PostgreSQL na EXT3/4, XFS, BTRFS a ZFS

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Which file system should we use for PostgreSQL on production systems?

According to our benchmarks from 2003,

the best file system is ...

What does it actually means when a file system is “stable” and “production ready”?

1) reliability

2) consistent performance

3) management & monitoring

DISCLAIMER

I'm not a dedicated fan (or enemy) of any of the file systems discussed in the talk.

SSD

File systems

EXT3, EXT4, XFS, ...

- EXT3/4, XFS, … (and others)
  - traditional design from 90., with journaling and such
  - similar goals / concepts / implementatins
  - continuous improvements
  - mature, reliable, proven by time and production deployments
- basic history
  - 2001 - EXT3
  - 2002 - XFS (1994 - SGI Irix 5.3, 2000 GPL, 2002 Linux)
  - 2008 - EXT4

EXT3, EXT4, XFS, ...

- evolution, not revolution
  - new features (e.g. TRIM, write barriers, ...)
  - scalability improvements (metadata, ...)
  - bug fixes
- conceived at the times of rotational storage
  - mostly work on SSD drives
  - stop-gap for future storage types (NVRAM, ...)
- mostly no support for
  - volume management, multiple drives, snapshots
  - addressed by LVM and/or RAID (hw/sw) – sometimes issues

BTRFS, ZFS

- basic idea
  - integrate all the layers (LVM + dm + ...)
  - designed for consumer-level hardware (expect failures)
  - designed for large data volumes
- that will (hopefully) give us ...
  - flexible management
  - built-in snapshostting
  - compression, deduplication
  - checksums

BTRFS, ZFS

- BTRFS
  - merged in 2009, but still considered “experimental”
  - on-disk format marked as “stable” (1.0)
  - some say it's “stable” or even “production ready” ...
  - default file system in some distributions
- ZFS
  - originally Sun / Solaris, but “got Oracled” :-(
  - slightly fragmented development (Illumos, Oracle, ...)
  - available on other BSD systems (FreeBSD)
  - “ZFS on Linux” project (but CDDL vs. GPL apod.)

Generic “mount options”

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- TRIM (discard)
  - enables TRIM commands (sent from kernel to SSD)
  - impacts internal cleanup (block erasure) / wear leveling
  - not entirely necessary, but may help SSD with “garbage collection”
- write barriers
  - prevents controller from reordering writes (e.g. journal x data)
  - ensures consistency of file system, does not prevent data loss
  - write cache + battery => write barriers may be disabled (really?)
- SSD alignment

Specific “mount options”

BTRFS

- nodatacow
  - disables “copy on write” (CoW), enables when snapshotting
  - also disables checksums (require “full” CoW)
  - probably also eliminates “torn-page resiliency” (full_page_writes=on)
- ssd
  - should enable SSD-related optimizations (but not sure which)
- compress=lzo/zlib
  - speculative compression

ZFS

- recordsize=8kB
  - standard ZFS page has 128kB (PostgreSQL uses 8kB pages)
  - makes ARC cache inefficient (smaller number of “slots”)
- logbias=throughput [latency]
  - influences access to ZIL
  - prioritizes latency vs. throughput
- zfs_arc_max
  - limits size of ARC cache (50% RAM by default)
  - should be freed automatically, but external module ...

Benchmark

pgbench (TPC-B)

- transactional benchmark (TPC-B) / stress-test
  - many tiny queries (access through PK, ...)
  - mix of different I/O types (read/write, random/sequential)
- two variants
  - read-only (SELECT)
  - read-write (SELECT + INSERT + UPDATE)
- three data volume categories
  - small (~200MB)
  - medium (~50% RAM)
  - large (~200% RAM)

Hardware

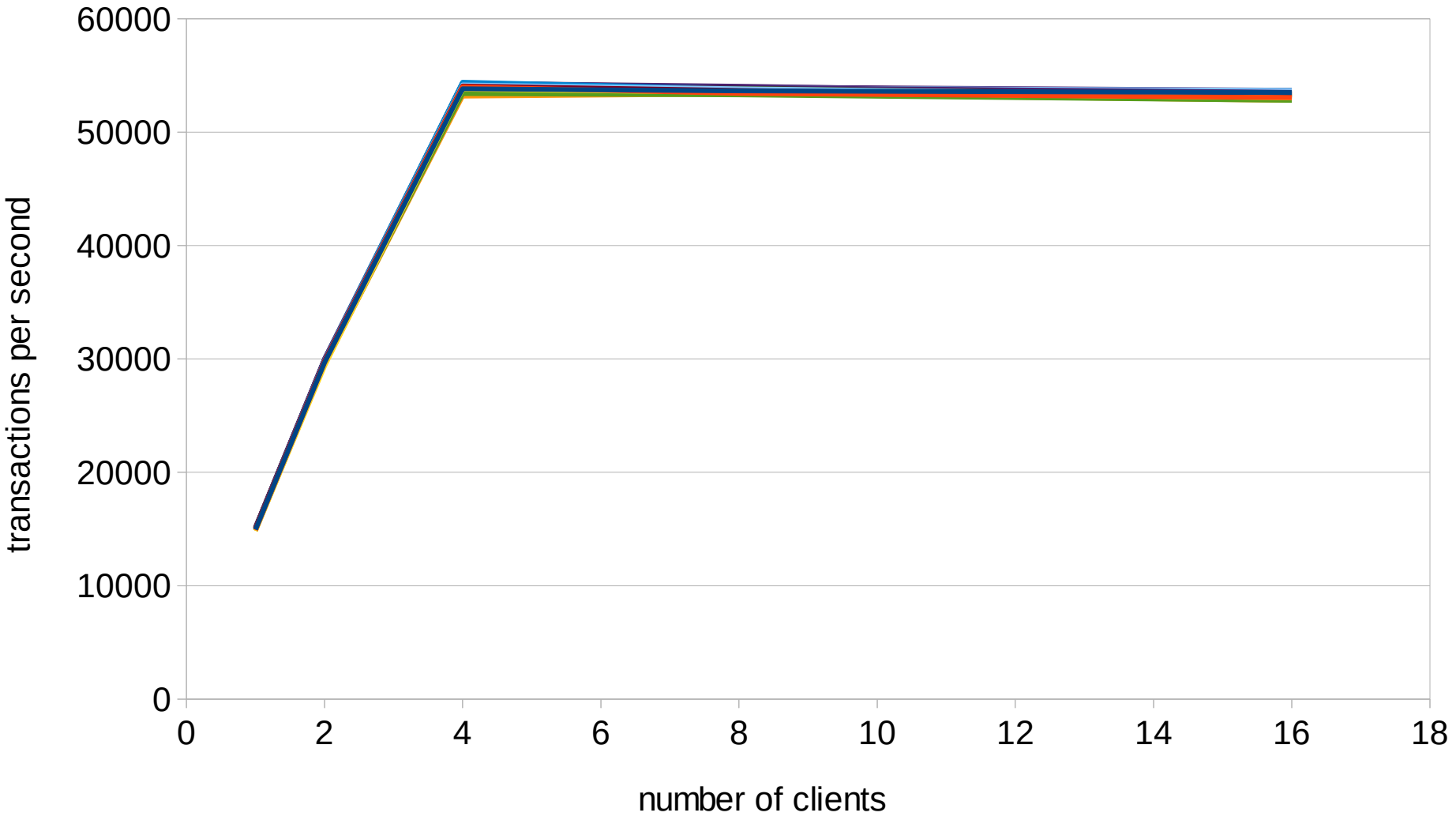
- CPU: Intel i5-2500k
  - 4 cores @ 3.3 GHz (3.7GHz)
  - 6MB cache
  - 2011-2013
- 8GB RAM (DDR3 1333)
- SSD Intel S3700 100GB (SATA3)
- Gentoo + kernel 4.0.4
- PostgreSQL 9.4

Hardware (Cosium)

- CPU 2x Intel Xeon E5-2687W v3, 3,1GHz, Cache 25Mo, 9,60GT/s QPI, Turbo, HT, 10C/20T (160W)
- RAM256GB RAM (16x DUAL IN-LINE MEMORY MODULE, 16GB, 2133, 2RX4, 4G, DDR4, R)
- storage A 2x Samsung XS1715 NVME SSD 1.6 TB
- storage B 2x 300GB SAS 10k RPM drive
- storage C 4x 1.2TB SAS 10k RPM drive
- RAID Dell Perc H330 (no write cache)

But that is not representative!

pgbench read-only



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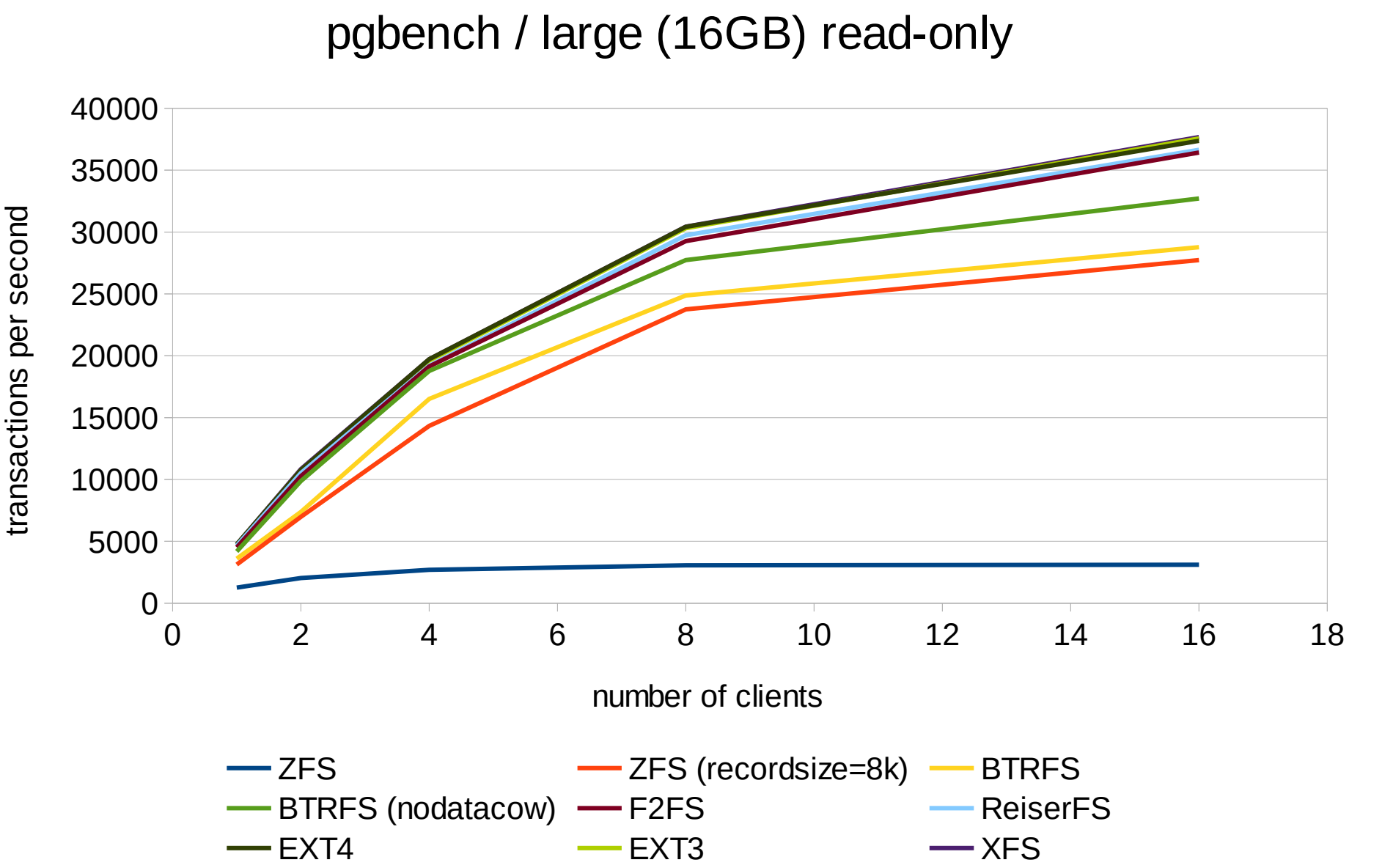

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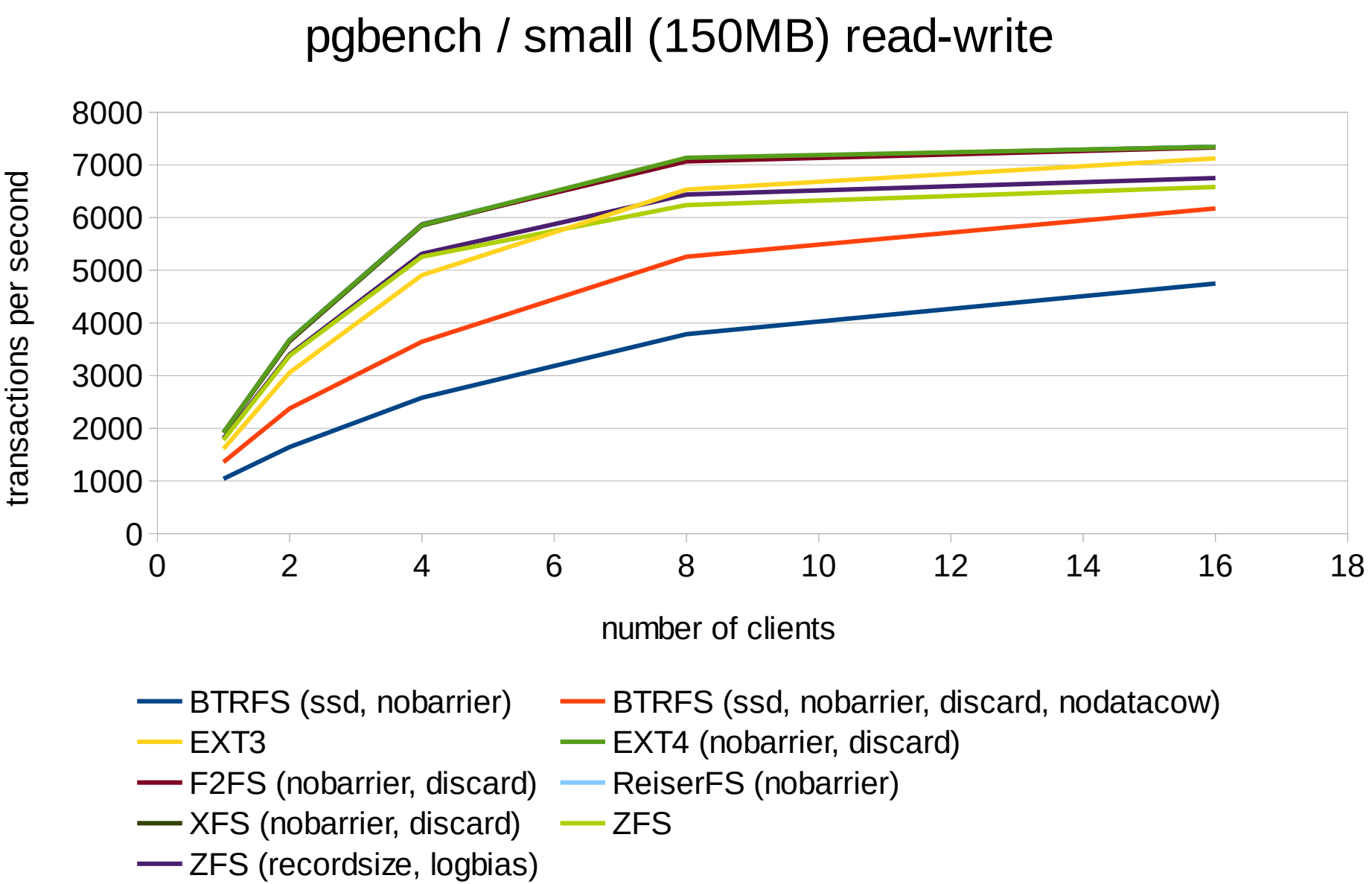
pgbench read-write



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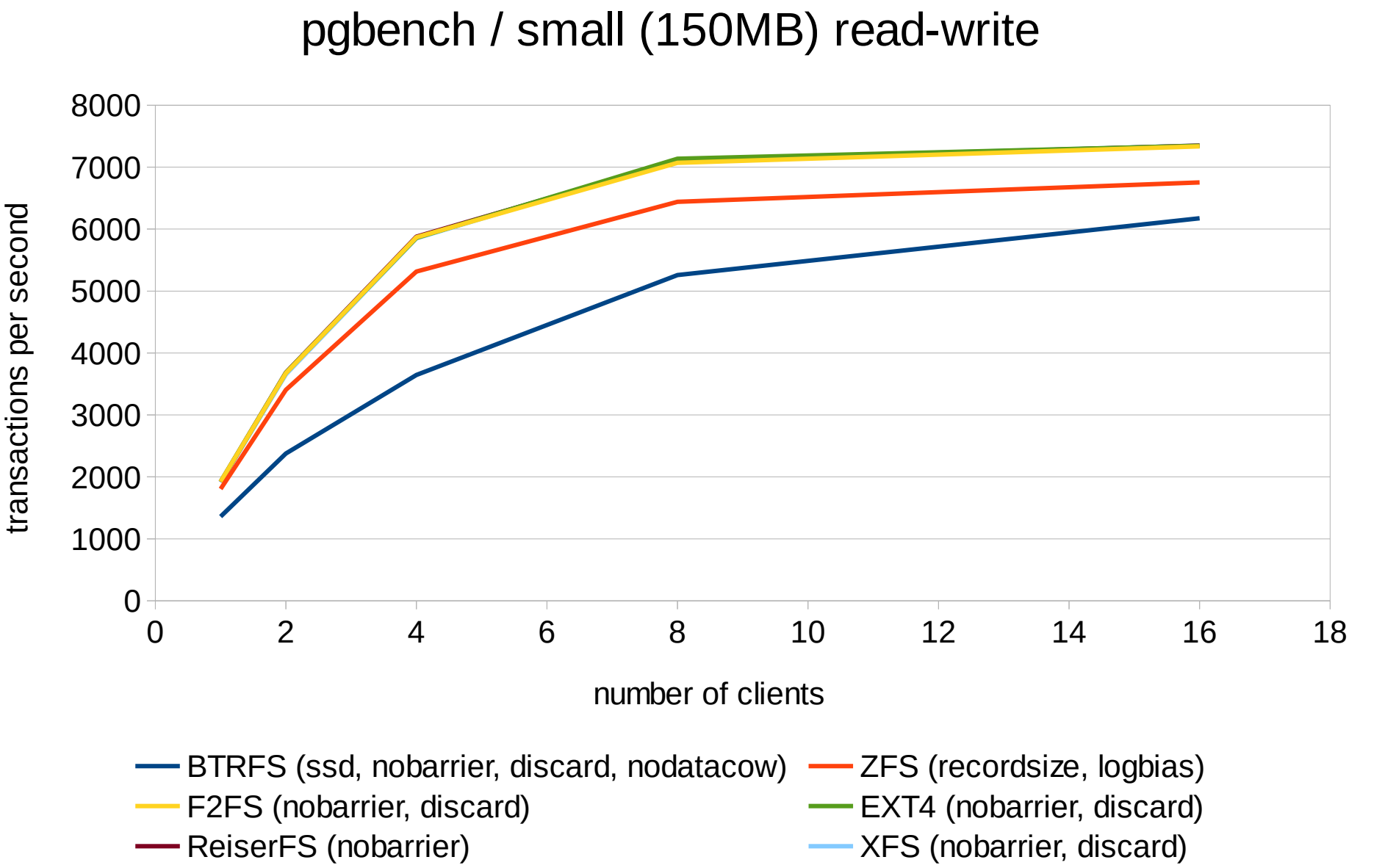

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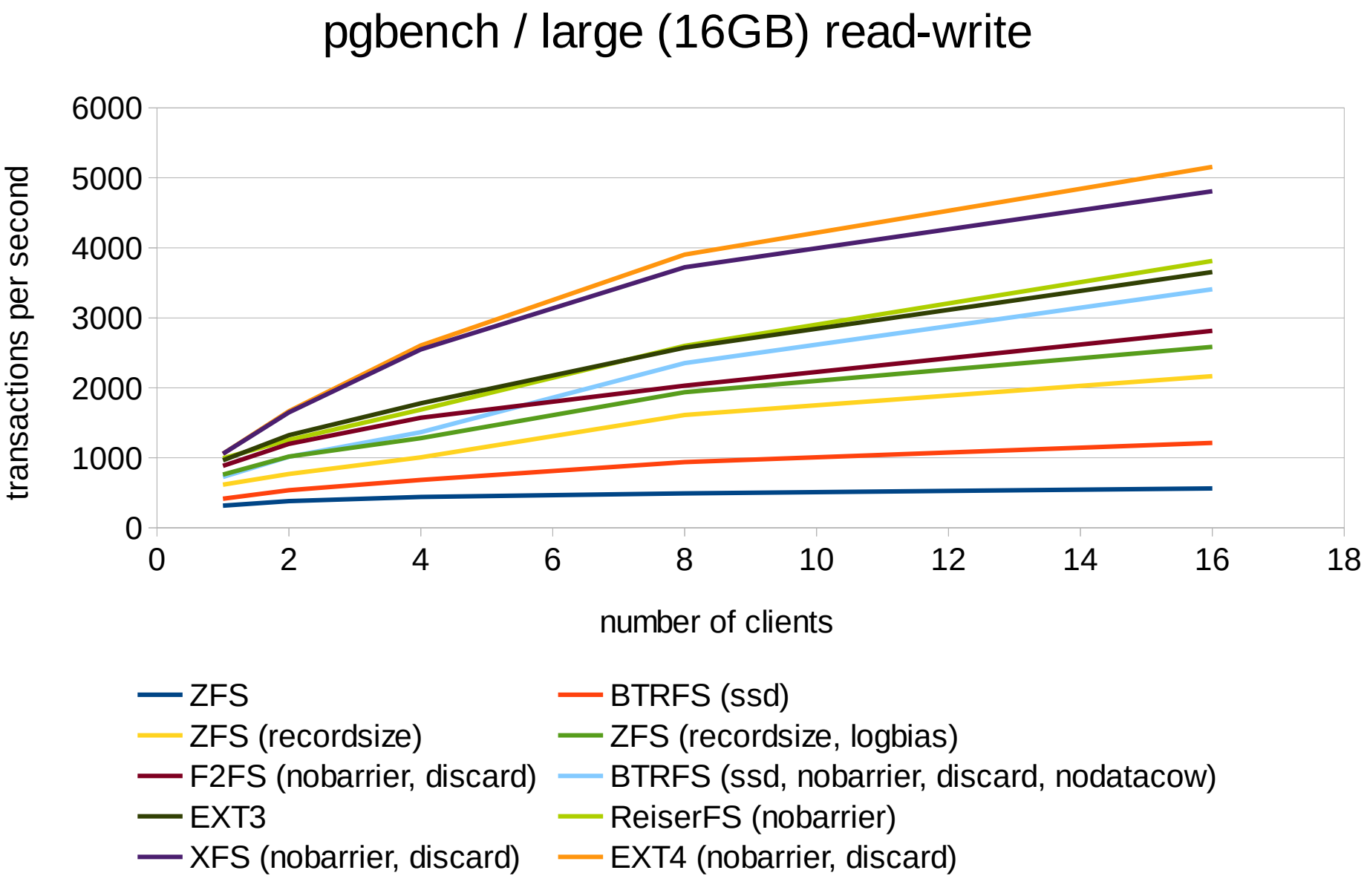

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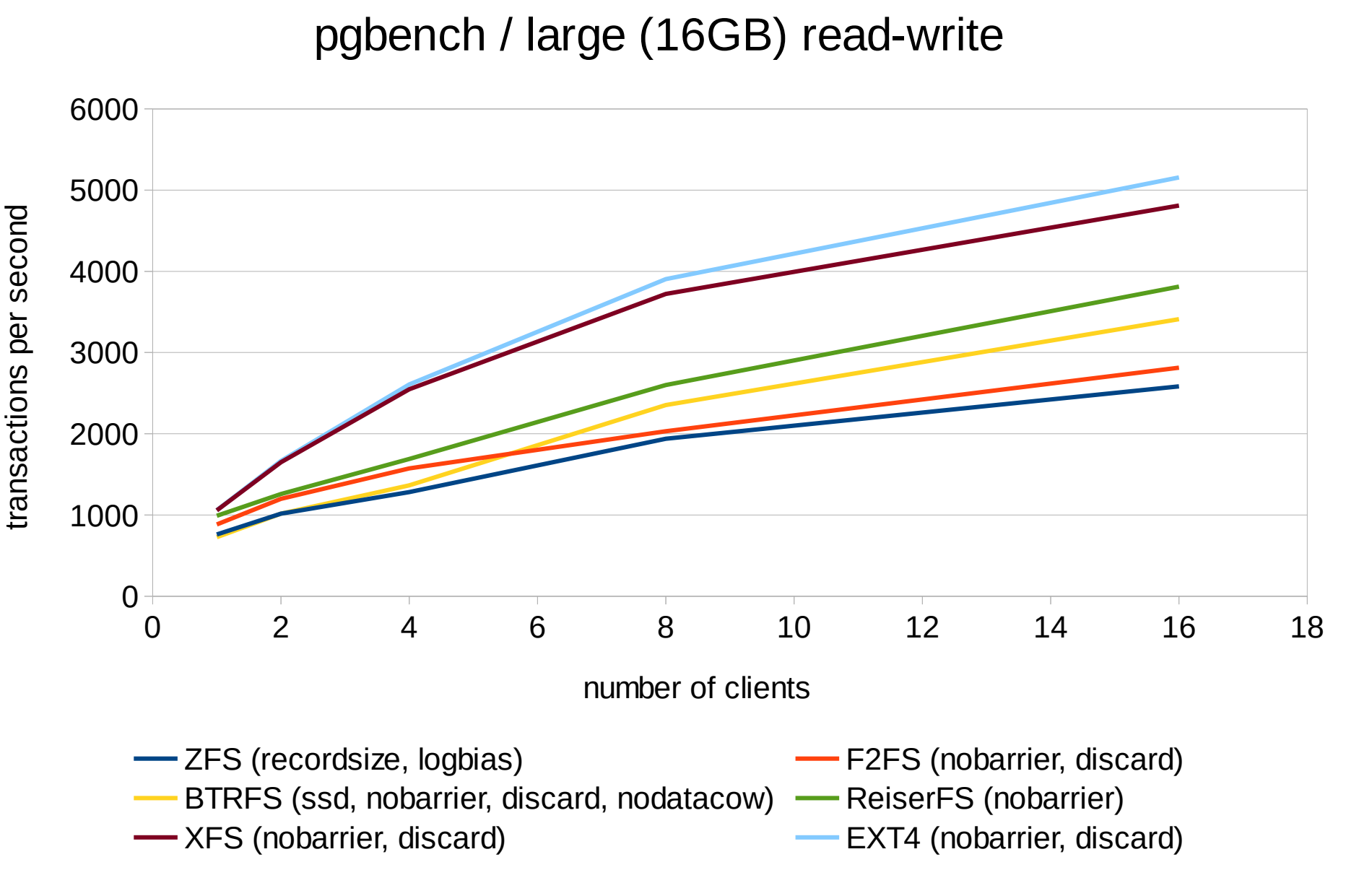

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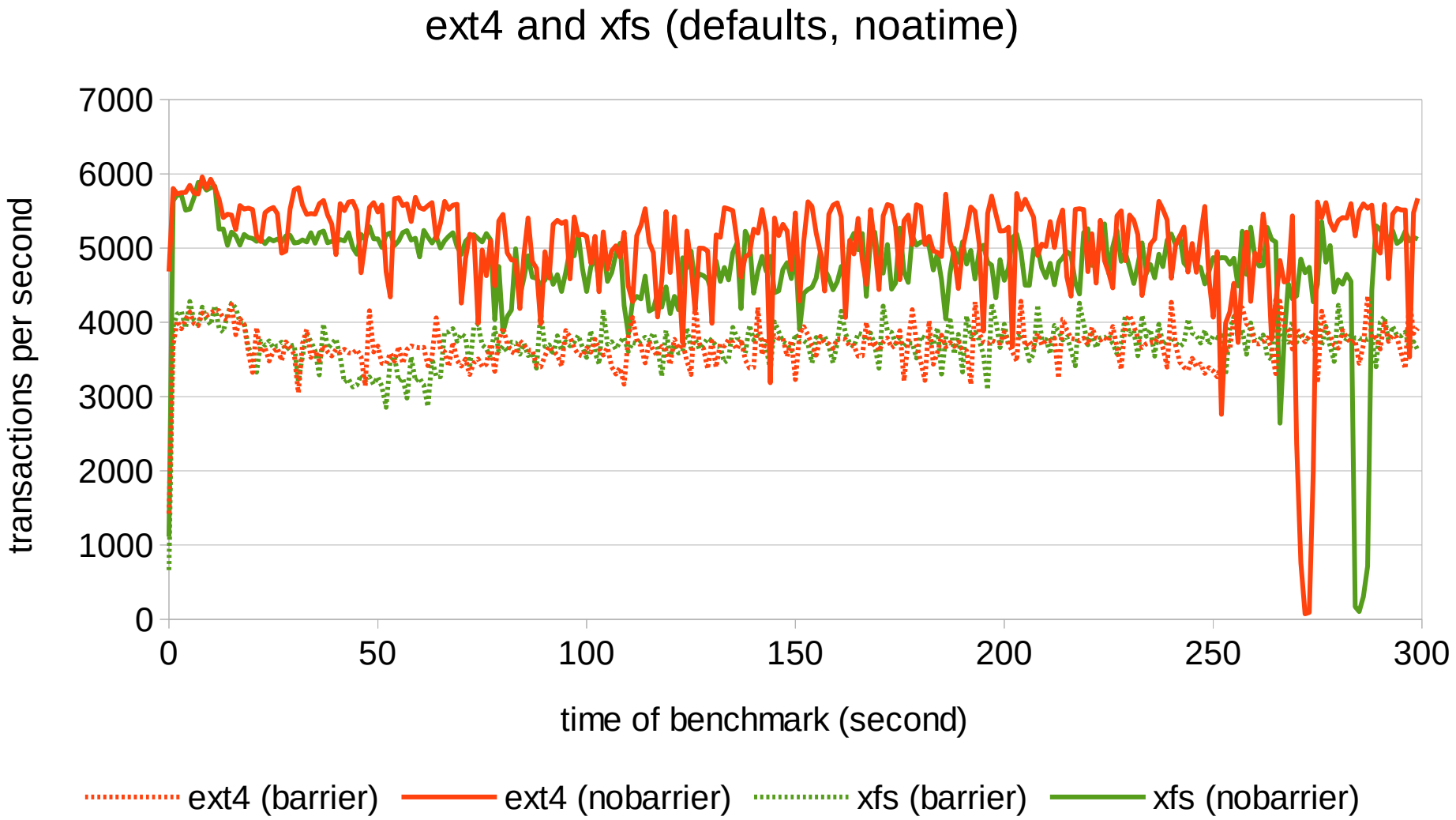
Write barriers



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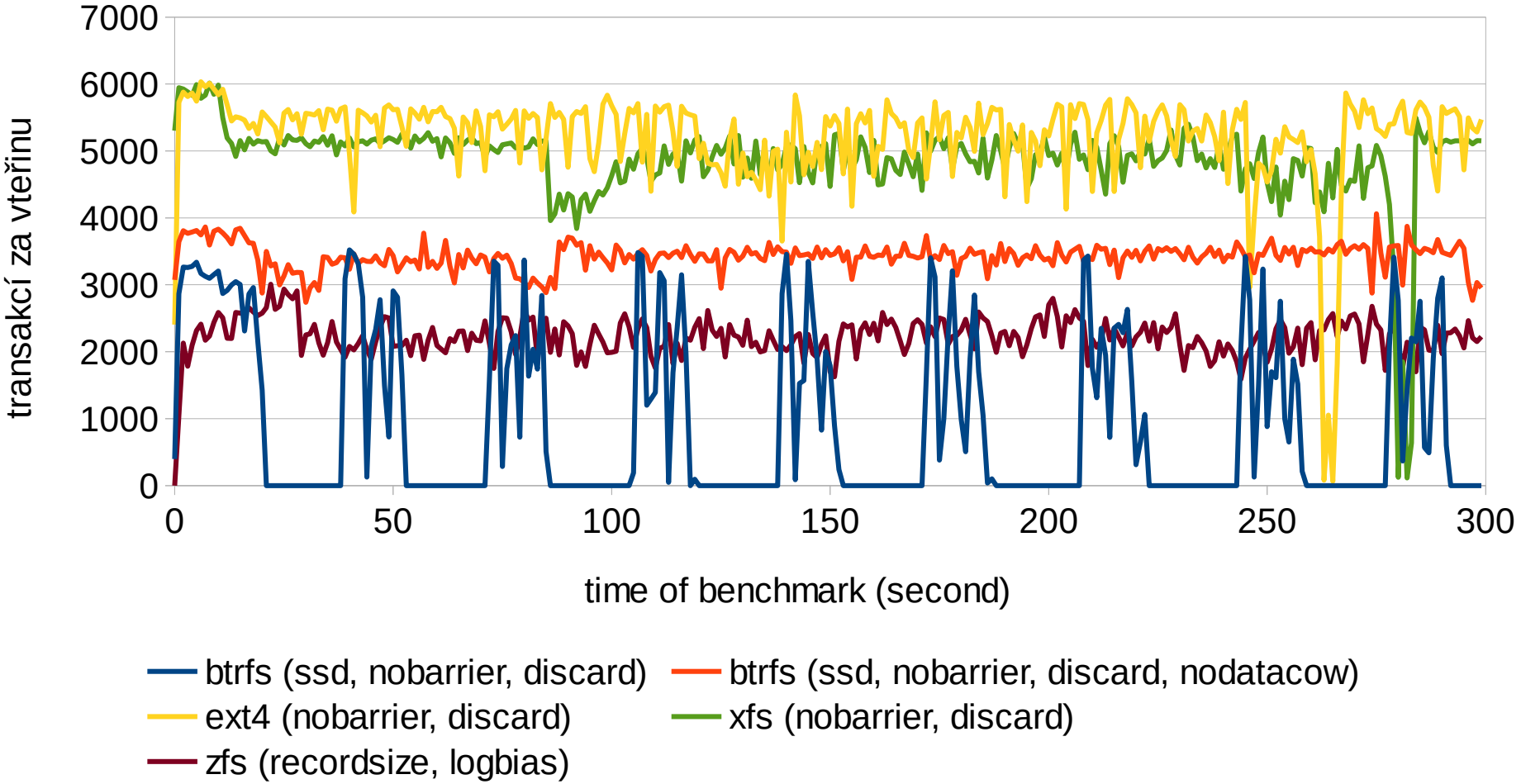
Performance variability

pgbench / large (16GB) read-write

number of transactions per second over time



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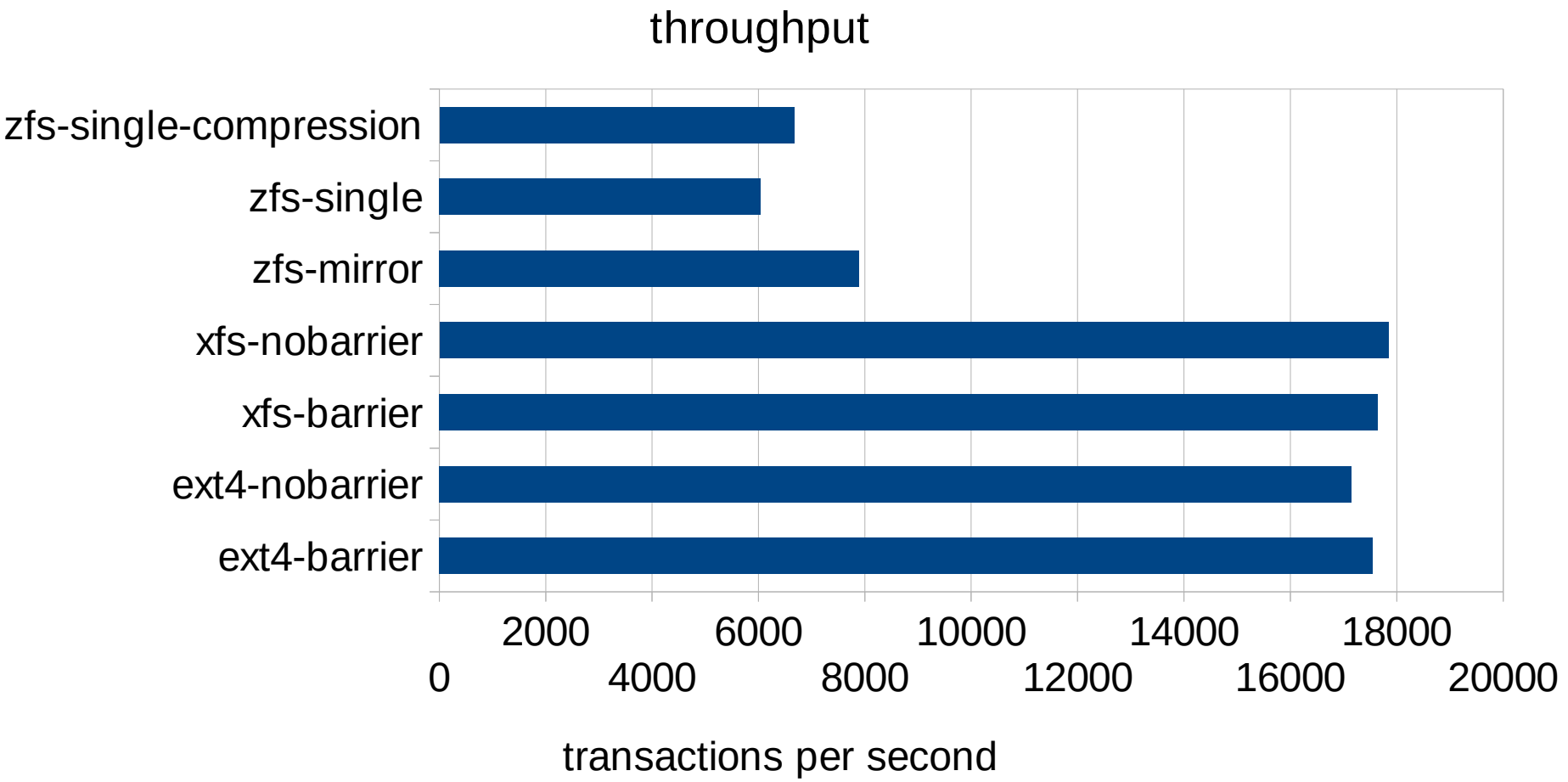
NVME drives

pgbench / large, 60 clients on NVME



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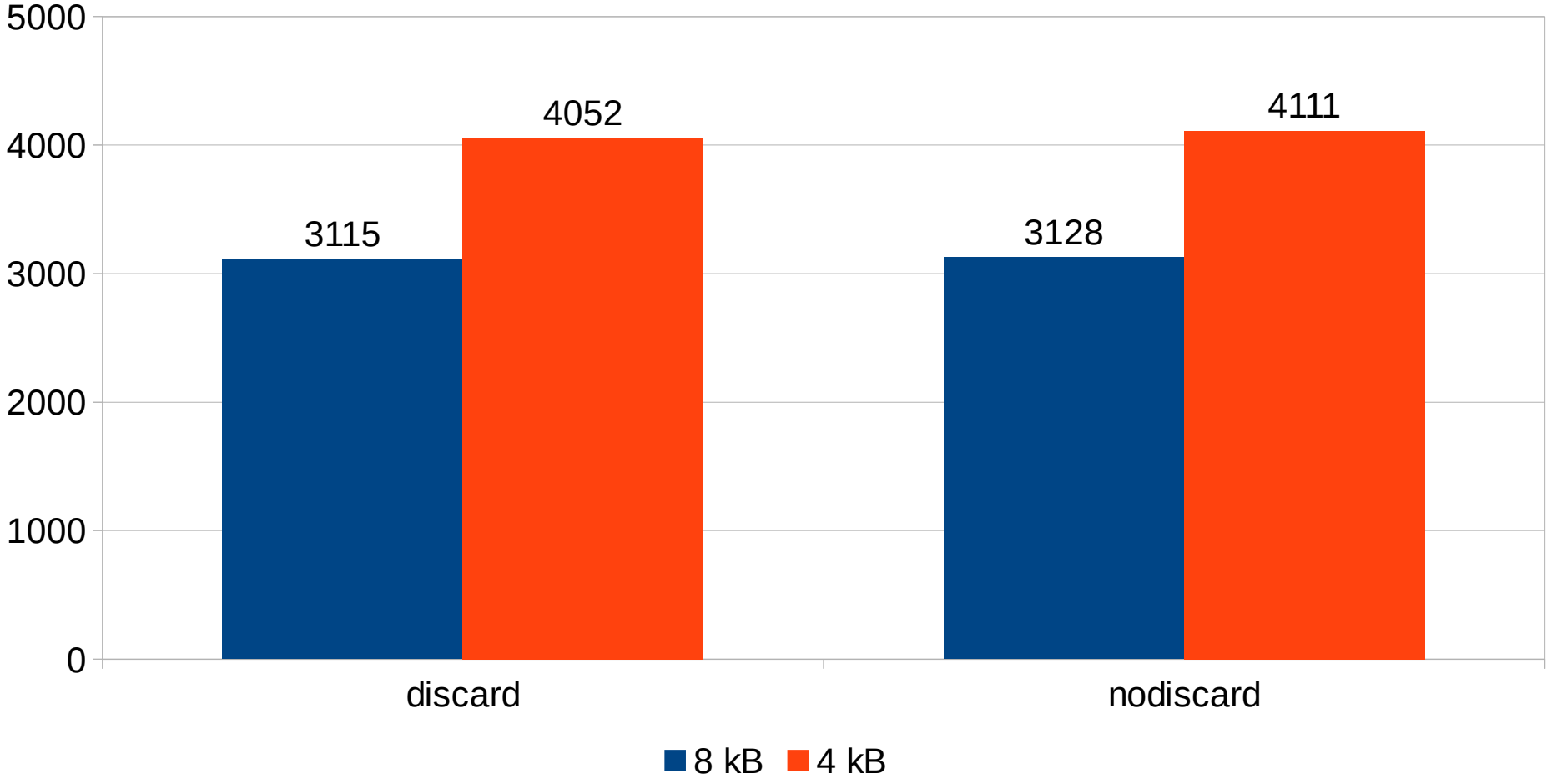
4kB vs. 8kB

PostgreSQL se 4kB a 8kB pages

pgbench read-write, 16 clients, scale 5000 (~80GB)



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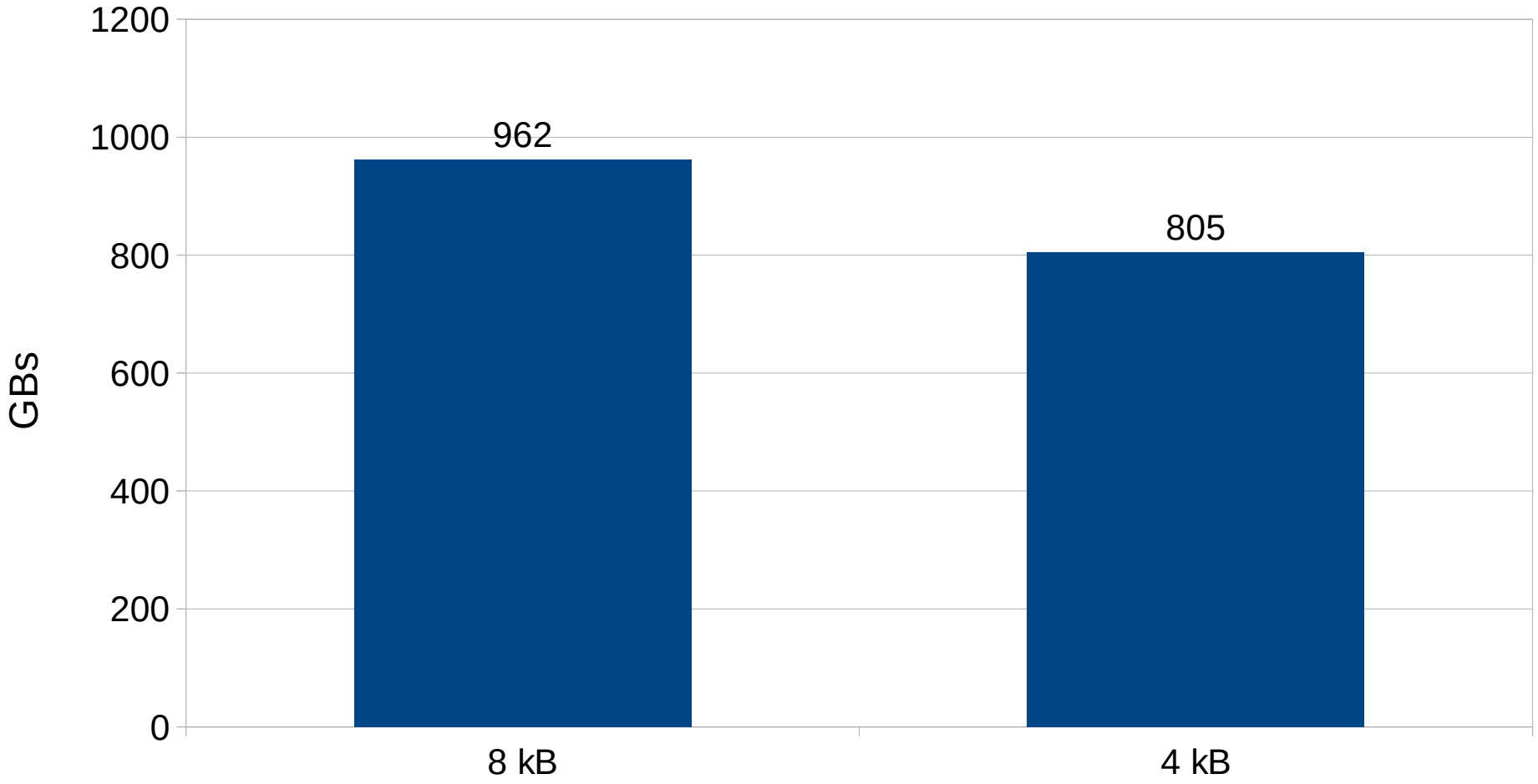
Host_Writes_32MB vs. 4kB/8kB pages

amount of data written to SSD (4 hours)



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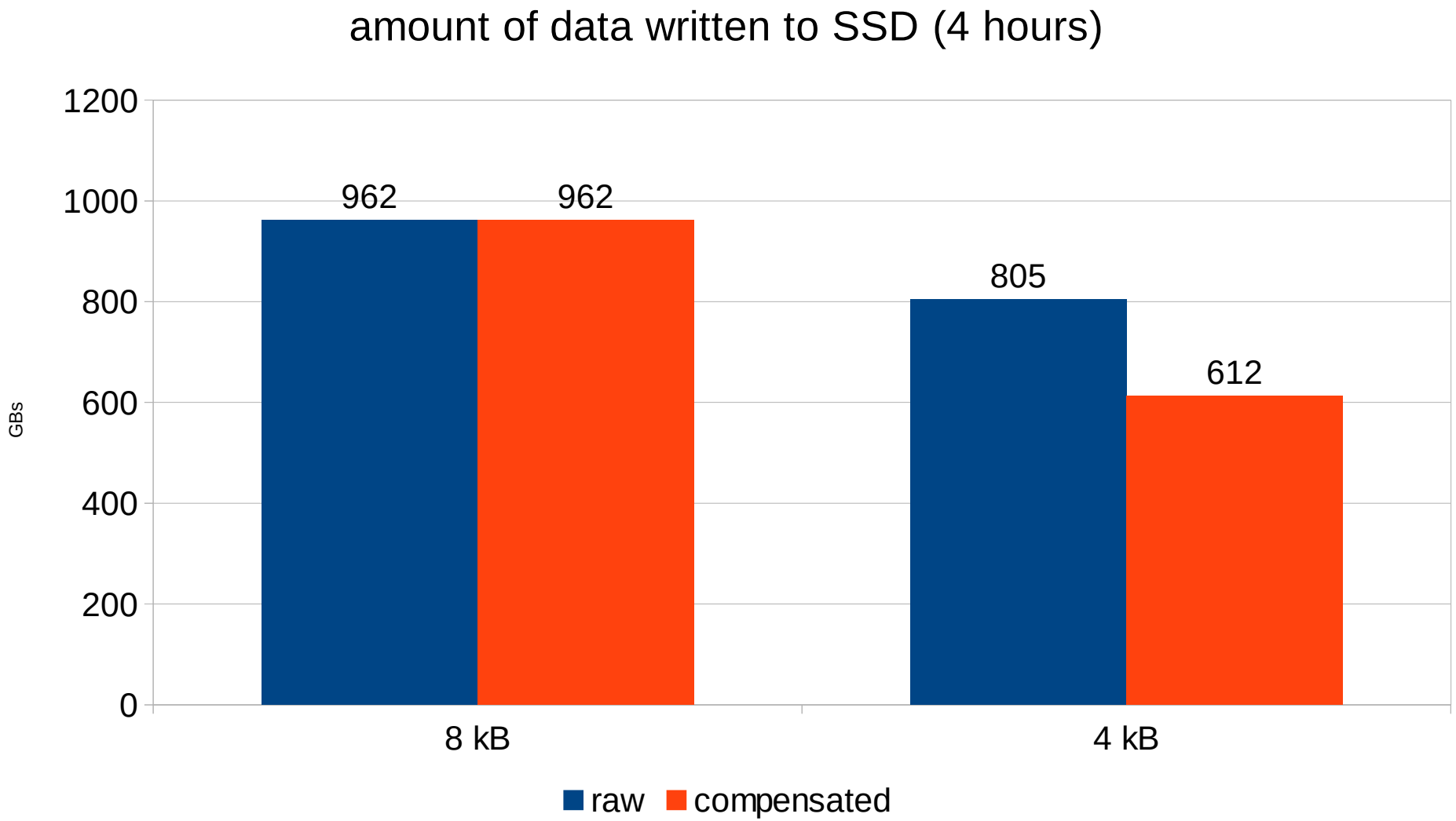

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EXT / XFS

- similar behavior
  - mostly compromise between throughput and latency
  - EXT4 – higher throughput, more jitter
  - XFS – lower throughput, less jitter
- significant impact of “write barriers”
  - requires reliable drives / RAID controller with BBU
- minimal TRIM impact
  - depends on SSD model (different over-provisioning etc.)
  - depends on how full the SSD is
  - benchmark does not delete (over-writes pages)

BTRFS, ZFS

- significant price for features (based on CoW)
  - about 50% reduction of performance when writing data
- BTRFS
  - most problems I've ran into were na on BTRFS
  - good: no data corruption bugs (but not tested)
  - bad: unstable and inconsistent behavior, lockups
- ZFS
  - alien in the Linux world, separate ARC cache
  - much more mature than BTRFS, nice stable behavior
  - ZFSonLinux actively developed (current 0.6.5, tested 0.6.3)

Conclusion

Conclusion

- if traditional file system is sufficient
  - use EXT4/XFS, depending on your distribution
  - no extreme differences in behavior / performance
  - worth spending some time in tuning
- if you need “advanced” features
  - e.g. snapshotting, multi-device support ...
  - ZFS is good choice (maybe consider FreeBSD)
  - BTRFS (now) definitely not recommended

Questions?

BTRFS, ZFS

```
Tasks: 215 total,   2 running, 213 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.0%us, 12.6%sy,  0.0%ni, 87.4%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Mem:  16432096k total, 16154512k used,   277584k free,     9712k buffers
Swap:  2047996k total,    22228k used,  2025768k free, 15233824k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
24402 root      20   0     0    0    0 R 99.7  0.0   2:28.09 kworker/u16:2
24051 root      20   0     0    0    0 S  0.3  0.0   0:02.91 kworker/5:0
    1 root      20   0 19416  608  508 S  0.0  0.0   0:01.02 init
    2 root      20   0     0    0    0 S  0.0  0.0   0:09.10 kthreadd
    ...

Samples: 59K of event 'cpu-clock', Event count (approx.): 10269077465
Overhead  Shared Object        Symbol
  37.47%  [kernel]             [k] btrfs_bitmap_cluster
  30.59%  [kernel]             [k] find_next_zero_bit
  26.74%  [kernel]             [k] find_next_bit
   1.59%  [kernel]             [k] _raw_spin_unlock_irqrestore
   0.41%  [kernel]             [k] rb_next
   0.33%  [kernel]             [k] tick_nohz_idle_
   ...
```

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BTRFS, ZFS

```
$ df /mnt/ssd-s3700/
Filesystem     1K-blocks     Used Available Use% Mounted on
/dev/sda1       97684992 71625072  23391064  76% /mnt/ssd-s3700

$ btrfs filesystem df /mnt/ssd-s3700
Data: total=88.13GB, used=65.82GB
System, DUP: total=8.00MB, used=16.00KB
System: total=4.00MB, used=0.00
Metadata, DUP: total=2.50GB, used=2.00GB    <= full (0.5GB for btrfs)
Metadata: total=8.00MB, used=0.00
: total=364.00MB, used=0.00

$ btrfs balance start -dusage=10 /mnt/ssd-s3700
```

https://btrfs.wiki.kernel.org/index.php/Balance_Filters

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EXT3/4, XFS

- Linux Filesystems: Where did they come from?
  (Dave Chinner @ linux.conf.au 2014)
  https://www.youtube.com/watch?v=SMcVdZk7wV8
- Ted Ts'o on the ext4 Filesystem
  (Ted Ts'o, NYLUG, 2013)
  https://www.youtube.com/watch?v=2mYDFr5T4tY
- XFS: There and Back … and There Again?
  (Dave Chinner @ Vault 2015)
  https://lwn.net/Articles/638546/
- XFS: Recent and Future Adventures in Filesystem Scalability
  (Dave Chinner, linux.conf.au 2012)
  https://www.youtube.com/watch?v=FegjLbCnoBw
- XFS: the filesystem of the future?
  (Jonathan Corbet, Dave Chinner, LWN, 2012)
  http://lwn.net/Articles/476263/