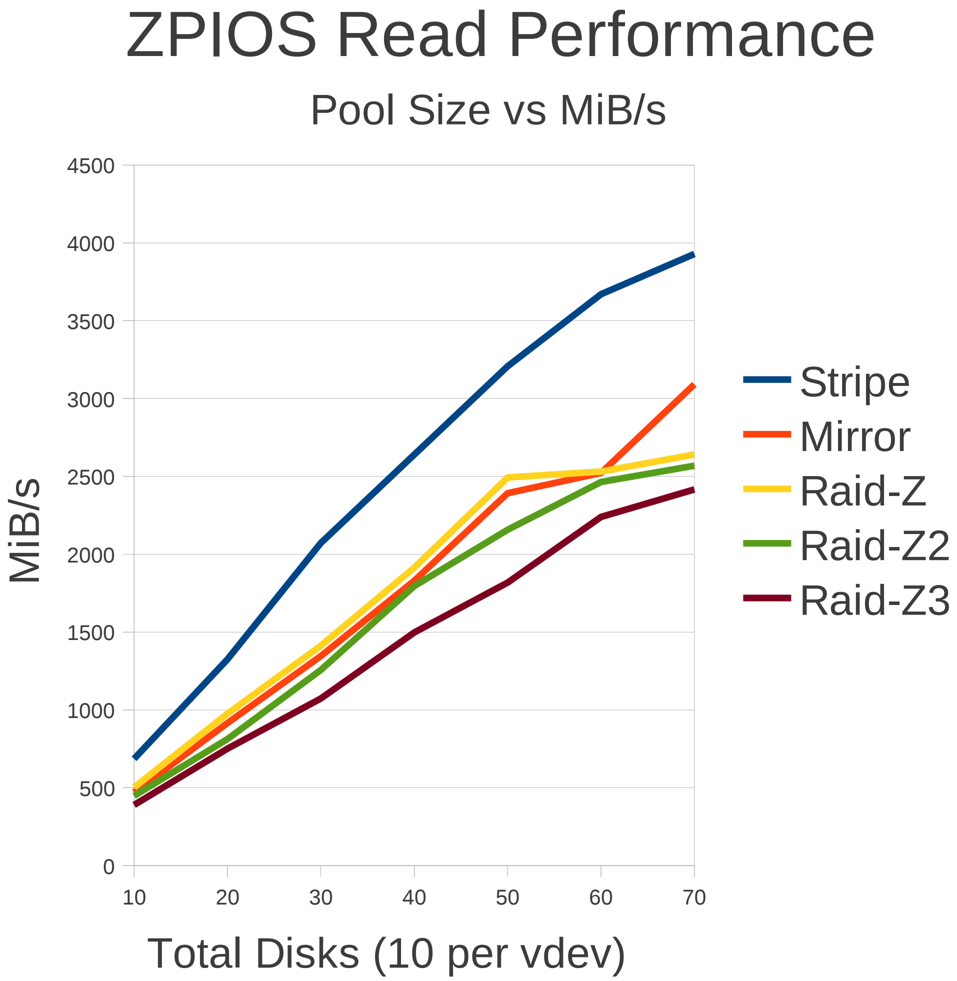
- Same number of drives
- SATA vs SAS disk
- RAID-Z2 vs RAID-6
- Write Performance is Limited by the ZFS Port
- Read Performance is Limited by Lustre/CPU
- ZFS is unoptimized, this can all be improved!

Single Node Write Performance



- Write performance is consistent with Lustre
- Lustre workload
  - Random 1MiB I/Os
  - 128 thrs to 4096 objs
- 60 MiB/s per disk for small pools (10 disks)
- Limited by taskq when scaled up
- This is fixable

Single Node Read Performance



- Read performance is significantly better than Lustre
- Lustre Workload
  - Random 1MiB I/Os
  - 128 thrs to 4096 objs
- Shows good scaling
- Prefetch disabled
- 50-60 MiB/s per disk even for large pools
- >90% CPU utilization when using 70 disks
- Can be optimized

More Information

- ZFS & SPL
  - http://zfsonlinux.org
    - Mailing Lists
      - zfs-announce@zfsonlinux.org
      - zfs-discuss@zfsonlinux.org
      - zfs-devel@zfsonlinux.org
    - Download software
    - Documentation
- Lustre support for ZFS
  - http://zfsonlinux.org/lustre.html
- Licenses
  - CDDL - http://hub.opensolaris.org/bin/view/Main/licensing_faq
  - GPLv2 - http://www.gnu.org/licenses/gpl-2.0.html
    - Linus - http://linuxmafia.com/faq/Kernel/proprietary-kernel-modules.html
    - RMS - http://lkml.indiana.edu/hypermail/linux/kernel/0301.1/0362.html