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Ceph S3 - Dynamic Placement and Optimized Retention

Storage Classes, LUA and LifeCycle Policies

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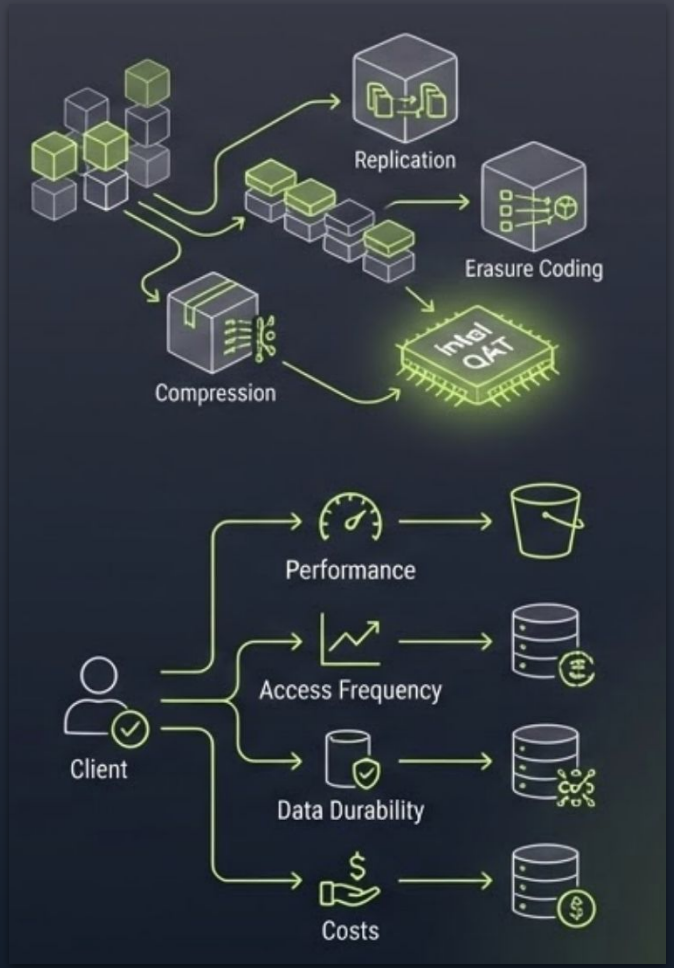
Storage Classes

- Multiple S3 Storage Classes per cluster, linked to varied data placement schemes (replication, erasure coding, compression via Intel QAT).
- This enables S3 clients to place objects based on criteria like performance, access frequency, durability, and cost.
- S3 clients select the Storage Class upon writing an object, but they often choose incorrectly or fail to specify one.



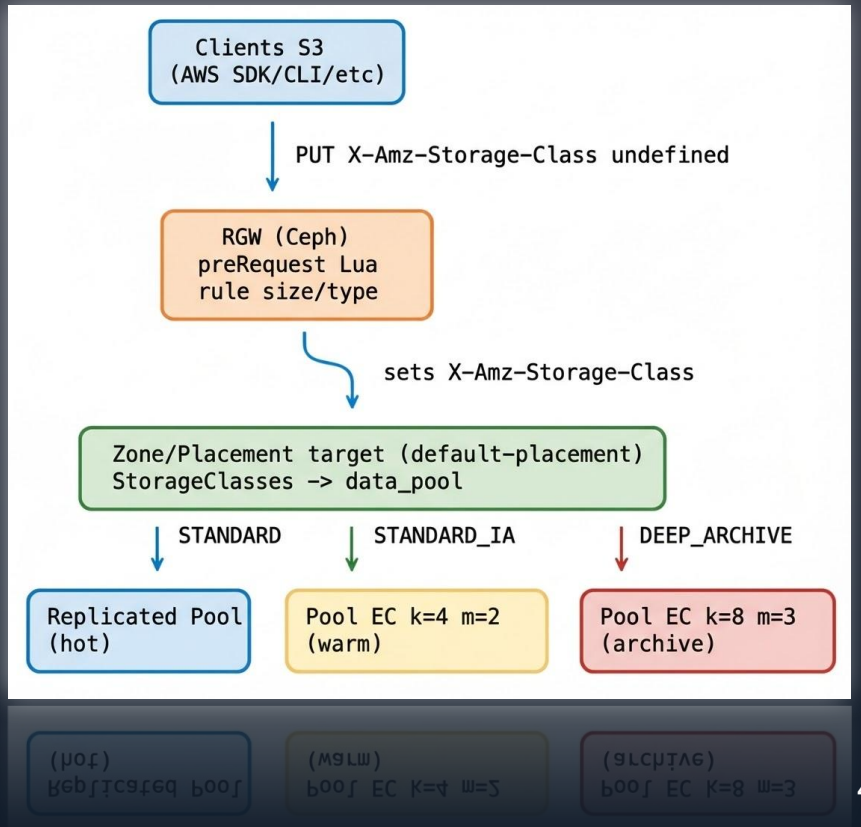
Dynamic Placement

...what if we chose for them?

- When the client does not specify it or incongruously forces it.

- And automatically assigns a storage class to an object based on:
  - the object type (.mp4, .data, .pdf)
  - the object size (< 64kB, > 1MB)
  - the tenant (labo1, labo2)
  - the bucket (large or small objects)
  - the upload method (MPU or not)

➡ Storage efficiency and access performance would be ensured right from the moment data is written.



Dynamic Placement - LUA Scripting

- S3 Gateways can execute LUA scripts on the fly based on the context: prerequest, postrequest, background, getdata, putdata
- These LUA scripts can read and modify objects metadata on-the-fly

Therefore, we can dynamically set or modify an object's Storage Class upon writing, according to certain criteria.

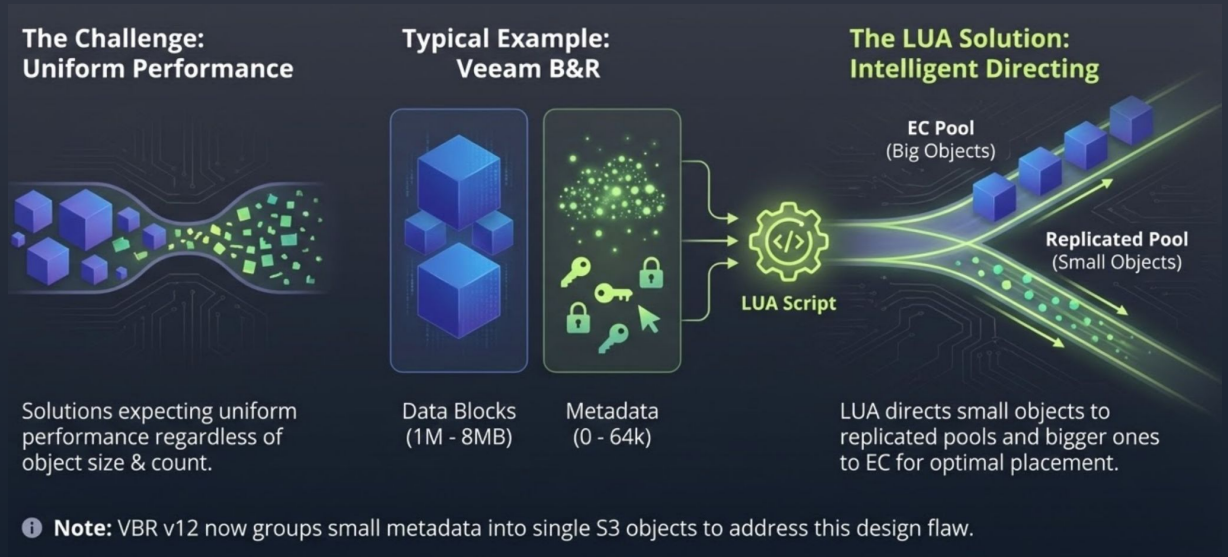
```
-- Rule line: STORAGECLASS;PATTERN;OP;BYTES;BUCKET;TENANT;OVERRIDE
-- OP in {<, <=, =, >=, >, *}
local function parse_rule(line, lineno)
  local parts = {}
  for field in string.gmatch(line, "([^;]+)") do parts[#parts+1] =
trim(field) end
  if #parts < 1 then return nil end
  local bytes_num, bytes_pretty = parse_size(parts[4] or "0")
  local r = {
    storage_class = parts[1] or "",
    pattern       = (parts[2] ~= "" and parts[2]) or "*",
    op            = (parts[3] ~= "" and parts[3]) or "*",
    bytes         = bytes_num,
    bytes_str     = bytes_pretty,
    bucket        = (parts[5] ~= "" and parts[5]) or "*",
    tenant        = (parts[6] ~= "" and parts[6]) or "*",
    override      = to_bool(parts[7], false),
    lineno        = lineno
  }
  if r.storage_class == "" then return nil end
  return r
end

local function size_matches(op, threshold, content_len)
  if op == "*" then return true end
  if not content_len then return false end
  if op == "<"  then return content_len <  threshold end
  if op == "<=" then return content_len <= threshold end
  if op == ">"  then return content_len >  threshold end
  if op == ">=" then return content_len >= threshold end
  if op == "="  then return content_len == threshold end
  return false
end
```

docs.ceph.com/en/latest/radosgw/lua-scripting

Where LUA scripting can help?

- Solutions expecting uniform performance regardless of the size and the number of objects they write to S3 buckets. Typical example is Veeam B&R:
  - stores data objects (1M to 8MB)
  - stores metadata objects: index, locks, pointers (from 0 octet to 64K)



LUA directs small objects to replicated pools and bigger ones to EC pools

Where LUA scripting can help?

- LUA scripts could provide an additional protection layer beyond bucket ACLs to block requests based on specific criteria (user, tenant, etc.).

  For example, this could enforce read-only or write-only bucket access on publicly exposed S3 Gateways.

  Emin Mert Sunacoglu and Marcel Lauhoff's work to block requests:
  - Branch: https://github.com/mertsunacoglu/ceph/tree/wip-lua-abort
  - Pull Request: #66065

- Other use cases:
  - Trace requests for a specific bucket
  - Apply default metadata when not specified by the client
  - Log operations only when errors occur
  - Capture operation traces for analytics

Check LUA code samples in upstream doc

LUA performance and reliability

- What about LUA's CPU and RAM consumption?
  - Initial tests at CLYSO showed that LUA does not add much latency (10s of µs) https://github.com/mertsunacoglu/ceph/blob/wip-lua-benchmarks/src/test/bench_rgw_lua.cc
  - Squid: execution of a script in a context can use up to 128KB of RAM (rgw_lua_max_memory_per_state)

- What if the script fails on timeout (1s) or syntax error?
  - Script failures are non-fatal for S3 client requests, the client receives a normal response as if the script wasn't applied.

- Performance improvement is being worked on upstream: https://github.com/ceph/ceph/pull/66832

  "Improves performance by caching the Lua bytecode, which also reduces the number of network calls to read the RADOS object containing the LUA script."

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Lifecycle Policies - Optimized Retention

- Transition objects between Storage Classes based on criteria (Days, ObjectSizeGreaterThan, ObjectSizeLessThan since Squid PR #63304), to optimize storage for rarely used data
- Delete noncurrent versions of objects, eventually retaining some versions
- Free up some space by cleaning up incomplete uploads (MPU)

Lifecycle rules can also use tags or prefixes to apply only on specific objects

docs.ceph.com/en/latest/radosgw/lua-scripting

Lifecycle Policies - Optimized Retention

The rule to the right:

- ➢ cleans up MPU parts after 10 days
- ➢ moves objects to DEEP_ARCHIVE mapped to the EC 8+3 pool after 30 days
- ➢ deletes objects after 365 days (be careful!)

  Prefer removing old versions of an object if using versioning

```
{
    "Rules": [
        {
            "Filter": {
                "Prefix": ""
            },
            "Status": "Enabled",
            "Transitions": [
                {
                    "Days": 30,
                    "StorageClass": "DEEP_ARCHIVE"
                }
            ],
            "AbortIncompleteMultipartUpload": {
                "DaysAfterInitiation": 10
            },
            "Expiration": {
                "Days": 365
            },
            "ID": "double transition and expiration"
        }
    ]
}
```

docs.ceph.com/en/latest/radosgw/lua-scripting

CONFIG

Dynamic Placement and Optimized Retention

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RGW (S3) Service Configuration

Creating Ceph pools

```
ceph osd erasure-code-profile set ec42 k=4 m=2
ceph osd erasure-code-profile set ec83 k=8 m=3

ceph osd pool create s3.hot.data 256 256 replicated
ceph osd pool create s3.warm.data 128 128 erasure ec42
ceph osd pool create s3.archive.data 64 64 erasure ec83

ceph osd pool application enable s3.hot.data rgw
ceph osd pool application enable s3.warm.data rgw
ceph osd pool application enable s3.archive.data rgw
```

Adding Storage Classes and Default Storage Class

```
radosgw-admin zonegroup placement add --rgw-zonegroup france
--placement-id default-placement --storage-class STANDARD_IA

radosgw-admin zonegroup placement add --rgw-zonegroup france
--placement-id default-placement --storage-class DEEP_ARCHIVE

radosgw-admin zonegroup placement default --rgw-zonegroup france
--placement-id default-placement --storage-class STANDARD_IA

radosgw-admin zonegroup get | grep default_placement
    "default_placement": "default-placement/STANDARD_IA"

radosgw-admin period update --commit
```

Verification

```
radosgw-admin zone placement list
[
    {
        "key": "default-placement",
        "val": {
            "index_pool": "s3.buckets.index",
            "storage_classes": {
                "DEEP_ARCHIVE": {
                    "data_pool": "s3.archive.data",
                    "compression_type": "zstd"
                },
                "STANDARD": {
                    "data_pool": "s3.hot.data"
                },
                "STANDARD_IA": {
                    "data_pool": "s3.warm.data",
                    "compression_type": "lz4"
                }
            },
            "data_extra_pool": "s3.buckets.non-ec",
            "index_type": 0,
            "inline_data": true
        }
    }
]
```

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RGW (S3) Service Configuration

Configuring the data, index and non-ec pools in the zone

```
# STANDARD est déjà présente; s'assurer qu'elle pointe vers le pool répliqué "hot"
radosgw-admin zone placement add --rgw-zone nancy \
  --placement-id default-placement \
  --storage-class STANDARD \
  --data-pool s3.hot.data \
  --index-pool s3.buckets.index \
  --data-extra-pool s3.buckets.non-ec

# STANDARD_IA -> EC 4+2
radosgw-admin zone placement add --rgw-zone nancy \
  --placement-id default-placement \
  --storage-class STANDARD_IA \
  --data-pool s3.warm.data \
  --compression lz4

# DEEP_ARCHIVE -> EC 8+3
radosgw-admin zone placement add --rgw-zone nancy \
  --placement-id default-placement \
  --storage-class DEEP_ARCHIVE \
  --data-pool s3.archive.data \
  --compression zstd
```

Applying the configuration

```
radosgw-admin period update --commit
```

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RGW (S3) Service Configuration

Modifying RGW service configuration

```
$ ceph orch ls --export --service_type=rgw --format yaml > rgw.yaml

$ vim rgw.yaml
service_type: rgw
service_id: monde-france-nancy
service_name: rgw.monde-france-nancy
placement:
  count: 1
  label: rgws_nancy
spec:
  rgw_frontend_port: 8080
  rgw_realm: monde
  rgw_zone: nancy
  rgw_zonegroup: france
custom_configs:
  - mount_path: /etc/ceph/rgw_storageclass_rules.conf
    content: |
      # Paramètres globaux MPU
      mpu_default_class=DEEP_ARCHIVE
      mpu_force=true

      # Paramètres globaux défaut non-MPU
      default_class=STANDARD_IA
      default_force=false

      # Règles PUT objet (non-MPU)
      # STORAGECLASS;PATTERN;OP;BYTES;BUCKET;TENANT;OVERRIDE
      #STANDARD_IA;%.pdf;*;0;*;*;true
      #INTELLIGENT_TIERING;*;<;32768;bucket-logs;*;true
      #ONEZONE_IA;%.eml;*;0;*;tenant-a;false
      #GLACIER;%.iso;<;1073741824;media-bucket;*;true

      STANDARD;*;<=;2MiB;*;*;true
      DEEP_ARCHIVE;%.data;*;0B;*;*;true
```

Applying configuration and redeploy RGWs

```
$ ceph orch apply -i rgw.yaml
Scheduled rgw.monde-france-metz update...
Scheduled rgw.monde-france-nancy update…

$ ceph orch redeploy rgw.monde-france-nancy
Scheduled to redeploy rgw.monde-france-nancy.r03h01.veyyjq on host 'r03h01'
```

Verification

```
$ container_id=$(ssh -n r03h01 podman ps | grep rgw | awk '{print $1}')

$ ssh -n r03h01 podman exec -it $container_id cat
/etc/ceph/rgw_storageclass_rules.conf
# MPU PUTs settings
mpu_default_class=DEEP_ARCHIVE
mpu_force=true

# non-MPU PUTs settings
default_class=STANDARD_IA
default_force=false

# non-MPU PUTs rules
# STORAGECLASS;PATTERN;OP;BYTES;BUCKET;TENANT;OVERRIDE
#STANDARD_IA;%.pdf;*;0;*;*;true
#INTELLIGENT_TIERING;*;<;32768;bucket-logs;*;true
#ONEZONE_IA;%.eml;*;0;*;tenant-a;false
#GLACIER;%.iso;<;1073741824;media-bucket;*;true

STANDARD;*;<=;2MiB;*;*;true
DEEP_ARCHIVE;%.data;*;0B;*;*;true
```

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RGW (S3) Service Configuration

Downloading LUA script

github.com/frednass/s3-dynamic-placement-and-archiving

```
$ curl -k -s https://raw.githubusercontent.com/frednass/s3-dynamic-placement-and-archiving/refs/heads/main/rgw_storageclass_rules.lua -o rgw_storageclass_rules.lua
$ radosgw-admin script put --infile=./rgw_storageclass_rules.lua --context=preRequest
```

Adding LUA script to Rados Gateway (RGW)


```
$ curl -k -s https://raw.githubusercontent.com/frednass/s3-dynamic-placement-and-archiving/refs/heads/main/rgw_storageclass_rules.lua -o rgw_storageclass_rules.lua
$ radosgw-admin script put --infile=./rgw_storageclass_rules.lua --context=preRequest
```

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Applying S3 Lifecycle Policy

Creating the bucket

```
$ rclone mkdir s3:/newbucket2
```

Adding Lifecycle Policy to the test bucket

```
$ aws s3api put-bucket-lifecycle-configuration \
--endpoint http://10.38.1.59:8080 \
--bucket newbucket2 \
--lifecycle-configuration file://lifecycle.json
```

Creating the Lifecycle Policy

```
$ vim lifecycle.json
{
    "Rules": [
        {
            "Filter": {
                "Prefix": ""
            },
            "Status": "Enabled",
            "Transitions": [
                {
                    "Days": 30,
                    "StorageClass": "DEEP_ARCHIVE"
                }
            ],
            "AbortIncompleteMultipartUpload": {
                "DaysAfterInitiation": 10
            },
            "Expiration": {
                "Days": 365
            },
            "ID": "double transition and expiration"
        }
    ]
}
```

Check that it applies

```
$ aws s3api --endpoint http://10.38.1.59:8080 get-bucket-lifecycle-configuration
--bucket newbucket2
{
    "Rules": [
        {
            "Expiration": {
                "Days": 365
            },
            "ID": "double transition and expiration",
            "Prefix": "",
            "Status": "Enabled",
            "Transitions": [
                {
                    "Days": 30,
                    "StorageClass": "DEEP_ARCHIVE"
                }
            ],
            "AbortIncompleteMultipartUpload": {
                "DaysAfterInitiation": 10
            }
        }
    ]
}
```

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Applying S3 Lifecycle Policy

Check Lifecycle status

```
$ radosgw-admin lc list
[
    {
        "bucket":
":newbucket2:f50809af-d67e-426c-bccd-78f8ff6af983.1276537.1",
        "shard": "lc.6",
        "started": "Thu, 01 Jan 1970 00:00:00 GMT",
        "status": "UNINITIAL"
    }
]
```

Manually trigger its execution

```
$ radosgw-admin lc process

$ radosgw-admin lc list
[
    {
        "bucket":
":newbucket2:f50809af-d67e-426c-bccd-78f8ff6af983.1276537.1",
        "shard": "lc.6",
        "started": "Sun, 28 Sep 2025 09:10:43 GMT",
        "status": "COMPLETE"
    }
]
```

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Dynamic Placement Verification

Increasing debug level

```
$ ceph config set global debug_rgw 20
```

Monitoring pools activity

```
Every 2.0s: rados df | grep -i -E 's3.*data|objects' ; echo ---- ; ceph df | grep -i -E 'objects|s3.*data'                    r01h01: Mon Sep 29 09:02:20 2025

POOL_NAME                    USED  OBJECTS  CLONES  COPIES  MISSING_ON_PRIMARY  UNFOUND  DEGRADED     RD_OPS       RD     WR_OPS       WR  USED COMPR  UNDER COMPR
s3.archive.data               0 B        0       0       0                   0        0         0       5435      0 B      17030   12 GiB         0 B          0 B
s3.hot.data                   0 B        0       0       0                   0        0         0     136913  1.5 GiB     288241  4.0 GiB         0 B          0 B
s3.warm.data                  0 B        0       0       0                   0        0         0      36005  8.3 GiB      85110   16 GiB         0 B          0 B
----
POOL                    ID  PGS   STORED  OBJECTS     USED  %USED  MAX AVAIL
s3.hot.data             24   32      0 B        0      0 B      0     37 GiB
s3.warm.data            25   32      0 B        0      0 B      0     74 GiB
s3.archive.data         26   32      0 B        0      0 B      0     80 GiB
```

Creating objects of different sizes from 16KiB to 4.7 MiB

```
for i in {1..300} ; do dd if=/dev/urandom of=file_${i}.dd bs=16k count=${i} ; done
```

Push objects to S3 storage

```
rclone sync . s3:/newbucket2 --s3-upload-cutoff 200M --s3-upload-concurrency 8
```

Check S3 Storage Classes associated with objects

```
radosgw-admin bucket list --bucket newbucket2
```

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Dynamic Placement Verification

Rados Gateway (RGW) Logs

- Object size > 2 MiB (4.7 MiB) is assigned the default SC STANDARD_IA and the EC 4+2 pool

```
2025-09-29T06:45:21.783+0000 7fbc51c28640 20 Lua INFO: Rule #1 (line 16) NO MATCH: obj='file_288.dd' size=4718592 bucket='newbucket2'
tenant='' reason=size op mismatch threshold=2mib
2025-09-29T06:45:21.783+0000 7fbc51c28640 20 Lua INFO: Rule #2 (line 17) NO MATCH: obj='file_288.dd' size=4718592 bucket='newbucket2'
tenant='' reason=name pattern mismatch threshold=0b
2025-09-29T06:45:21.783+0000 7fbc51c28640 20 Lua INFO: No rule applied: apply default StorageClass='STANDARD_IA' (default_force=false)
```

- Object size < 2 MiB (475 KiB) is assigned the SC STANDARD and the x3 replication pool

```
2025-09-29T06:45:21.806+0000 7fbb9babc640 20 Lua INFO: Rule #1 (line 16) MATCH -> apply StorageClass='STANDARD' (override=true)
obj='file_29.dd' size=475136 bucket='newbucket2' tenant='' threshold=2mib
2025-09-29T06:45:21.806+0000 7fbb9babc640 20 Lua INFO: Rule #2 (line 17) NO MATCH: obj='file_29.dd' size=475136 bucket='newbucket2'
tenant='' reason=name pattern mismatch threshold=0b
2025-09-29T06:45:21.806+0000 7fbb9babc640 20 Lua INFO: Applied StorageClass='STANDARD' to object 'file_29.dd'
```

- Object sent as multipart upload (MPU) placed directly in the archives

```
2025-09-29T07:46:38.837+0000 7fbbac2dd640 20 Lua INFO: MPU initiate: apply default StorageClass='DEEP_ARCHIVE' (force=true)
```

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Optimized Retention Verification

Monitoring how the different pools are filling up

```
Every 2.0s: rados df | grep -i -E 's3.*data|objects' ; echo ---- ; ceph df | grep -i -E 'objects|s3.*data'                    r01h01: Mon Sep 29 09:05:01 2025

POOL_NAME                  USED  OBJECTS  CLONES  COPIES  MISSING_ON_PRIMARY  UNFOUND  DEGRADED     RD_OPS       RD    WR_OPS       WR  USED COMPR  UNDER COMPR
s3.archive.data             0 B        0       0       0                   0        0         0       5781     0 B     17722   13 GiB         0 B          0 B
s3.hot.data               387 MiB      128       0      84                   0        0         0     137169  1.7 GiB    288625  4.2 GiB         0 B          0 B
s3.warm.data              870 MiB      346       0      76                   0        0         0      40217  8.9 GiB     98364   17 GiB         0 B          0 B
----
POOL                       ID  PGS   STORED  OBJECTS     USED  %USED  MAX AVAIL
s3.hot.data                24   32  129 MiB      128  387 MiB   0.35     36 GiB
s3.warm.data               25   32  580 MiB      346  870 MiB   0.77     73 GiB
s3.archive.data            26   32      0 B        0      0 B      0     79 GiB
```

1257 MiB

Reducing time between each execution

```
$ ceph config set global rgw_lc_debug_interval 1
```

Executing the Lifecycle Policy

```
$ radosgw-admin lc process
```

Checking at 30s (after radosgw-admin gc process --include-all)

```
Every 2.0s: rados df | grep -i -E 's3.*data|objects' ; echo ---- ; ceph df | grep -i -E 'objects|s3.*data'                    r01h01: Mon Sep 29 09:06:27 2025

POOL_NAME                  USED  OBJECTS  CLONES  COPIES  MISSING_ON_PRIMARY  UNFOUND  DEGRADED     RD_OPS       RD    WR_OPS       WR  USED COMPR  UNDER COMPR
s3.archive.data           978 MiB      346       0    3806                   0        0         0       5905  113 MiB     18192   13 GiB         0 B          0 B
s3.hot.data                 0 B        0       0       0                   0        0         0     137425  1.8 GiB    288753  4.2 GiB         0 B          0 B
s3.warm.data                0 B      300       0    1800                   0        0         0      42275  9.4 GiB    104041   17 GiB         0 B          0 B
----
POOL                       ID  PGS   STORED  OBJECTS     USED  %USED  MAX AVAIL
s3.hot.data                24   32      0 B        0      0 B      0     36 GiB
s3.warm.data               25   32      0 B      300      0 B      0     73 GiB
s3.archive.data            26   32  711 MiB      346  978 MiB   0.87     80 GiB
```

978 MiB

Checking at 365s (after radosgw-admin gc process --include-all) → pools are empty

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Optimized Retention Verification

Rados Gateway (RGW) Logs

Transition at 15 and Expiration at 30 during the tests

- Object written

```
2025-09-29T08:12:56.866+0000 7fbc34bee640  1 beast: 0x7fbb4f01e6f0: 10.38.1.55 - fred [29/Sep/2025:08:12:56.842 +0000] "PUT /newbucket2/file_98.dd?x-id=PutObject HTTP/1.1"
200 1605632 - "rclone/v1.71.1" - latency=0.023999780s

2025-09-29T08:12:56.869+0000 7fbbf7373640  1 beast: 0x7fbb4f01e6f0: 10.38.1.55 - fred [29/Sep/2025:08:12:56.867 +0000] "HEAD /newbucket2/file_98.dd HTTP/1.1" 200 0 -
"rclone/v1.71.1" - latency=0.000999991s
```

- Object transitioned to Storage Class DEEP_ARCHIVE

```
2025-09-29T08:13:11.052+0000 7fbc5bc5d640 20 lifecycle: operator()(): key=file_98.ddwp_thrd: 2, 0
2025-09-29T08:13:11.052+0000 7fbc5bc5d640 20 lifecycle: obj_has_expired(): mtime=2025-09-29T08:12:56.861730+0000 days=30 base_time=2025-09-29T08:13:11.053797+0000
timediff=15.0538 cmp=30 is_expired=0
2025-09-29T08:13:11.052+0000 7fbc5bc5d640 20 lifecycle: check(): key=file_98.dd: is_expired=0 wp_thrd: 2, 0
2025-09-29T08:13:11.052+0000 7fbc5bc5d640 20 lifecycle: obj_has_expired(): mtime=2025-09-29T08:12:56.861730+0000 days=15 base_time=2025-09-29T08:13:11.053827+0000
timediff=15.0538 cmp=15 is_expired=1
2025-09-29T08:13:11.052+0000 7fbc5bc5d640 20 lifecycle: check(): key=file_98.dd: is_expired=1 wp_thrd: 2, 02025-09-29T08:09:24.627+0000 7fbc5ac5b640  2 lifecycle:
TRANSITIONED::newbucket2[f50809af-d67e-426c-bccd-78f8ff6af983.1788835.1]):file_98.dd -> DEEP_ARCHIVE wp_thrd: 2, 2
```

- Object deleted

```
2025-09-29T08:13:26.005+0000 7fbc5d460640 20 lifecycle: operator()(): key=file_98.ddwp_thrd: 1, 1
2025-09-29T08:13:26.005+0000 7fbc5d460640 20 lifecycle: obj_has_expired(): mtime=2025-09-29T08:12:56.861730+0000 days=30 base_time=2025-09-29T08:13:26.005972+0000
timediff=30.006 cmp=30 is_expired=1
2025-09-29T08:13:26.005+0000 7fbc5d460640 20 lifecycle: check(): key=file_98.dd: is_expired=1 wp_thrd: 1, 1
2025-09-29T08:13:26.005+0000 7fbc5d460640 20 lifecycle: obj_has_expired(): mtime=2025-09-29T08:12:56.861730+0000 days=15 base_time=2025-09-29T08:13:26.005992+0000
timediff=30.006 cmp=15 is_expired=1
2025-09-29T08:13:26.005+0000 7fbc5d460640 20 lifecycle: check(): key=file_98.dd: is_expired=1 wp_thrd: 1, 1
2025-09-29T08:09:39.524+0000 7fbc5b45c640  2 lifecycle: DELETED::newbucket2[f50809af-d67e-426c-bccd-78f8ff6af983.1788835.1]):file_98.dd wp_thrd: 2, 1
```

DEMO

Dynamic Placement and Optimized Retention

Acknowledgments

- Yuval Lifshitz for coding LUA scripting support in Rados Gateways
- Steven Umbehocker for his work on RGW auto tiering
- Anthony D'Atri and Curt Bruns talk on RGW Lua scripting
- Laurent Barbe (Ksperis) for sharing his experience on using Veeam B&R with S3 storage:
    - Choose Amazon's Storage Class names (for compatibility reasons).
    - STANDARD SC on NVMes drives for objects < 64 KiB in size
    - STANDARD_IA SC on HDDs or Hybrid drives for objects > 64 KiB in size
    - STANDARD set as default SC

Thank you!

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