Operational characteristics of a ZFS-backed Lustre filesystem

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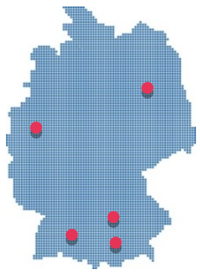

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Turnaround 2013 30,70 Mio. Euro

Portfolio

IT Services for complex computing environments
Comprehensive solutions for Linux- und Windows-based **HPC**

scVENUS system management software for efficient administration of homogeous and heterogeneous networks

Use Case

Environment

- Lustre 1.8 filesystem on JBOD hardware runs out of life
  - ldiskfs on top of mdraid
  - whacky hardware (frequent drive failures)
  - abandoned storage management software (no-go with compliant Java versions)
  - performance issues unless using Sun/Oracle Lustre kernel (stuck with 1.8.5)

Environment

- Re-use storage and server hardware for scratch filesystem
  - upgrade to current OS and Lustre versions
  - avoid mdraid layer
  - avoid obsolete JBOD management
  - increase drive redundancy

-> Lustre (2.5.3) with ZFS backend using raidz3 (8+3) vdevs

-> Learn from previous installation and apply overall improvements, not specifically tied to ZFS

Administration & Maintenance

Deployment

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- Looser dependency on kernel version (facilitates security updates)
- Using spl and zfs auto-build of modules via dkms
- Backported support for zfs/spl 0.6.4 (LU-6038) to Lustre 2.5.3
- Step-by-step creation:
    - Create ZPool
    - Test with temporary ZFS posix layer
    - Zap test filesystem
    - Set `canmount=off`
    - Create Lustre backend filesystems

Stability

- Server OOM with zfs/spl 0.6.3 during iozone rewrite test
- Clients crashed due to empty ACLs (otherwise filtered out by ldiskfs, LU-5150)
- ZFS uncovered several faulty drives (previously undetected/unidentified by mdraid)

JBOD storage

- There's life beyond crappy Java management tools
- There's standard tools and even a SCSI standard for talking to storage enclosures
  - `sg_ses` and `/sys/class/enclosure` FTW!
  - Easy, automated matching of `/dev/sdX` to corresponding drive slot
  - Steering locator LEDs from OS, no need for external tools
- /dev/disk/by-vdev makes it even easier:
  - ZFS reports failed drive in enclosure X, slot Y
    -> location immediately visible form zpool status output
    (optimize disk names for most common daily tasks, ie. open calls for failed drives, replace failed drives)
- Less impact from resilvering compared to md raid rebuild

High Availability

- Pacemaker integration
  - Split JBOD drives into 'left' and 'right' pools, controlled by either frontend server
  - Separate resources for each ZPool and each Lustre target
- Customized scripts for more finegrained control than supplied init script
  - ZFS: ZPool import with **`cachefile=none`** (no MMP equivalent, requires fencing)
  - Filesystem: modified to grok ZFS pool syntax

Debugging

zdb

- Under-the-hood debugging of ZFS/ZPool internals
- Almost, but not quite, entirely unlike **`debugfs`**
- User interface apparently designed by Huffman-coding a standard set of options onto a Morse alphabet
- Calling **`zdb -ddddd`** is perfectly normal, and not to be mistaken with **`zdb -dddd`**

zdb – Example

- Find physical location of data in file 'x':

```
# ls -i x
12345678 x

# zdb -ddddd tank/fs1 12345678

Dataset tank/fs1 [ZPL], ID 45, cr_txg 19, 251M, 3292
objects, rootbp DVA[0]=<3:59b6000:800>
DVA[1]=<0:5d67800:800> [L0 DMU objset] fletcher4 lz4 LE
contiguous unique double size=800L/200P
birth=1626187L/1626187P fill=3292
cksum=154bf6b90b:7136427a15d:147c0807d0853:2a4d1fac6823a

(tbc)
```

zdb – Example

```
# zdb -ddddd tank/fs1 12345678

(cont.)
Object  lvl   iblk   dblk  dsize  lsize   %full  type
12345678    2     16K    128K    259K    256K  100.00   ZFS
plain file
(...)
Indirect blocks:
 0 L1  3:59b0000:800 4000L/200P F=2 B=1626187/1626187
 0      L0 3:5956800:2c000 20000L/20000P F=1
                                        B=1626187/1626187
 20000  L0 3:5982800:2c000 20000L/20000P F=1
                                        B=1626187/1626187
```

zdb – Examples

- Data virtual address (DVA): `<vdev>:<offset>:<size>`
- Data at L0 DVAs (if F=1)
- Map DVA to physical location on disk:
  - Easy for simple vdev types (single drive, mirror):
    `block = (offset + headersize) / blocksize,`
    with `headersize = 4*1024*1024 (4MB)`
  - For raidz{,2,3}: Read the source
  - Or just `zdb -R tank <DVA>` (if you still can)
  - Or cheat with `strace zdb -e -R tank <DVA>`
    (on exported test pool; analyze disk access)

Performance Characteristics

Performance Baseline

- Study performance of Lustre client
- Relate to performance of local ZFS (ZPL)
- Study FS behaviour with more general I/O patterns, not just bulk I/O
- Study performance in relation to capabilities of storage hardware:
    - Interconnect performance
    - HDD performance

HDD Performance

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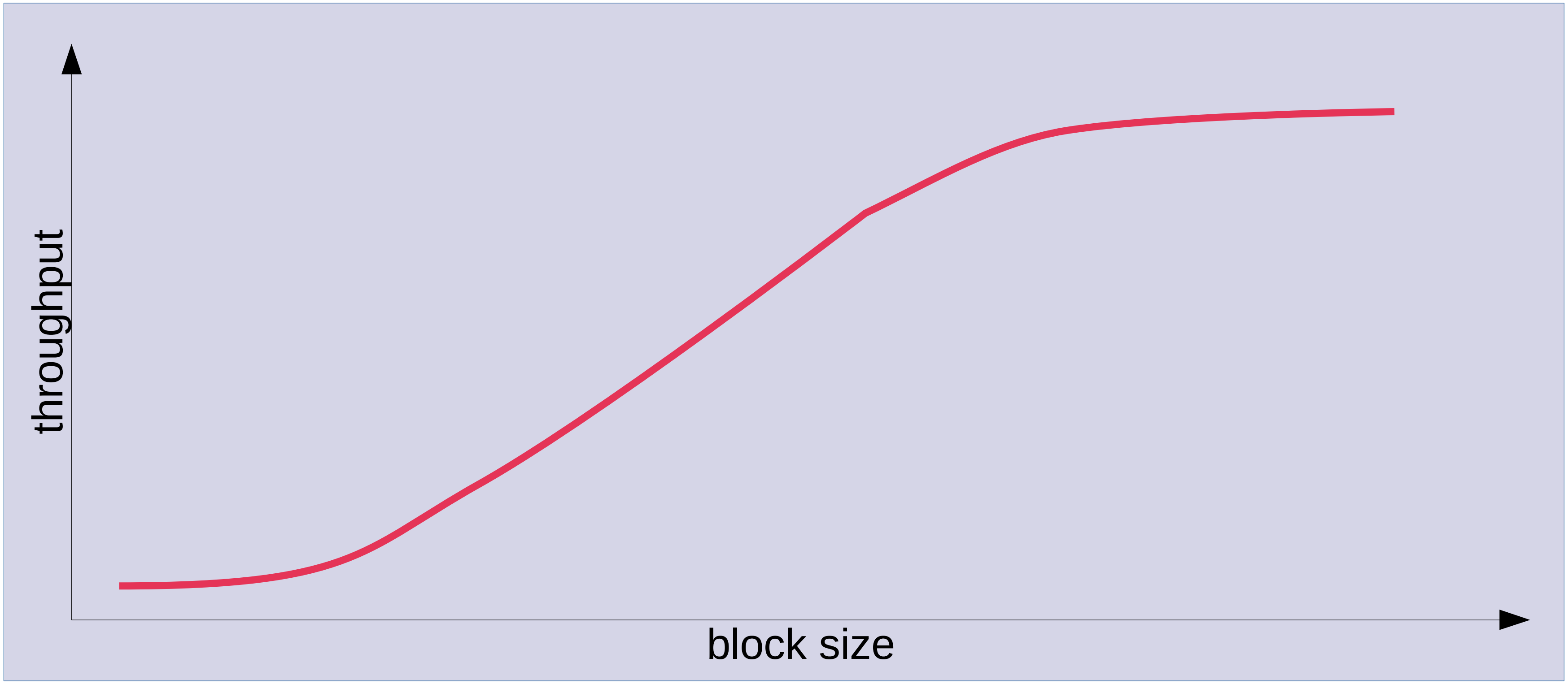
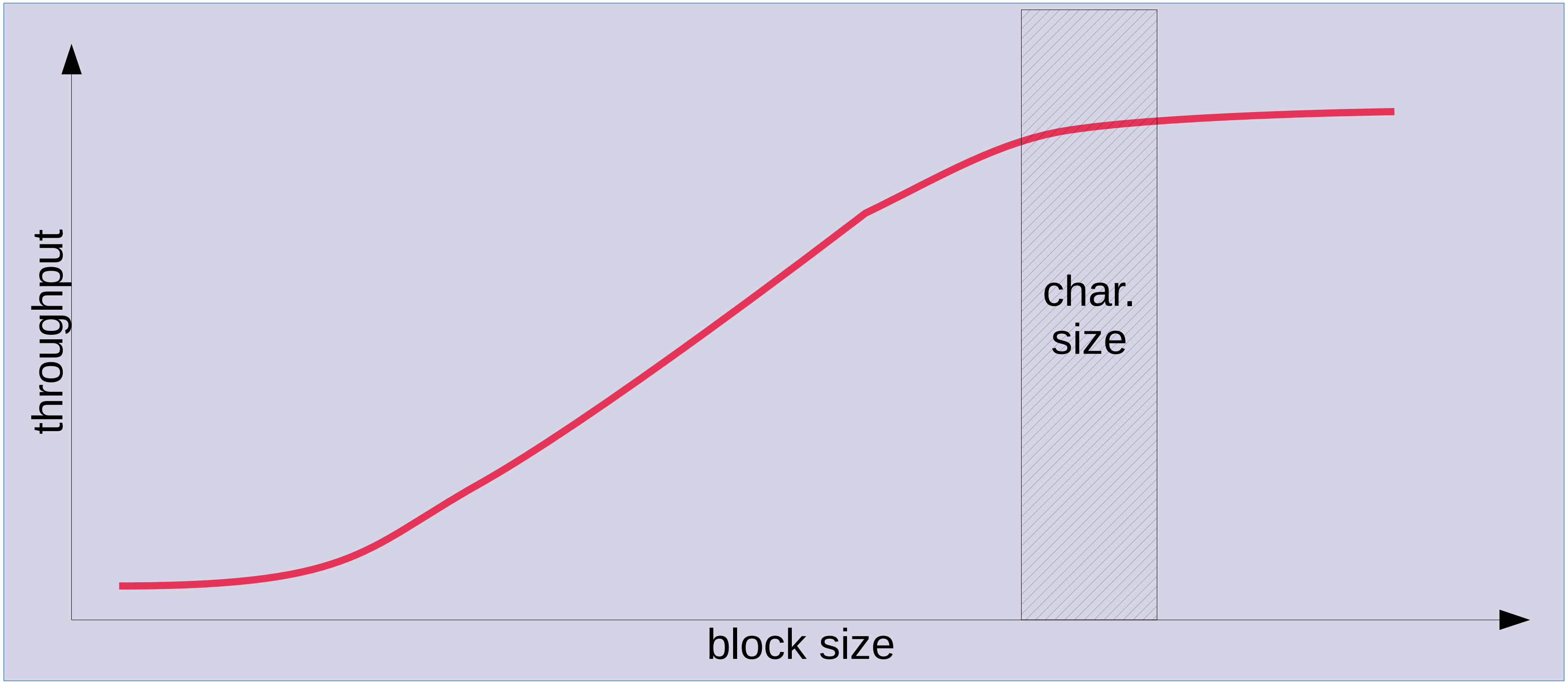


HDD Performance



HDD Performance

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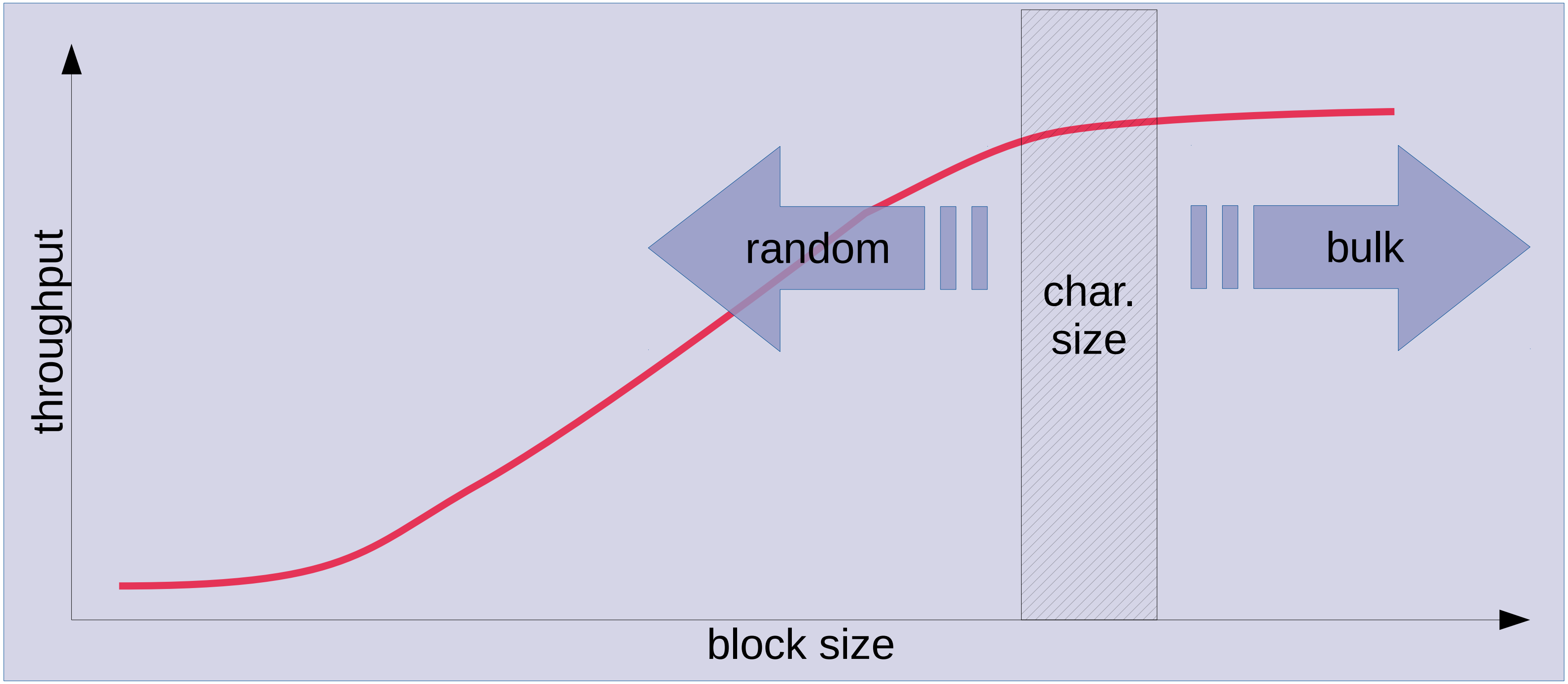

HDD Performance

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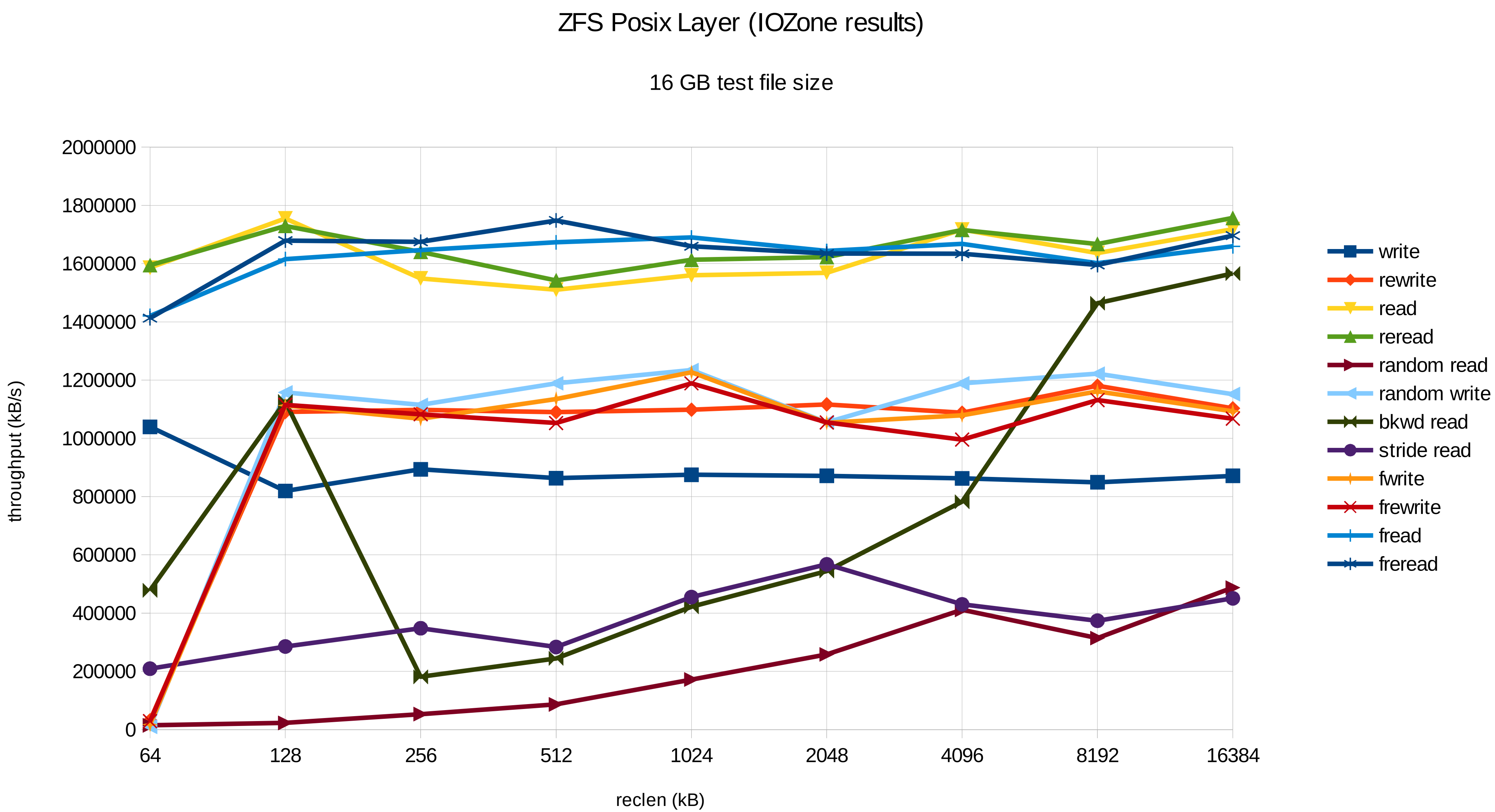
- HDD datasheet:
  - 1 TB capacity
  - 7200 RPM
  - 8-9 ms seek latency
  - 90 MB/s sequential throughput
- Characteristic values:
  - Max. rotational latency = 1 / RPM = 8.3 ms
  - Random IOPS =
    1s / (seek latency + 1/2 rotational latency) = 79
  - Seq. throughput / Random IOPS = **1.1 MB** char. I/O size

Performance Expectations

- Configuration:
  - 6x vdev raidz3 (8+3)
  - 128k recordsize
  - No compression
- Bulk throughput:
  - Writes need to transfer parity from host to disk
  - Max. write throughput = 8/11 x max. read throughput
- Per vdev:
  - Expected char. I/O size for 8+3 raidz3:
    8 x 1.1 MB = 8.8 MB
  - Might saturate at smaller I/O size due to interconnect limit

Benchmark Results (ZPL)



Benchmark Results (Lustre Client)

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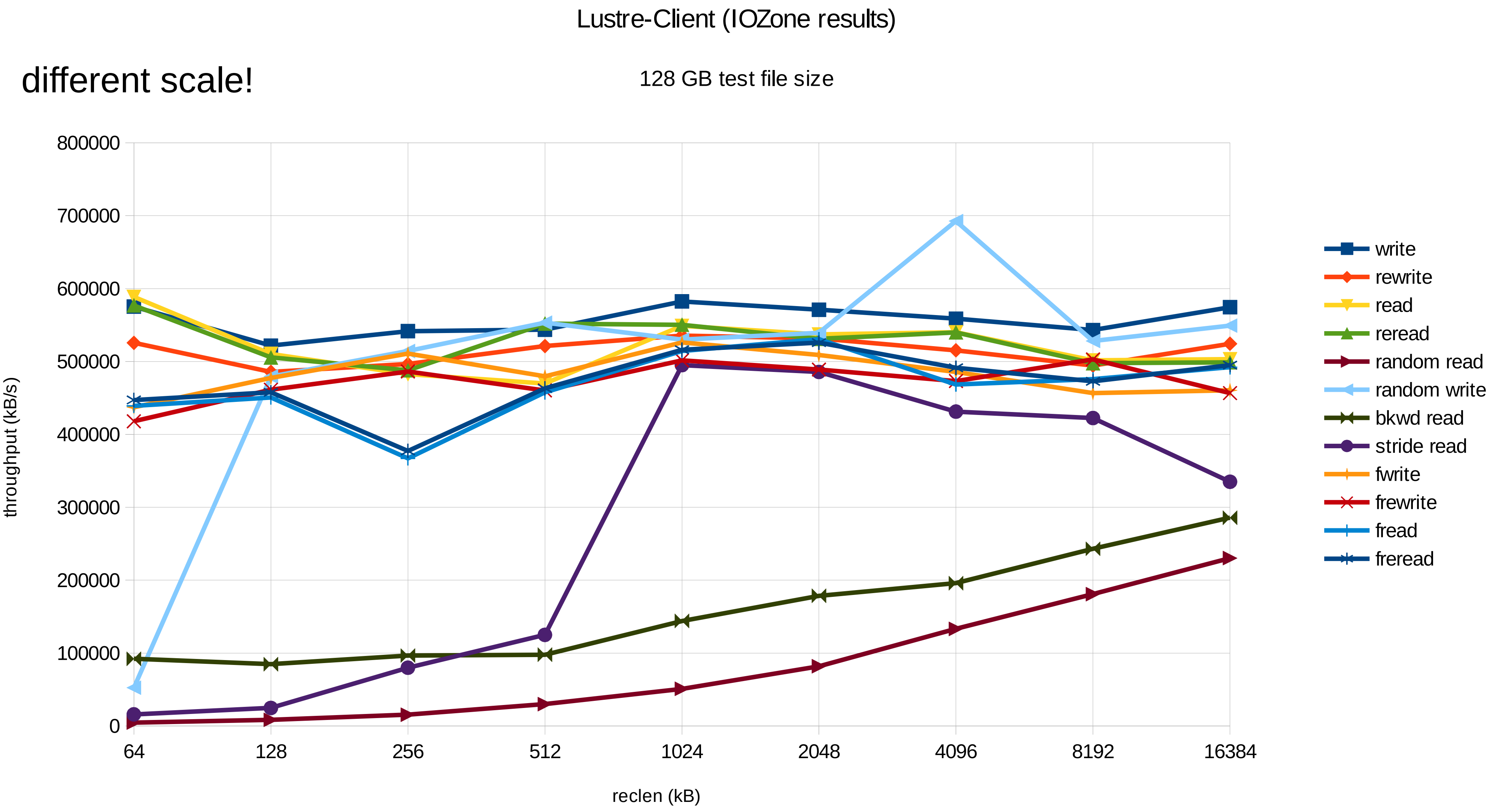
different scale!



Results

- ZPL:
  - RMW overhead for random I/O < recordsize
  - Significant metadata overhead for write operations (write vs. rewrite, rewrite vs. read)
  - For I/O units >= recordsize, random write performance similar to bulk
  - Read performance also depends on write pattern, IOPS bound for I/O units < 4-8 MB
  - In some tests, weird things happen at 4 MB I/O size
- Lustre:
  - Glosses over ZPL small I/O performance drawbacks
  - 2.5.3: consistent but slow single-stream performance
  - (not shown here) Bulk I/O saturates interconnect

Conclusion

- ZFS (and OS update) provide stable configuration on previously unstable hardware
- Easier administration and maintenance than mdraid-based setup
- Well suited for JBOD storage
- Different backend FS uncovered bug in Lustre, but otherwise stable
- ZFS performance meets expectations
- Lustre performance
    - ok for most I/O loads with units >= 128kB
    - single-stream performance generally slow, considering upgrade to later Lustre versions

Vielen Dank für Ihre Aufmerksamkeit.

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