PostgreSQL-Consulting

data egret

Linux IO internals for PostgreSQL administrators in 2020

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Why this talk

- Linux is a most common OS for databases
- DBAs often run into IO problems
- Most of the information on topic is written by kernel developers (for kernel developers) or is checklist-style
- Checklists are useful, but up to certain workload

The main IO problem for databases for a long time was

- **How to maximize page throughput between memory and disks**
- Things involved:
  - Disks
  - Memory
  - CPU
  - IO Schedulers
  - Filesystems
  - Database itself
- IO problems for databases are not always only about disks

The main IO problem for databases for a long time was

- **How to maximize page throughput between memory and disks**
- Things involved:
  - **Disks** - **because latency of this part was very significant**
  - Memory
  - CPU
  - IO Schedulers
  - Filesystems
  - Database itself
- IO problems for databases are not always only about disks

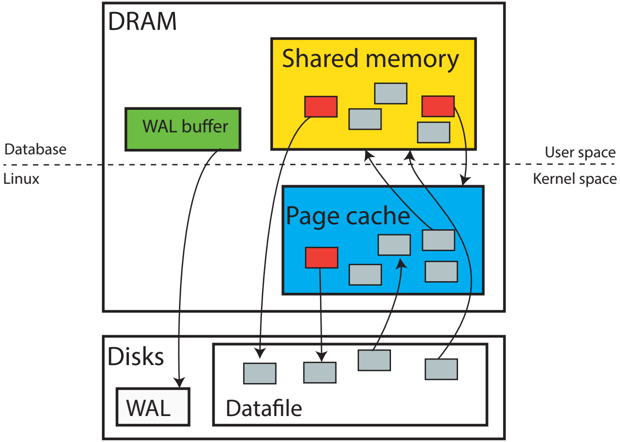
Throughput and latency

- Maximizing IO performance through maximizing throughput is easy up to certain moment
- Minimizing latency of IO usually is tricky
- With large adoption of proper SSDs, hardware latency dropped dramatically

Because of high latency of rotating disks

- Database development was concentrated around maximization of throughput
- So did Linux kernel development
- Many rotating disks era IO optimization techniques are not that good for SSDs

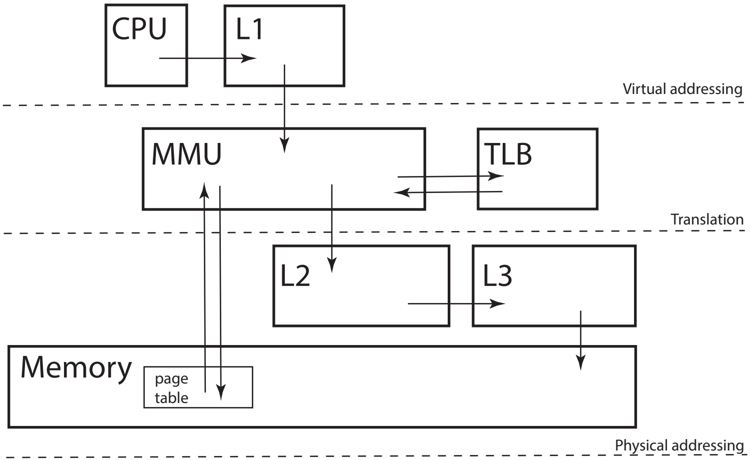
PostgreSQL database



Key things about such workload

- Shared memory segment can be very large
- Keeping in-memory pages synchronized with disk generates huge IO
- WAL should be written fast and safe
- One and every layer of OS IO stack involved

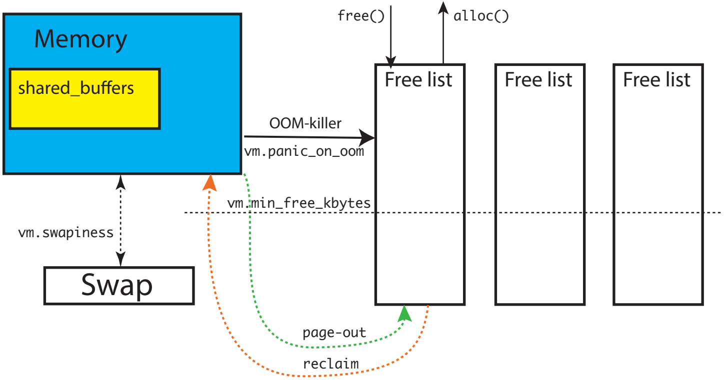
Memory allocation and mapping



DBAs takeaways:

- Database with huge shared memory segment benefits from huge pages
- But not from transparent huge pages
  - Databases operate large continuous shared memory segments
  - THP defragmentation can lead to severe performance degradation in such cases

Freeing memory



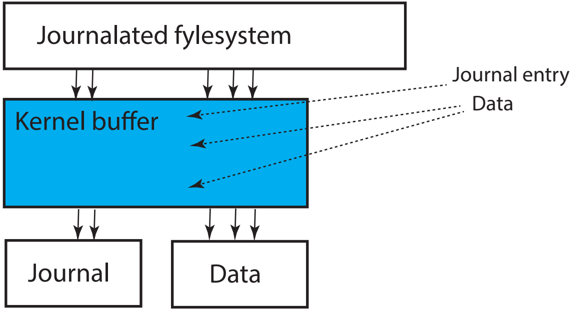
- Page-out happens if:
  - someone calls fsync
  - 30 sec timeout exceeded (*vm.dirty_expire_centisecs*)
  - Too many dirty pages (*vm.dirty_background_ratio* and *vm.dirty_ratio*)
- It is reasonable to tune *vm.dirty_** on rotating disks with RAID controller, but helps a little on server class SSDs

DBAs takeaways:

- *vm.overcommit_memory*
  - 0 - heuristic overcommit, reduces swap usage
  - 1 - always overcommit
  - **2 - do not overcommit** (*vm.overcommit_ratio* = *50* by default)
- vm.min_free_kbytes - reasonably high (can be easy 1000000 on a server with enough memory)
- **vm.swappiness = 1**
  - 0 - swap disabled
  - 60 - default
  - 100 - swap preffered instead of other reaping mechanisms
- Your database would not like OOM-killer

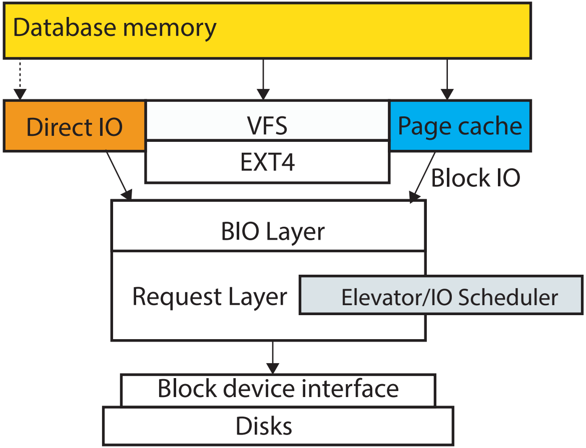
- *vm.panic_on_oom* effectively disables OOM-killer, but that is probably not the result you desire
- Or for a certain process: echo -17 > /proc/12465/oom_adj but again

Filesystems: write barriers

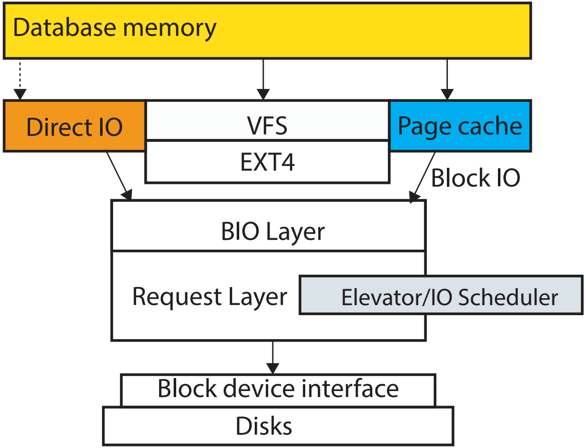


DBAs takeaways:

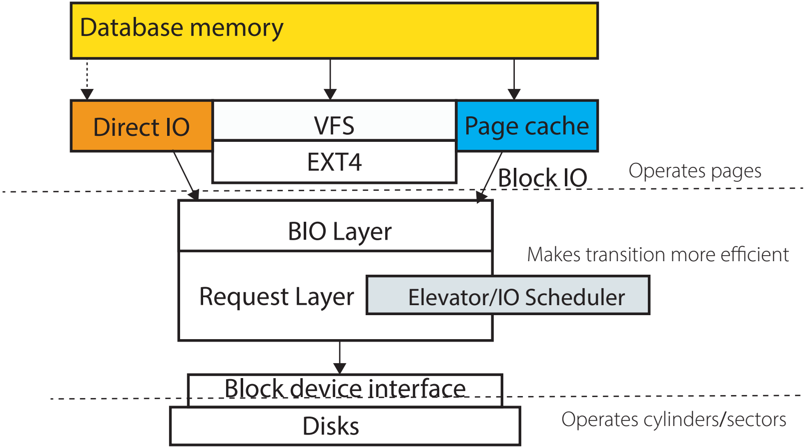
- ext4 or xfs
- Disable write barrier (only if SSD/controller cache is protected by capacitor/battery)


Database memory
Direct IO
VFS
EXT4
Page cache
Block IO
BIO Layer
Request Layer
Elevator/IO Scheduler
Block device interface
Disks

IO stack (as it used to look like)



IO stack (as it used to look like)



Elevators: before 2.6 kernel

- **Linus Elevator** - the only one in times of 2.4
- *merging* and *sorting* request queues
- Had **lots** of problems

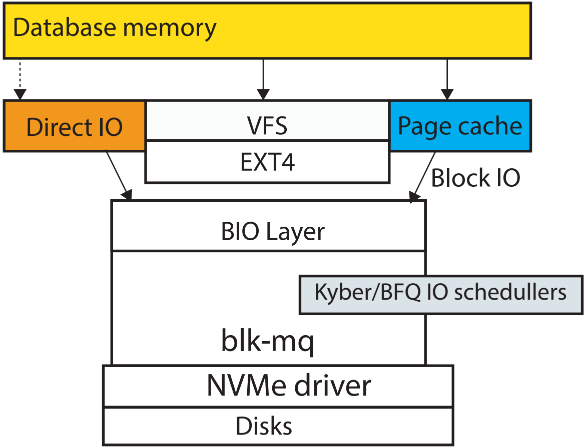
Elevators: between 2.6 and early 3.*

- **CFQ** - universal, default one
- **deadline** - rotating disks
- **noop** or **none** - then disks throughput is so high, that it can not benefit from keen scheduling
  - PCIe SSDs
  - SAN disk arrays

Elevators: 3.13 and newer

- Effectiveness of **noop** clearly shows ineffectiveness of others, or ineffectiveness of smart sorting as an approach
- **blk-mq** scheduler was merged into 3.13 kernel
- Much better deals with parallelism of modern SSD - basically separate IO queue for each CPU
- The best option for good SSDs right now
- **blk-mq and NVMe driver is actually more than scheduler, but a system aimed to substitute whole request layer**

IO stack (with blk-mq)



Good diagram on Linux IO stack

- **https://www.thomas-krenn.com/en/wiki/Linux_Storage_Stack_Diagram**
- Regular updates
- Some things are difficult to draw, but it is a complex topic

Non Volatile Memory Express or NVMe

- Sets of standards, which helps to use modern SSDs more effectively
- For Linux it is first of all NVMe driver (or subsystem)
- Most common example of NVMe SSDs are PCIe NAND drives
- With NVMe v.5 (currently 3 is ready for production) can work up to 32GB/sec
- Are databases NVMe ready?

Latest development on new block layer

- IO polling
- New IO schedulers Kyber and BFQ (Kernel 4.12)
- IO tagging
- Direct IO improvements
- io_uring (Kernel 5.1)

Notes on Direct IO

- Currently PostgreSQL supports DirectIO only for WAL, but it is unusable on practice
- Requires a lots of development
- Very OS specific
- Allows to use specific things, like O_ATOMIC
- PostgreSQL is the only database, which is not using Direct IO
- Many people consider Direct IO as a dirty hack
- Looks like io_uring has better perspectives

Questions?

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