High Performance JSON PostgreSQL vs. MongoDB

FOSDEM PGDay 2018

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Wei Shan Ang
PostgreSQL VS MongoDB
GlobalSign

- GlobalSign identity & crypto services provider
- WebTrust certified Certificate Authority - 3rd in the world
- High volume services - IoT devices, cloud providers
- Cryptographic identities, timestamping, signing, etc
About Me

- Database Engineer with 6 years of experience
- From Singapore but now based in London
- Originally worked on Oracle systems
- Switched to open-source databases in 2015
- Currently working in GlobalSign as a “Data Reliability Engineer”
Motivation

- Most benchmark results are biased - commercial interests
- We feel that benchmark results are measured “creatively”
- We use PostgreSQL and MongoDB a lot!
- We wanted to test the latest versions

For example, marketing technology vendor Mintigo leverages MongoDB to power its predictive analytics. They chose MongoDB over PostgreSQL for the flexibility of the document-based model and MongoDB’s ability to scale. “We initially prototyped on an alternative database technology called PostgreSQL. It’s a great relational database but it soon became clear that it would never handle the schema flexibility or scale that we needed,” explains Tal Segalov, CTO and Co-Founder of Mintigo.

Other organizations select MongoDB for its performance and scalability, such as the Ansible team at Red Hat that selected MongoDB for a log analysis application. “MongoDB performs orders of magnitude better than Postgres on the same, even double, the hardware and has other desirable features (i.e. arbitrary JSON structure querying, horizontal scaling),” says Chris Meyers of Red Hat. eHarmony was able to accelerate compatibility matching between potential partners 95% faster after migrating from relational databases, including Postgres.

I see no reason to use Mongoddb, PostgreSQL still beats Mongoddb!
PostgreSQL
PostgreSQL

- Around for 21 years
- JSON supported since 9.2
- JSONB supported since 9.4
- Does not have any statistics about the internals of document types like JSON or JSONB
  - Can be overcome with default_statistics_target or ALTER TABLE TABLE_NAME ALTER int4 SET STATISTICS 2000;
- Many JSON/JSONB operator/functions released since 9.2 (jsonb_set, jsonb_insert)
- Many JSON/JSONB bug fixes too
PostgreSQL Ecosystem

- "Build it yourself"
- Many High Availability solutions - all 3rd party
  - repmgr, pacemaker/corosync, Slony, Patroni and many more
- Connection Pooling
  - pgBouncer (single-threaded), pgpool-II
- Sharding
  - CitusDB
- Live version upgrades - tricky!
  - pg_upgrade, Slony, pg_dump and pg_logical
MongoDB
MongoDB

- Relatively “young” database software
  - 8 years since first release

- Known as a /dev/null database in the early days (jepsen.io)
  - Tremendous stability improvements since then
  - All known reliability issues has been fixed since 3.2.12

- Lots of WiredTiger bug fixes since 3.2
  - Cache eviction
  - Checkpoints
  - Lost updates and dirty writes

<table>
<thead>
<tr>
<th>Version</th>
<th>Lost updates</th>
<th>Dirty Reads</th>
<th>Stale Reads</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0.14</td>
<td>Allowed (no v1)</td>
<td>Allowed (no maj. read)</td>
<td>Allowed (no lin. read)</td>
</tr>
<tr>
<td>3.2.11</td>
<td>Allowed (v1 bugs)</td>
<td>Kinda</td>
<td>Allowed (no lin. read)</td>
</tr>
<tr>
<td>3.2.12</td>
<td>Prevented</td>
<td>Prevented</td>
<td>Allowed (no lin. read)</td>
</tr>
<tr>
<td>3.4.0-rc3</td>
<td>Allowed (v1 bugs)</td>
<td>Kinda</td>
<td>Kinda</td>
</tr>
<tr>
<td>3.4.0-rc4</td>
<td>Allowed (v1 bugs)</td>
<td>Kinda</td>
<td>Kinda</td>
</tr>
<tr>
<td>3.4.0</td>
<td>Prevented</td>
<td>Prevented</td>
<td>Prevented</td>
</tr>
</tbody>
</table>

Source: jepsen.io
MongoDB

● Everything comes as standard:
  ○ Built-in replication
  ○ Built-in sharding
  ○ Live cluster version upgrades (*ish*)
    ■ Shutdown slave, upgrade slave, startup slave, repeat
Server Hardware

- 2x Intel(R) Xeon(R) CPU E5-2630 v4
  - 20 cores / 40 threads
- 32GB Memory
- FreeBSD 11
- ZFS file system
- 2 x 1.6TB (Intel SSD DC S3610, MLC)
Why do we use ZFS?

- Highly tunable filesystem
  - Layered caching (ARC, L2ARC, ZIL)
  - Advanced cache algorithm
    - Most Recently Used (MRU)
    - Most Frequently Used (MFU)
- Free snapshots
- Block level checksums
- Fast compression
- Nexenta, Delphix, Datto, Joyent, Tegile, Oracle (obviously) and many more!
The Setup

- 1-3 Client machines (depending on the test)
- 1 Server, two jails - one for Postgres & one for Mongo
- PostgreSQL 9.6.5 with pgBouncer 1.7.2
- MongoDB 3.4.9 with WiredTiger
Performance Tuning

- We had to tune PostgreSQL heavily
  - System V IPC (shmmmax, shmall, semmns and etc)
  - pgBouncer (single threaded, we need multiple instances to handle the load)

- MongoDB tuning was easy!
  - WiredTiger cache size
  - Compression settings
  - Default settings are usually good enough

- ZFS tuning
  - atime
  - recordsize
  - checksum
  - compression
Sample JSON Document

```json
{
  "_id" : NumberLong(2),
  "name" : "IPAYAYpUvUDGiCd",
  "addresses" : [
    {
      "number" : 59,
      "line1" : "EPJKLhmEPrrdYqaFxxEVMF",
      "line2" : "Rvlgkmb"
    },
    {
      "number" : 59,
      "line1" : "DdCBXEW",
      "line2" : "FEV"
    }
  ],
  "phone_number" : "xPOYCOFs pielxbGxpYePi",
  "dob" : ISODate("2017-09-05T00:03:28.956Z"),
  "age" : 442006075,
  "balance" : 0.807247519493103,
  "enabled" : false,
  "counter" : 442006075,
  "padding" : BinData(0,"")
}
```
About Me

- **Engineer on the High Performance Platforms team**
  - Our team builds a high volume CA platform & distributed systems
  - Based in Old Street, London
  - Greenfields project, all new stuff!

- **Day job has me breaking all the things**
  - Simulating failures, network partitions, etc
  - Assessing performance and durability

- **Maintain performance fork of Go MongoDB driver**
  - [github.com/globalsign/mgo](https://github.com/globalsign/mgo)
MPJBT Benchmark Tool

- MongoDB PostgreSQL JSONB Benchmarking Tool
  - *Seriously,* we’re open to better names……..
- Written in Golang
- Open source!
- Models typical workloads (but maybe not yours!)
  - Inserts, selects, select-updates, range queries, etc.
- Lockless outside of the database drivers
  - Low contention improves ability to push servers
Why Go?

- Designed from the start for high concurrency
  - Thousands of concurrent workers is totally fine

- Co-operative scheduler can maximise I/O throughput
  - When blocked, Go switches to another worker
  - Blocked worker is woken up when it’s unblocked
  - Much cheaper context switching - occurs in userland

- Familiarity - I use it every day!
Does it deliver?
Insert 10,000,000 records
Average isn’t very helpful

- I have an average of 52.2ms
Average isn’t very helpful

- I have an average of 52.2ms

120.080231
36.237584
25.904811
44.053916
66.617778
59.713100
74.620329
1.689589
90.641940
27.202953
51.162331
52.202392
52.511745
50.439697
52.975609
52.567941
53.067609
52.122890
51.159180
52.390616
Inserts - Latency Histogram
Inserts - Latency Histogram
Inserts - Throughput

<table>
<thead>
<tr>
<th>Insert</th>
<th>Throughput</th>
<th>Average Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insert</td>
<td>30877op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>27509op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>29997op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>31143op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>22576op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>0op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>0op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>1op/s</td>
<td>2561ms</td>
</tr>
<tr>
<td>Insert</td>
<td>0op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>20703op/s</td>
<td>6ms</td>
</tr>
<tr>
<td>Insert</td>
<td>31154op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>31298op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>30359op/s</td>
<td>0ms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insert</th>
<th>Throughput</th>
<th>Average Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insert</td>
<td>26081op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>25938op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>26649op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>26009op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>26029op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>25522op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>25960op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>25576op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>26159op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>25628op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>26071op/s</td>
<td>0ms</td>
</tr>
<tr>
<td>Insert</td>
<td>25856op/s</td>
<td>0ms</td>
</tr>
</tbody>
</table>
MongoDB cache eviction bug?

![Graph showing Inserts Throughput vs Dirty Cache/Bytes in Cache](image-url)
MongoDB cache eviction bug - not a bug?

- Reported to MongoDB (twice!)
  - https://jira.mongodb.org/browse/SERVER-29311
  - Offered to run any tests and analyse data

- Ran 36 different test combinations
  - ZFS compression: lz4, zlib, off
  - MongoDB compression: snappy, zlib, off
  - Filesystem block sizes
  - Disk configurations
  - Tried running on Linux/XFS

- Always saw the same pauses
  - Described as an I/O bottleneck
Profile with Dtrace!

- Dynamic tracer built into FreeBSD (and others)
  - Originally created by Sun for Solaris
  - Ported to FreeBSD
  - Low profiling overhead

- Traces in both kernel and userspace
  - Hook syscalls, libc, application functions, etc
  - Access function arguments, kernel structures, etc

- Hooks expressed in D like DSL
  - Conditionally trigger traces
  - Really simple to use
Trace the Virtual File System

- Measures application file system operations
  - Kernel level
  - File system agnostic (XFS, ZFS, anything)

- Records data size & latency:
  - Reads - `vfs::vop_read`
  - Writes - `vfs::vop_write`

- Configured to output ASCII histograms
  - Per second aggregations
  - Broken down by type
  - Timestamped for correlating with MPJBT logs
VFS Writes vs. Throughput - PostgreSQL
VFS Writes vs. Throughput - MongoDB
Insert / Update / Select comparison

- Preloaded 10,000,000 records in the table
  - No padding - records are ~320 bytes

- 3 clients running different workloads
  - 50 workers inserting
  - 50 workers updating
  - 50 workers performing a range over partial index

- Both databases become CPU bound
  - Database server is under maximum load
  - Typically avoided in a production environment
  - Always good to know your maximum numbers
<table>
<thead>
<tr>
<th></th>
<th>Insert</th>
<th>Update</th>
<th>Select</th>
</tr>
</thead>
<tbody>
<tr>
<td>99th%</td>
<td>13ms</td>
<td>99th%</td>
<td>99th%</td>
</tr>
<tr>
<td></td>
<td>18,070 op/s</td>
<td>22,304 op/s</td>
<td>18,960 op/s</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MongoDB
PostgreSQL
<table>
<thead>
<tr>
<th></th>
<th>Insert</th>
<th>Update</th>
<th>Select</th>
</tr>
</thead>
<tbody>
<tr>
<td>99th%</td>
<td>4ms</td>
<td>4ms</td>
<td>3ms</td>
</tr>
<tr>
<td>Average</td>
<td>25,244 op/s</td>
<td>26,085 op/s</td>
<td>27,778 op/s</td>
</tr>
</tbody>
</table>
Workload - 1MB Inserts

99th Percentile Latency
- MongoDB => 4.5s
- PostgreSQL => 1.5s
Insert Performance

CPU 35%

- insert 65543op/s avg.0ms
- insert 65113op/s avg.0ms
- insert 69881op/s avg.0ms
- insert 55728op/s avg.0ms
- insert 57502op/s avg.0ms
- insert 64428op/s avg.0ms
- insert 64872op/s avg.0ms
- insert 68804op/s avg.0ms
- insert 63204op/s avg.0ms
- insert 63279op/s avg.0ms

CPU 40%

- insert 42011op/s avg.0ms
- insert 53330op/s avg.0ms
- insert 57815op/s avg.0ms
- insert 54331op/s avg.0ms
- insert 39616op/s avg.0ms
- insert 51919op/s avg.0ms
- insert 53366op/s avg.0ms
- insert 56678op/s avg.0ms
- insert 40283op/s avg.0ms
- insert 47300op/s avg.0ms
## Update Performance

- **CPU 85%**
  - update 2416 op/s avg.0ms
  - update 0  op/s avg.0ms
  - update 0  op/s avg.0ms
  - update 2856 op/s avg.33ms
  - update 21425op/s avg.0ms
  - update 0   op/s avg.0ms
  - update 0   op/s avg.0ms
  - update 12798op/s avg.5ms
  - update 11094op/s avg.0ms
  - update 21302op/s avg.0ms

- **CPU 65%**
  - update 31252op/s avg.0ms
  - update 32706op/s avg.0ms
  - update 33801op/s avg.0ms
  - update 28276op/s avg.0ms
  - update 34749op/s avg.0ms
  - update 29972op/s avg.0ms
  - update 28565op/s avg.0ms
  - update 32286op/s avg.0ms
  - update 30905op/s avg.0ms
  - update 32052op/s avg.0ms
So...why are we even using MongoDB? PostgreSQL is awesome right?
autovacuum: VACUUM public.test02 (to prevent wraparound)
Vacuum Performance - Insert Workload
Horizontally Scalable
Table Size Comparison

MongoDB and PostgreSQL

- **Before Compression**
- **After Compression**

Size in GB

- MongoDB
- PostgreSQL

~ 1 billion records

*Lower is better*
Summary
50/50 CHOICE
WRONG 100% OF THE TIME
Summary

- There is no such thing as the best database in the world!
- Choosing the right database for your application is never easy
  - How well does it scale?
  - How easy is it to perform upgrades?
  - How does it behave under stress?
- What is your application requirements?
  - Do you really need ACID?
- Do your own research!
Summary - PostgreSQL

- PostgreSQL has poor performance out of the box
  - Requires a decent amount of tuning to get good performance out of it
- Does not scale well with large number of connections
  - pgBouncer is a must
- Combines ACID compliance with schemaless JSON
- Queries not really intuitive
Summary - MongoDB

- MongoDB has decent performance out of the box.
- Unstable throughput and latency
- Scale well with large number of connections
- Strong horizontal scalability
- Throughput bug is annoying
- MongoDB rolling upgrades are ridiculously easy
- Developer friendly - easy to use!
TODO

- Released MPJBT on Github
  - Open source for all
  - github.com/domodwyer/mpjbt
- Run similar tests against CitusDB
  - You guys have inspired us to keep looking!
- Run performance test for MongoRocks (LSM)
Questions?

Thank You!

Like what you see?
We are hiring!
Come and speak to us!
References

- https://jepsen.io/analyses/mongodb-3-4-0-rc3
- https://github.com/domodwyer/mpjbt
- https://jira.mongodb.org/browse/WT-3633
Previous Benchmark Results

- http://erthalion.info/2015/12/29/json-benchmarks/
- https://www.slideshare.net/toshiharada/ycsb-jsonb
Appendix
pgbouncer.ini

- PostgreSQL does not support connection pooling
- PgBouncer is an extremely lightweight connection pooler
- Setting up and tearing down a new connection is expensive
- Each PostgreSQL connection forks a new process

Configuration
- `pool_mode = transaction`
- `max_client_conn = 300`
postgresql.conf

- shared_buffer = 16GB
- max_connections = 400
- fsync = on
- synchronous_commit = on
- full_page_writes = off
- wal_compression = off
- wal_buffers = 16MB
- min_wal_size = 2GB
- max_wal_size = 4GB
- checkpoint_completion_target = 0.9
- work_mem = 33554KB
- maintenance_work_mem = 2GB
- wal_level = replica
mongod.conf

- `wiredTiger.engineConfig.cacheSizeGB`: 19
- `wiredTiger.engineConfig.journalCompressor`: snappy
- `wiredTiger.collectionConfig.blockCompressor`: snappy
- `wiredTiger.indexConfig.prefixCompression`: true
- `net.maxIncomingConnections`: 65536
- `wiredTigerConcurrentReadTransactions`: 256
- `wiredTigerConcurrentWriteTransactions`: 256
ZFS Tuning

- No separate L2ARC
- No separate ZIL
- 1 dataset for O/S
- 1 dataset for data directory
  - checksum=on
  - atime=off
  - recordsize=8K
  - compression=lz4 (PostgreSQL) or off (MongoDB)
/boot/loader.conf

- kern.maxusers=1024
- kern.ipc.semmns=2048
- kern.ipc.semmni=1024
- kern.ipc.semmnu=1024
- kern.ipc.shmall=34359738368
- kern.ipc.shmmax=34359738368
- kern.ipc.maxsockets=256000
- kern.ipc.maxsockbuf=2621440
- kern.ipc.shmseg=1024
/etc/sysctl.conf

- net.inet.tcp.keepidle=3000000
- net.inet.tcp.keepintvl=60000
- net.inet.tcp.keepinit=60000
- security.jail.sysvipc_allowed=1
- kern.ipc.shmmmax=34359738368
- kern.ipc.shmall=16777216
- kern.ipc.shm_use_phys=1
- kern.maxfiles=2621440
- kern.maxfilesperproc=2621440
- kern.threads.max_threads_per_proc=65535
- kern.ipc.somaxconn=65535
- kern.eventtimer.timer=HPET
- kern.timecounter.hardware=HPET
- vfs.zfs.arc_max: 8589934592 for PostgreSQL or 1073741824 for MongoDB