Garage, an S3 backend as reliable as possible

https://garagehq.deuxfleurs.fr/
mailto:garagehq@deuxfleurs.fr
#garage:deuxfleurs.fr on Matrix

Getting support for Garage

Alex Auvolat
PhD; co-founder of Deuxfleurs
Garage maintainer, Freelance

Quentin Dufour
PhD; co-founder of Deuxfleurs
Garage contributor, Freelance

Armaël Guéneau
PhD; member of Deuxfleurs
Garage contributor, Freelance

For support requests, write at:
`garagehq@deuxfleurs.fr`

Eligible: email support, architecture design, specific feature development, etc.

Meet Garage

A non-profit initiative

Part of a degrowth initiative

Garage has been created at Deuxfleurs where we experiment running Internet services without datacenter on commodity and refurbished hardware.

Developed by a community

Some recent contributors: Arthur C, Charles H, dongdigua, Etienne L, Jonah A, Julien K, Lapineige, MagicRR, Milas B, Niklas M, RockWolf, Schwitzd, trinity-1686a, Xavier S, babykart, Baptiste J, eddster2309, James O'C, Joker9944, Maximilien R, Renjaya RZ, Yureka...

Diluted open-source as a response to fauxpen-source

AGPL + no Contributor License Agreement = Garage ownership spreads among hundredth of contributors.

Mainly funded by the EU

Our initial goal

Being a self-sovereign community to be free of our degrowth choice

↓

As web citizens, datacenters are big black boxes.
We want to leave them to autonoumously manage our servers.

↓

We want reliable services without relying on dedicated hardware or places.

Building a resilient system with cheap stuff

- Commodity hardware (e.g. old desktop PCs)

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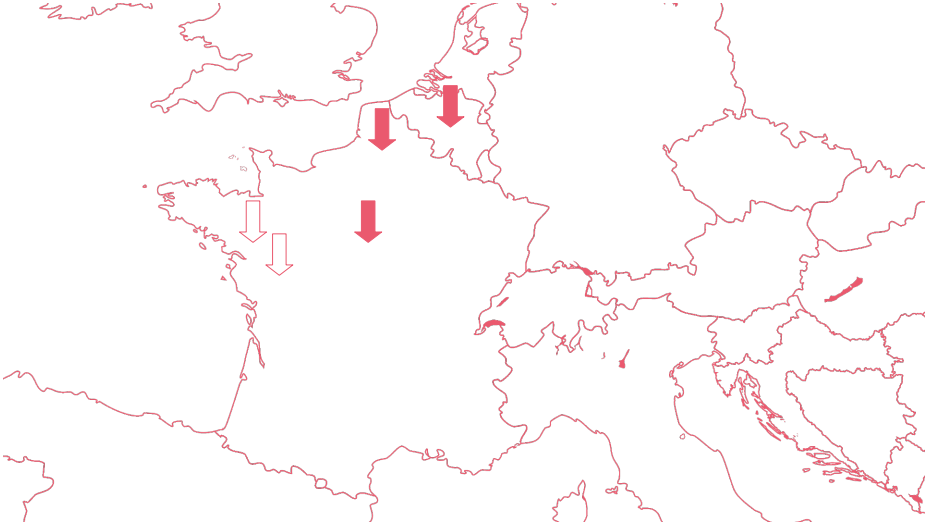
- **Geographical redundancy** (multi-site replication)

Building a resilient system with cheap stuff



Object storage: a crucial component

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Garage is a self-hosted drop-in replacement for the Amazon S3 object store

CRDTs / weak consistency instead of consensus

Internally, Garage uses only CRDTs (conflict-free replicated data types)

Why not Raft, Paxos, ...? Issues of consensus algorithms:

CRDTs / weak consistency instead of consensus

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- **Software complexity**

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- **Software complexity**
- **Performance issues:**
  - The leader is a **bottleneck** for all requests
  - **Sensitive to higher latency** between nodes
  - **Takes time to reconverge** when disrupted (e.g. node going down)

The data model of object storage

Object storage is basically a **key-value store**:

Key: file path + name	Value: file data + metadata

`index.html`	`Content-Type: text/html; charset=utf-8`
	`Content-Length: 24929`
	`<binary blob>`

`img/logo.svg`	`Content-Type: text/svg+xml`
	`Content-Length: 13429`
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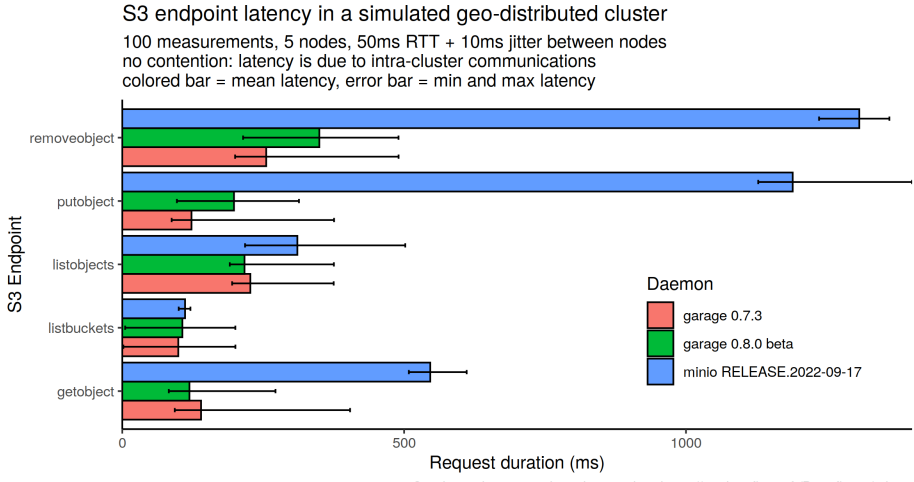
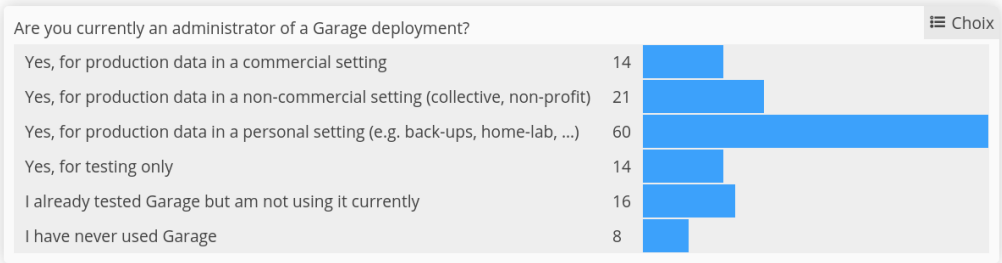
- Maps well to CRDT data types

Performance gains in practice

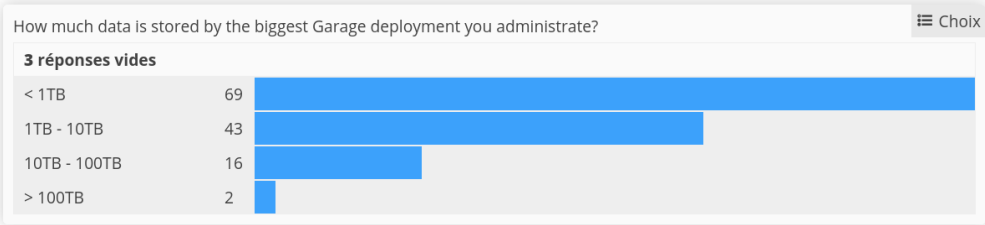


Production clusters

Deployment kinds



How big they are?



"Petabyte storage setup for a video site. Nginx as CDN in-front using garage-s3-website feature. Each storage node has 64TB storage with raid10, no replication within garage. 25gbit nic. haproxy to loadbalance across 5 nodes. mostly reads with very few writes."

"We currently manage 7 Garage nodes, 28TB total storage, 6M blocks for 3M objects and 4TB of object data. We have been running Garage in production for 2.5 years."

Operating Garage

```
$ garage status
==== HEALTHY NODES ====
ID                  Hostname  Address                                      Tags        Zone     Capacity  DataAvail
ec5753c546756825    df-pw5    [2a02:a03f:6510:5102:223:24ff:feb0:e8a7]:3991  [df-pw5]    bespin   500.0 GB  429.1 GB (89.0%)
76797283f6c7e162    carcajou  [2001:470:ca43::22]:3991                     [carcajou]  neptune  200.0 GB  166.3 GB (73.5%)
8073f25ffb7d6944    piranha   [2a01:cb05:911e:ec00:223:24ff:feb0:ea82]:3991  [piranha]   corrin   500.0 GB  457.3 GB (94.0%)
3aed398eec82972b    origan    [2a01:e0a:5e4:1d0:223:24ff:feaf:fdec]:3991     [origan]    jupiter  500.0 GB  457.1 GB (93.1%)
967786691f20bb79    caribou   [2001:470:ca43::23]:3991                      [caribou]   neptune  500.0 GB  453.1 GB (92.3%)
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3aed398eec82972b  origan    [2a01:e0a:5e4:1d0:223:24ff:feaf:fdec]:3991     [origan]    jupiter  500.0 GB  457.1 GB (93.1%)
967786691f20bb79  caribou   [2001:470:ca43::23]:3991                       [caribou]   neptune  500.0 GB  453.1 GB (92.3%)

==== FAILED NODES ====
ID                Hostname  Address                                      Tags        Zone    Capacity  Last seen
ec5753c546756825  df-pw5    [2a02:a03f:6510:5102:223:24ff:feb0:e8a7]:3991  [df-pw5]    bespin  500.0 GB  5 minutes ago
```
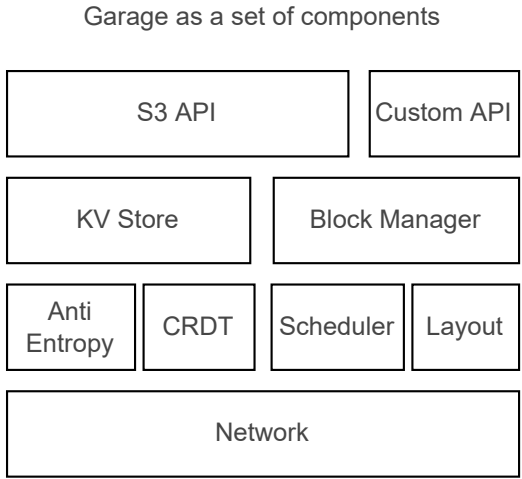

Garage's architecture



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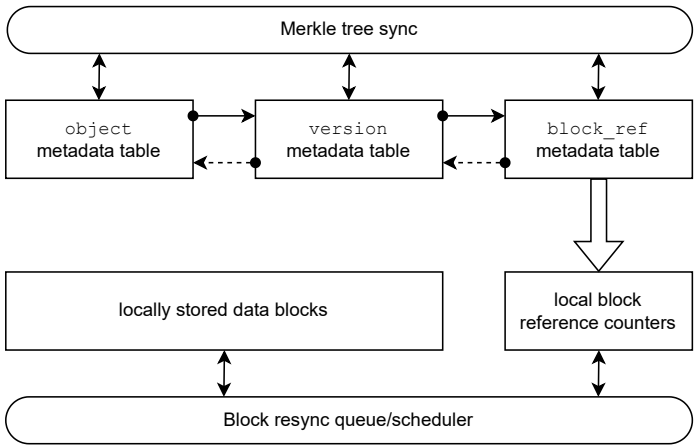


Digging deeper

```
$ garage stats

Garage version: 20240116133343 [features: k2v, sled, lmdb, sqlite, consul-discovery, kubernetes-discovery, metrics, telemetry-otlp, bundled-libs]
Rust compiler version: 1.68.0

Database engine: LMDB (using Heed crate)

Table stats:
  Table      Items   MklItems  MklTodo  GcTodo
  bucket_v2  19      20        0        0
  key        12      14        0        0
  object     67391   80964     0        0
  version    33909   42045     0        0
  block_ref  334735  370927    0        0

Block manager stats:
  number of RC entries (~= number of blocks): 42376
  resync queue length: 0
  blocks with resync errors: 0

If values are missing above (marked as NC), consider adding the --detailed flag (this will be slow).

Storage nodes:
  ID                Hostname  Zone     Capacity  Part.  DataAvail                 MetaAvail
  ec5753c546756825  df-pw5    bespin   500.0 GB  175    429.1 GB/482.1 GB (89.0%)  429.1 GB/482.1 GB (89.0%)
  76797283f6c7e162  carcajou  neptune  200.0 GB  70     166.3 GB/226.2 GB (73.5%)  166.3 GB/226.2 GB (73.5%)
  8073f25ffb7d6944  piranha   corrin   500.0 GB  173    457.3 GB/486.4 GB (94.0%)  457.3 GB/486.4 GB (94.0%)
  3aed398eec82972b  origan    jupiter  500.0 GB  175    457.1 GB/490.7 GB (93.1%)  457.1 GB/490.7 GB (93.1%)
  967786691f20bb79  caribou   neptune  500.0 GB  175    453.1 GB/490.8 GB (92.3%)  453.1 GB/490.8 GB (92.3%)

Estimated available storage space cluster-wide (might be lower in practice):
  data: 608.3 GB
  metadata: 608.3 GB
```

Digging deeper

```
$ garage worker list
TID  State  Name                          Tranq  Done  Queue  Errors  Consec  Last
1    Idle   Block resync worker #1        0      -     0      -       -
2    Idle   Block resync worker #2        0      -     0      -       -
3    Idle   Block resync worker #3        0      -     0      -       -
4    Idle   Block resync worker #4        0      -     0      -       -
5    Idle   Block resync worker #5        -      -     -      -       -
6    Idle   Block resync worker #6        -      -     -      -       -
7    Idle   Block resync worker #7        -      -     -      -       -
8    Idle   Block resync worker #8        -      -     -      -       -
9    Idle   Block scrub worker            4      -     -      -       -
10   Idle   bucket_v2 Merkle              -      -     0      -       -
11   Idle   bucket_v2 sync                -      -     0      1       0       17 hours ago
12   Idle   bucket_v2 GC                  -      -     0      -       -
13   Idle   bucket_v2 queue               -      -     0      -       -
14   Idle   bucket_alias Merkle           -      -     0      -       -
15   Idle   bucket_alias sync            -      -     0      1       0       17 hours ago
16   Idle   bucket_alias GC              -      -     0      -       -
17   Idle   bucket_alias queue           -      -     0      -       -
18   Idle   key Merkle                   -      -     0      -       -
19   Idle   key sync                     -      -     0      1       0       17 hours ago
20   Idle   key GC                       -      -     0      -       -
21   Idle   key queue                    -      -     0      -       -
22   Idle   object Merkle                -      -     0      -       -
23   Idle   object sync                  -      -     0      4       0       17 hours ago
24   Idle   object GC                    -      -     0      -       -
25   Idle   object queue                 -      -     0      -       -
26   Idle   bucket_object_counter Merkle  -      -     0      -       -
27   Idle   bucket_object_counter sync    -      -     0      4       0       17 hours ago
28   Idle   bucket_object_counter GC      -      -     0      -       -
29   Idle   bucket_object_counter queue   -      -     0      -       -
30   Idle   multipart_upload Merkle       -      -     0      -       -
31   Idle   multipart_upload sync         -      -     0      5       0       17 hours ago
32   Idle   multipart_upload GC           -      -     0      -       -
33   Idle   multipart_upload queue        -      -     0      -       -
34   Idle   bucket_mpu_counter Merkle     -      -     0      -       -
35   Idle   bucket_mpu_counter sync       -      -     0      -       -
36   Idle   bucket_mpu_counter GC         -      -     0      -       -
37   Idle   bucket_mpu_counter queue      -      -     0      -       -
38   Idle   version Merkle                -      -     0      -       -
39   Idle   version sync                  -      -     0      50      0       17 hours ago
40   Idle   version GC                    -      -     0      -       -
41   Idle   version queue                 -      -     0      -       -
42   Idle   block_ref Merkle              -      -     0      -       -
43   Idle   block_ref sync                -      -     0      45      0       17 hours ago
44   Idle   block_ref GC                  -      -     0      -       -
45   Idle   block_ref queue               -      -     0      -       -
46   Idle   object_lifecycle_worker       -      -     -      -       -
```

Digging deeper

```
$ garage worker get
8073f25ffb7d6944  lifecycle-last-completed    2024-01-23
8073f25ffb7d6944  resync-tranquility          1
8073f25ffb7d6944  resync-worker-count         4
8073f25ffb7d6944  scrub-corruptions_detected  0
8073f25ffb7d6944  scrub-last-completed        2023-12-27T13:49:33.234Z
8073f25ffb7d6944  scrub-next-run              2024-01-31T03:23:02.234Z
8073f25ffb7d6944  scrub-tranquility           4

$ garage worker get -a resync-tranquility
3aed398eec82972b  resync-tranquility  1
76797283f6c7e162  resync-tranquility  1
8073f25ffb7d6944  resync-tranquility  1
967786691f20bb79  resync-tranquility  1
ec5753c546756825  resync-tranquility  1
```

Potential limitations and bottlenecks

- Global:
  - Max. ∼100 nodes per cluster (excluding gateways)
- Metadata:
  - One big bucket = bottleneck, object list on 3 nodes only
- Block manager:
  - Lots of small files on disk
  - Processing the resync queue can be slow

Deployment advice for very large clusters

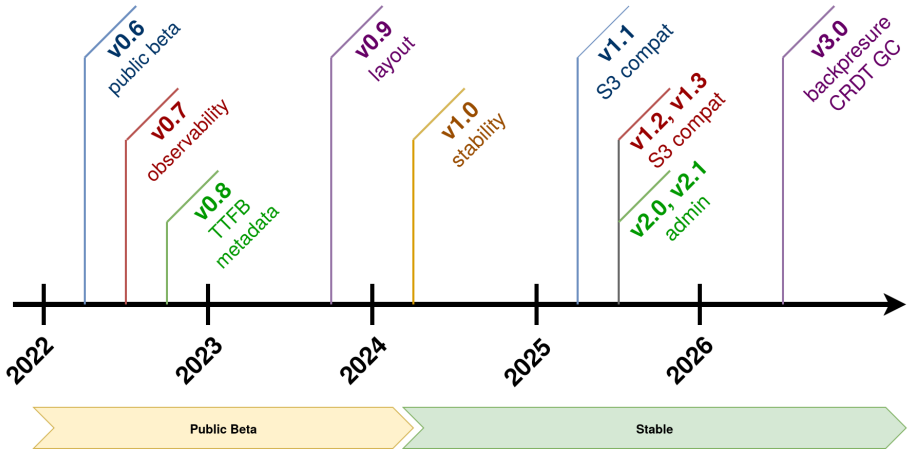
- Metadata storage:
  - ZFS mirror (x2) on fast NVMe
  - Use LMDB storage engine
- Data block storage:
  - Use Garage's native multi-HDD support
  - XFS on individual drives
  - Increase block size (1MB $\rightarrow$ 10MB, requires more RAM and good networking)
  - Tune `resync-tranquility` and `resync-worker-count` dynamically
- Other :
  - Split data over several buckets
  - Use less than 100 storage nodes
  - Use gateway nodes

Focus on Deuxfleurs

500+ hosted websites directly on Garage

partnership with web agencies, institutional website hosted.

Recent developments


v0.6
public beta
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CRDT GC
2022
2023
2024
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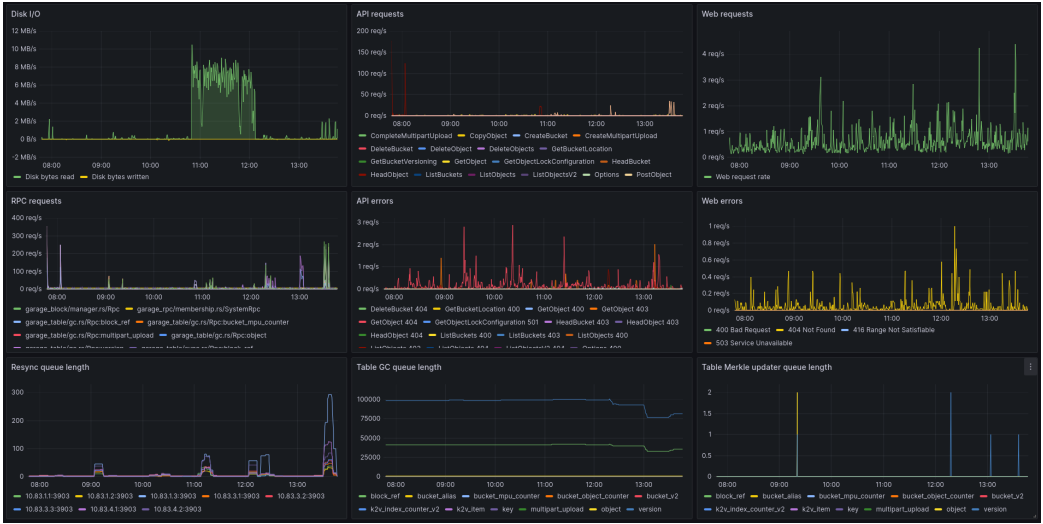
Stable

April 2022 - Garage v0.7.0

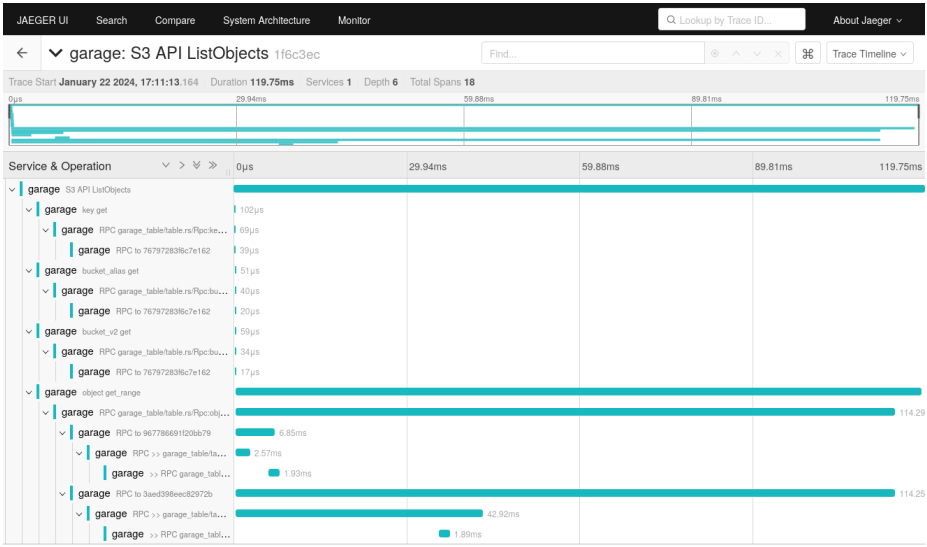
Focus on observability and ecosystem integration

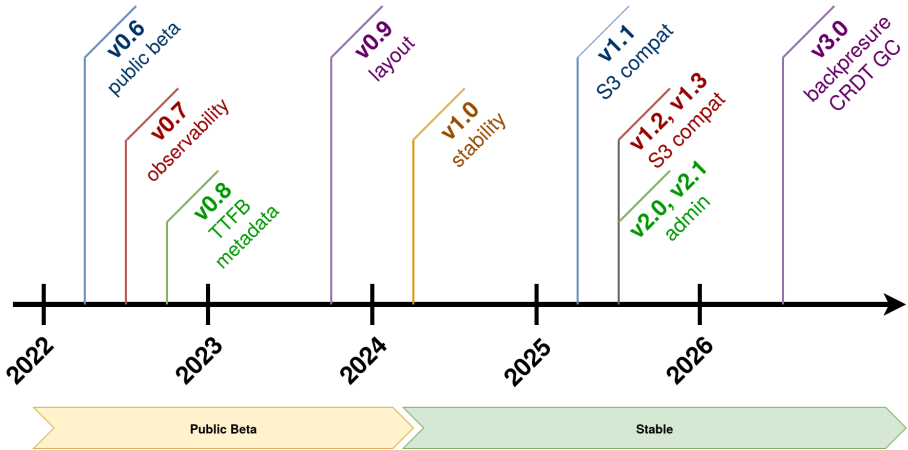
- **Monitoring:** metrics and traces, using OpenTelemetry
- Replication modes with 1 or 2 copies / weaker consistency
- Kubernetes integration for node discovery
- Admin API (v0.7.2)

Metrics (Prometheus + Grafana)



Traces (Jaeger)

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November 2022 - Garage v0.8.0

Focus on performance

- **Alternative metadata DB engines** (LMDB, Sqlite)
- **Performance improvements:** block streaming, various optimizations...
- Bucket quotas (max size, max #objects)
- Quality of life improvements, observability, etc.

About metadata DB engines

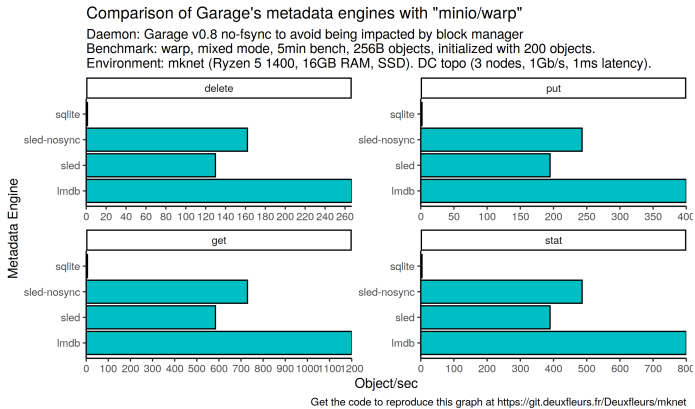
Issues with Sled:

- Huge files on disk
- Unpredictable performance, especially on HDD
- API limitations
- Not actively maintained

LMDB: very stable, good performance, file size is reasonable
Sqlite also available as a second choice

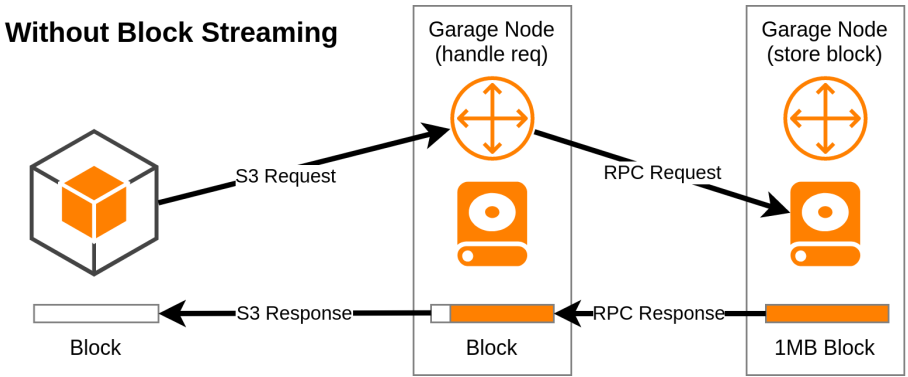
Sled will be removed in Garage v1.0

DB engine performance comparison

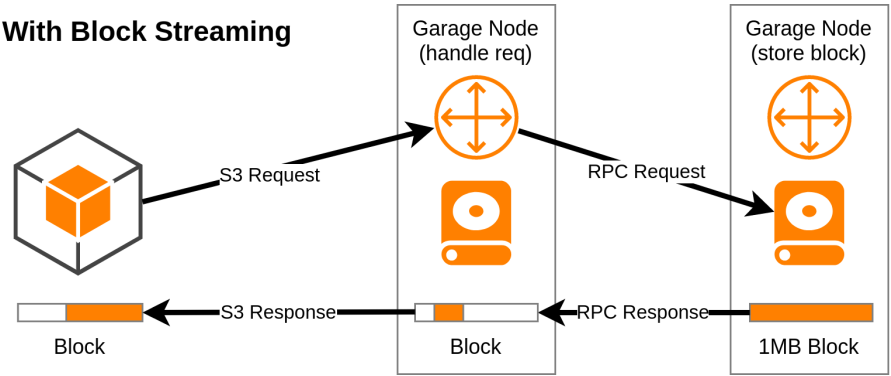


NB: Sqlite was slow due to synchronous mode, now configurable

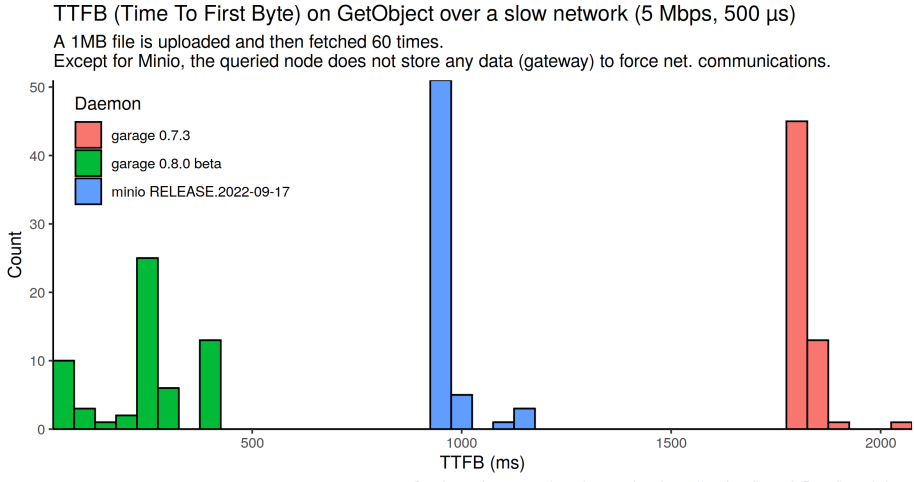
Block streaming



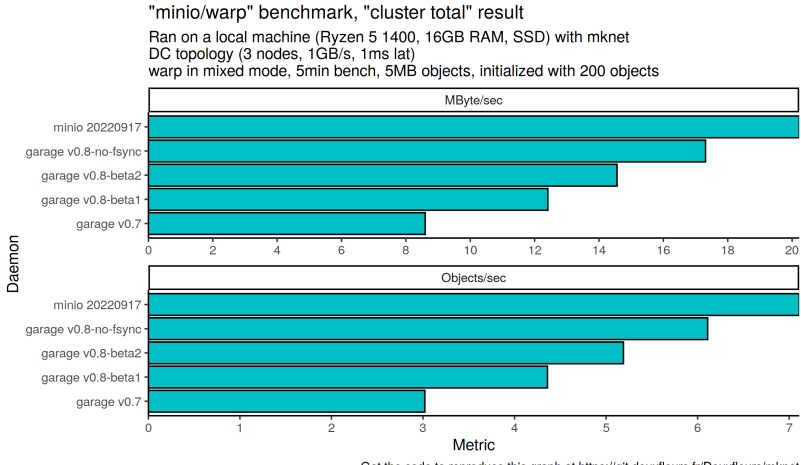
Block streaming

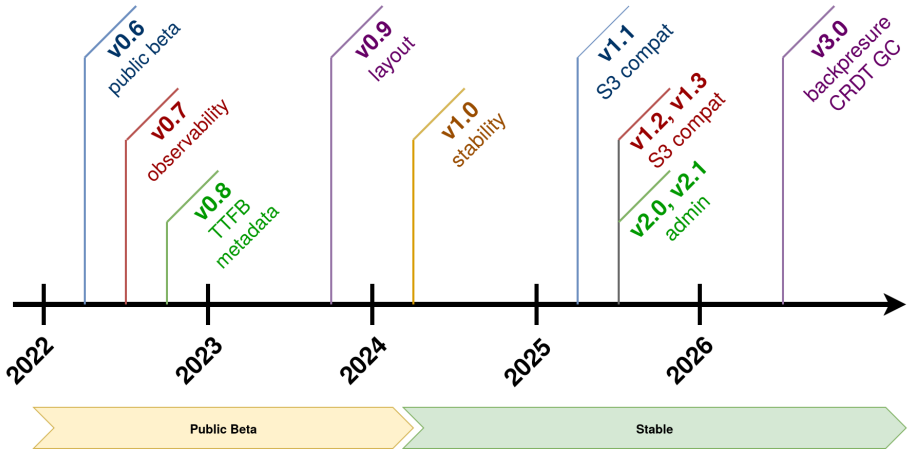


TTFB benchmark



Throughput benchmark

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2022
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2024
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2026
Public Beta
Stable

October 2023 - Garage v0.9.0

Focus on streamlining & usability

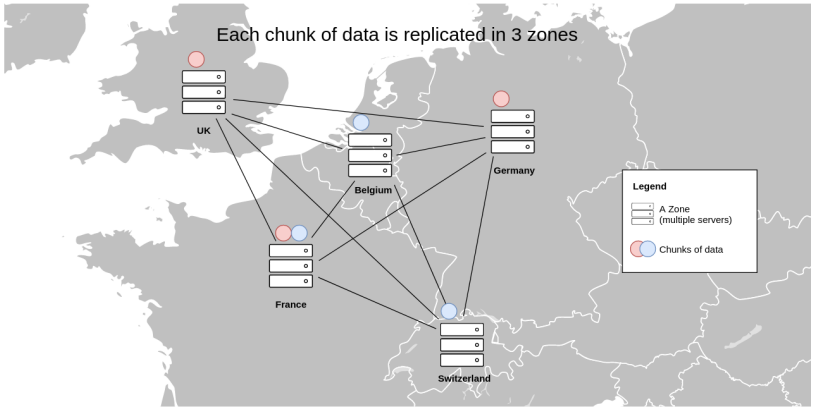
- Support multiple HDDs per node
- S3 compatibility:
  - support basic lifecycle configurations
  - allow for multipart upload part retries
- LMDB by default, deprecation of Sled
- New layout computation algorithm

Layout computation

```
[root@celeri:/home/lx]# docker exec -ti e338 /garage status
==== HEALTHY NODES ====
ID                Hostname   Address                                      Tags                                    Zone      Capacity
5fcb3b6e39db3dcb  concombre  [2001:470:ca43::31]:3901                     [concombre,neptune,france,alex]         neptune   500.0 GB
942dd71ea95f4904  df-ymf     [2a02:a03f:6510:5102:6e4b:90ff:fe3a:6174]:3901  [df-ymf,bespin,belgium,max]          bespin    500.0 GB
fdfaf7832d8359e0  df-ymk     [2a02:a03f:6510:5102:6e4b:90ff:fe3b:e939]:3901  [df-ymk,bespin,belgium,max]          bespin    500.0 GB
0a03ab7c082ad929  ananas     [2a01:e0a:e4:2dd0::42]:3901                  [ananas,scorpio,france,adrien]          scorpio   2.0 TB
a717e5b618267806  courgette  [2001:470:ca43::32]:3901                     [courgette,neptune,france,alex]         neptune   500.0 GB
2032d0a37f249c4a  abricot    [2a01:e0a:e4:2dd0::41]:3901                  [abricot,scopio,france,adrien]          scorpio   2.0 TB
8cf284e7df17d0fd  celeri     [2001:470:ca43::33]:3901                     [celeri,neptune,france,alex]            neptune   2.0 TB
17ee03c6b81d9235  df-ykl     [2a02:a03f:6510:5102:6e4b:90ff:fe3b:e86c]:3901  [df-ykl,bespin,belgium,max]          bespin    500.0 GB
```

Garage stores replicas on different zones when possible

Layout computation



Garage stores replicas on different zones when possible

What a "layout" is

A layout is a precomputed index table:

Partition	**Node 1**	**Node 2**	**Node 3**
Partition 0	df-ymk (bespin)	Abricot (scorpio)	Courgette (neptune)
Partition 1	Ananas (scorpio)	Courgette (neptune)	df-ykl (bespin)
Partition 2	df-ymf (bespin)	Celeri (neptune)	Abricot (scorpio)
⋮	⋮	⋮	⋮
Partition 255	Concombre (neptune)	df-ykl (bespin)	Abricot (scorpio)

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⋮	⋮	⋮	⋮
Partition 255	Concombre (neptune)	df-ykl (bespin)	Abricot (scorpio)

The index table is built centrally using an optimal algorithm,
then propagated to all nodes

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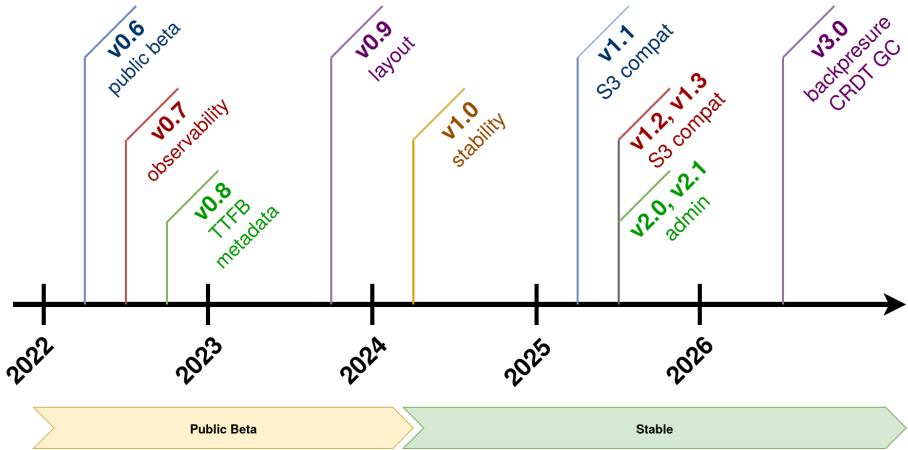
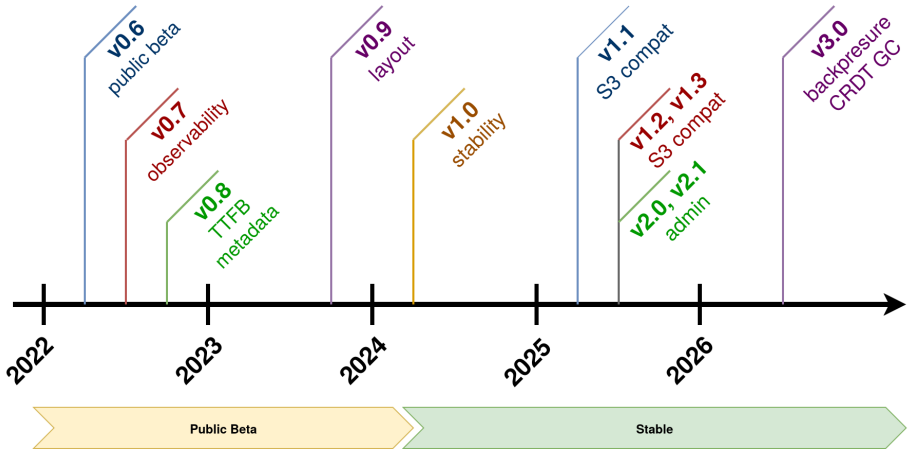
Oulamara, M., & Auvolat, A. (2023). *An algorithm for geo-distributed and redundant storage in Garage*. arXiv preprint arXiv:2302.13798.


v0.6
public beta
v0.7
observability
v0.8
TTFB
metadata
v0.9
layout
v1.0
stability
v1.1
S3 compat
v1.2, v1.3
S3 compat
v2.0, v2.1
admin
v3.0
backpresure
CRDT GC
2022
2023
2024
2025
2026
Public Beta
Stable

April 2024 - Garage v1.0.0

Focus on consistency, security & stability

- Fix consistency issues when reshuffling data (Jepsen testing)
- **Security audit** by Radically Open Security
- Misc. S3 features (SSE-C, checksums, ...) and compatibility fixes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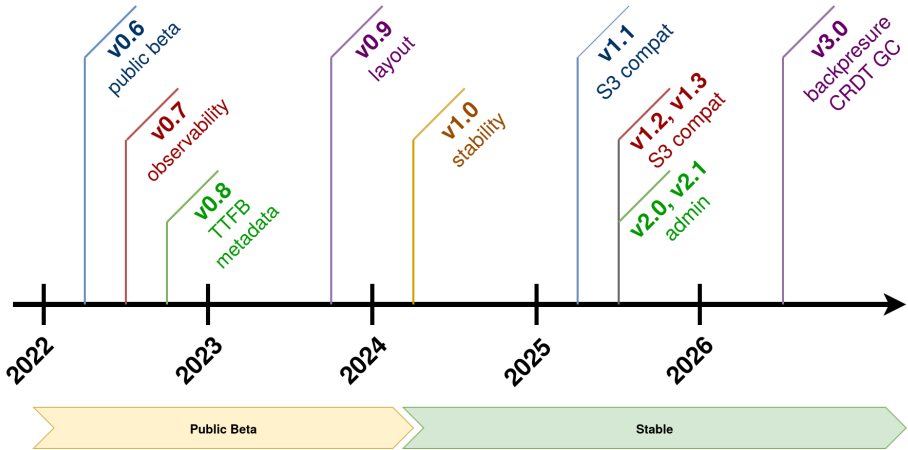
Garage v2.0 - Administration

Focus on administrative features that require a data model migration:

- Full support for website redirections
- Access key expiration
- Multiple admin token
- Full rework of the admin API
- New metadata engine: fjall (LSM-Tree, similar to RocksDB)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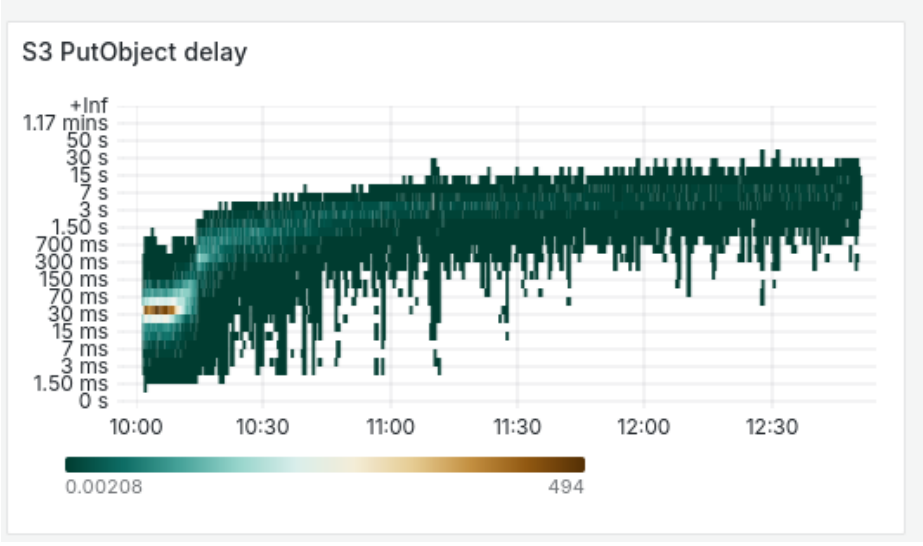
Garage v3.0 - Predictible performances

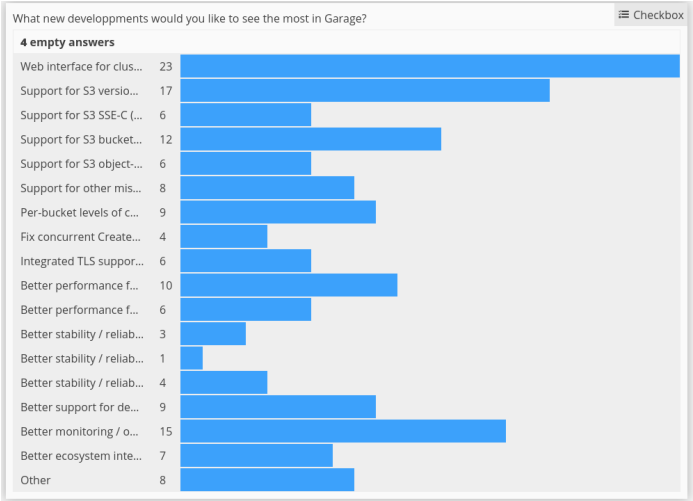
Currently trying to fund development for Garage v3.0:

- Fix backpressure issues during batch inserts of small files
- CRDT tombstone garbage collector

Small file batch insert = performance collapse



We run community surveys



Where to find us

Garage

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#garage:deuxfleurs.fr on Matrix