DSS

Data & Storage Services

CERN IT Department

Building an organic block* storage service at CERN with Ceph

**** and object and POSIX***

Dan van der Ster
Arne Wiebalck

CHEP 2013, Amsterdam
14 October 2013

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DSS Big Data at CERN

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Physics Data on CASTOR/EOS

- LHC experiments produce ~10GB/s, 25PB/year

User Data on AFS/DFS

- Home directories for 30k users
- Physics analysis dev't
- Project spaces (applications)

Service Data on AFS/NFS

- Databases, admin applications

Tape archival with CASTOR/TSM

- RAW physics outputs
- Desktop/Server backups

Service	Size	Files
AFS	240TB	1.9B
CASTOR	87.7PB	317M
EOS	19.8PB	160M

CERN developed CASTOR & EOS because until very recently our storage reqs were globally unique.

Following the Google / Amazon / Facebook innovations, we are now trying to leverage community solutions

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IT (R)evolution at CERN

Cloudifying CERN's IT infrastructure ...

- Centrally-managed and uniform hardware
  - *No more service-specific storage boxes*
- OpenStack VMs for most services
  - *Building for 100k nodes (mostly for batch processing)*
- Attractive desktop storage services
  - *Huge demand for a local Dropbox, Google Drive …*
- Remote data centre in Budapest
  - *More rack space and power, plus disaster recovery*

… brings new storage requirements

- Block storage for OpenStack VMs
  - *Images and volumes*
- Backend storage for existing and new services
  - *AFS, NFS, OwnCloud, Zenodo, ...*
- Regional storage
  - *Make use of the new data centre in Hungary*
- Failure tolerance, data checksumming, easy to operate, security, ...

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Possible Solutions

GlusterFS

- Cloud team at CERN found it wasn't stable enough
- Doesn't offer block device for physical machines

NFS (NetApp)

- Expensive
- Vendor lock-in

Ceph

- Interesting architecture (on paper)
- Offers almost all features we needed

Early 2013 we started investigating Ceph ...

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Never heard of Ceph?

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Ceph is a distributed, open-source storage system.

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Scalability

TeraBytes to ExaBytes
10s to 10'000 machines
Grow and shrink

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Commodity hardware
Configurable Replication

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Manageability

Self-organizing
Self-healing
CRUSH

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Self-organizing
Self-healing
CRUSH

Unification

Object store
Block store
File system

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Ceph's architecture

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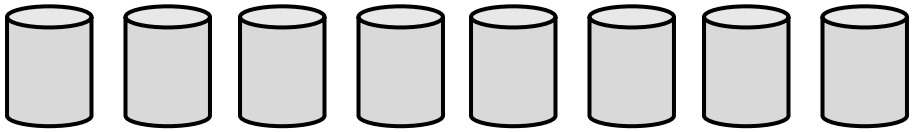
OSDs control a device on the hosts in a Ceph cluster



Object Storage Daemons

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DSS Ceph's architecture

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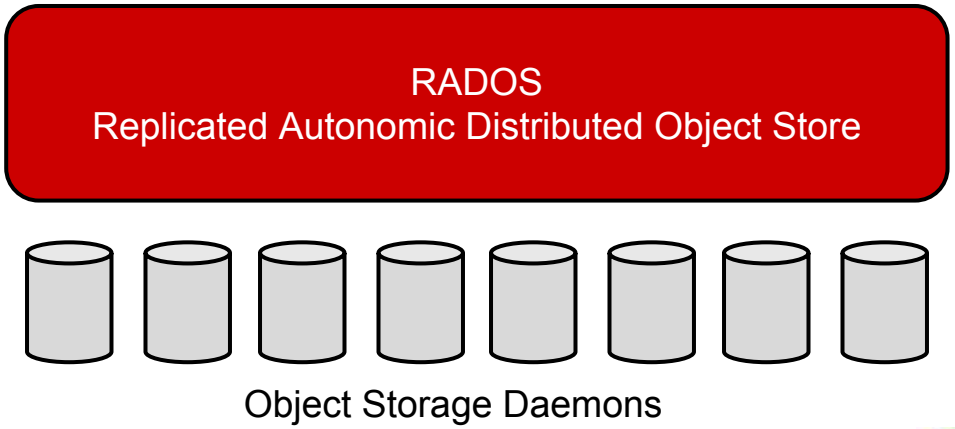
Reliable, self-managing, self-healing **object** store



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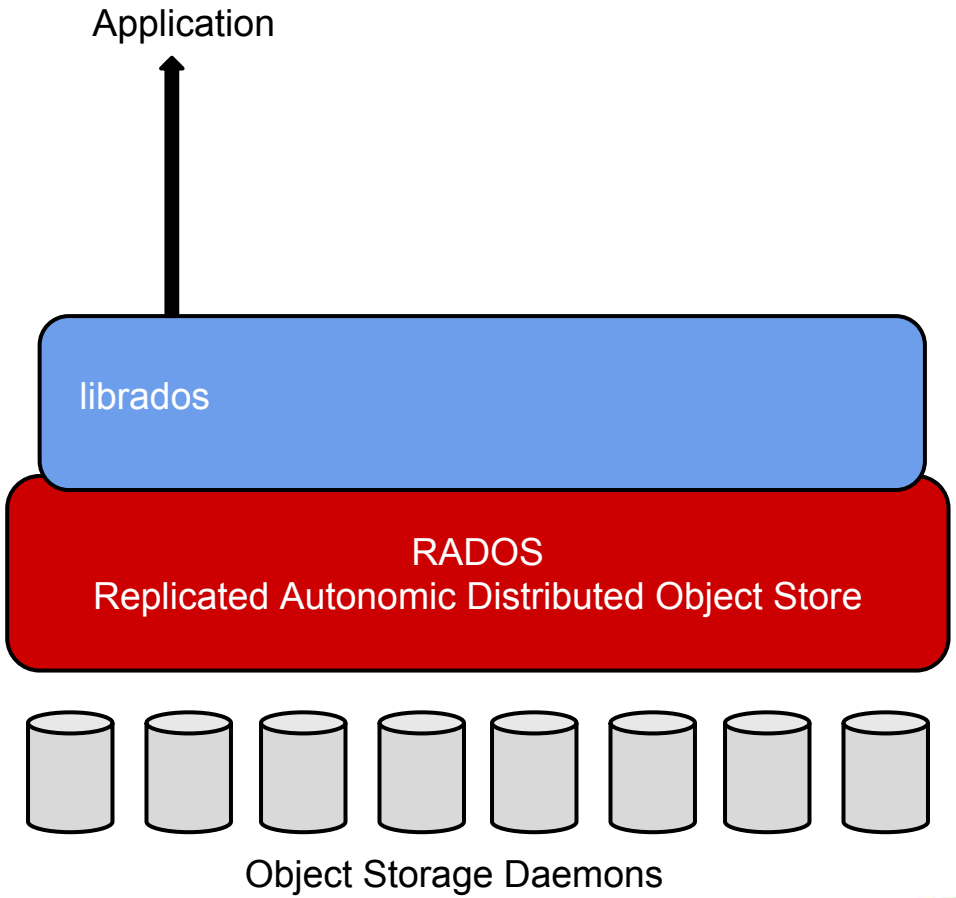
Ceph's architecture

Library for RADOS access from C, C++, Java, Python, ...



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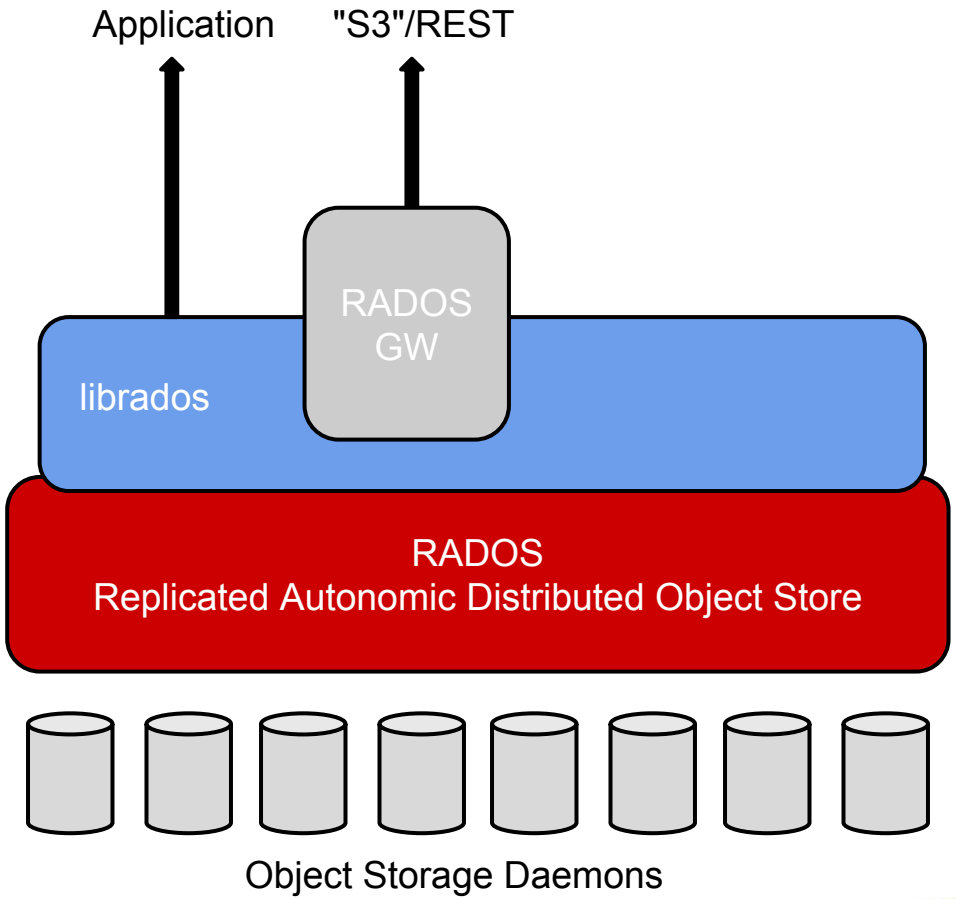
Ceph's architecture

REST gateway compatible with (a large subset of) Swift and Amazon's S3.



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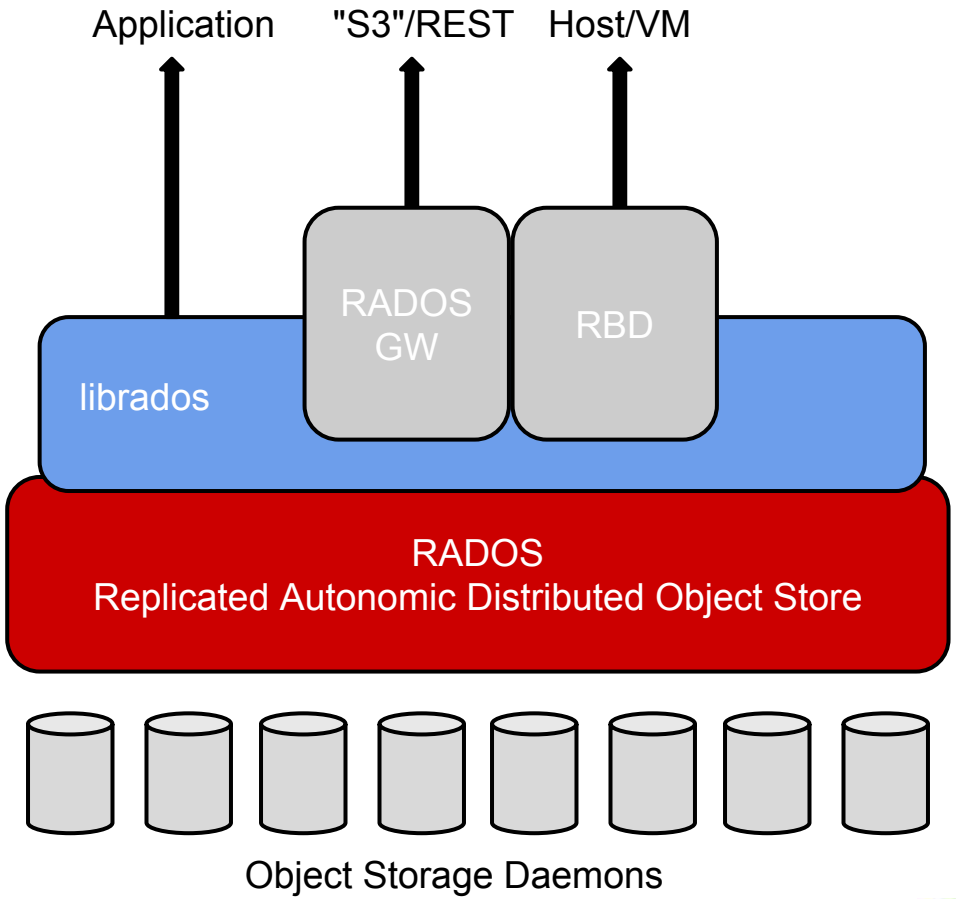
Ceph's architecture

Thinly provisioned distributed block device to be used from VMs or hosts in general; Linux kernel module or KVM/QEMU/libvirt+librbd.



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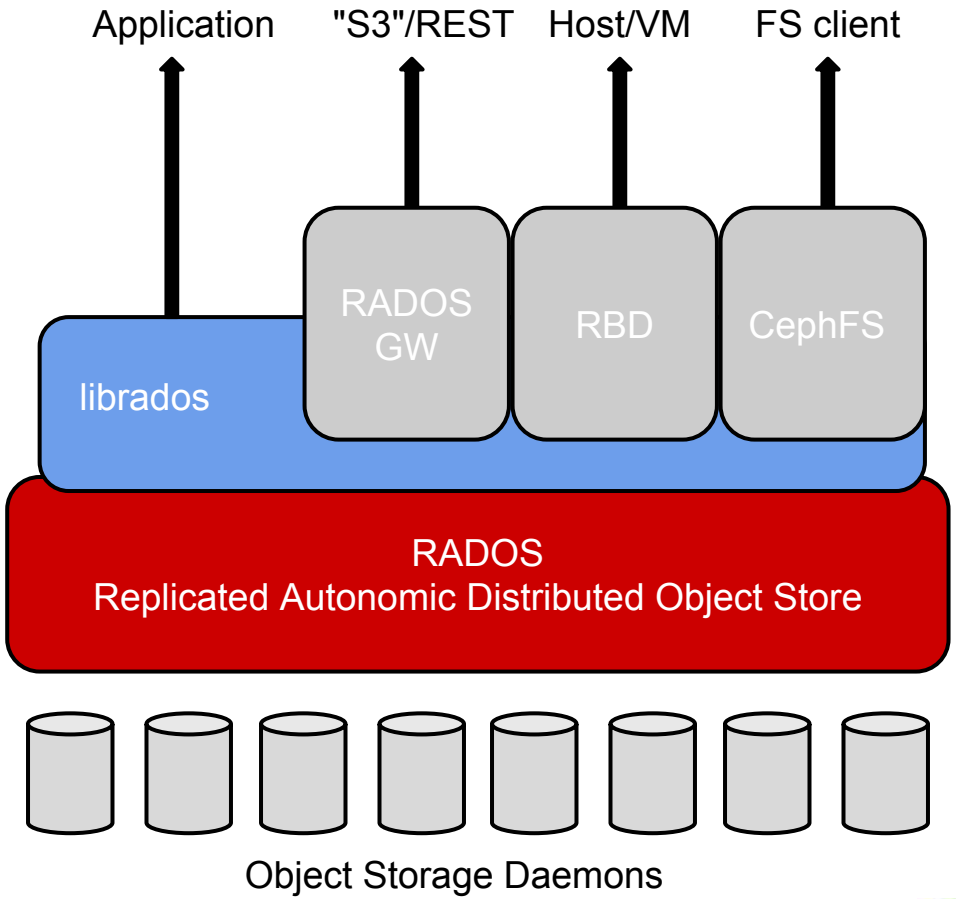
Ceph's architecture

POSIX-compliant distributed file system that ships with the Linux kernel since 2.6.34; usable via kernel module (FUSE available as well).



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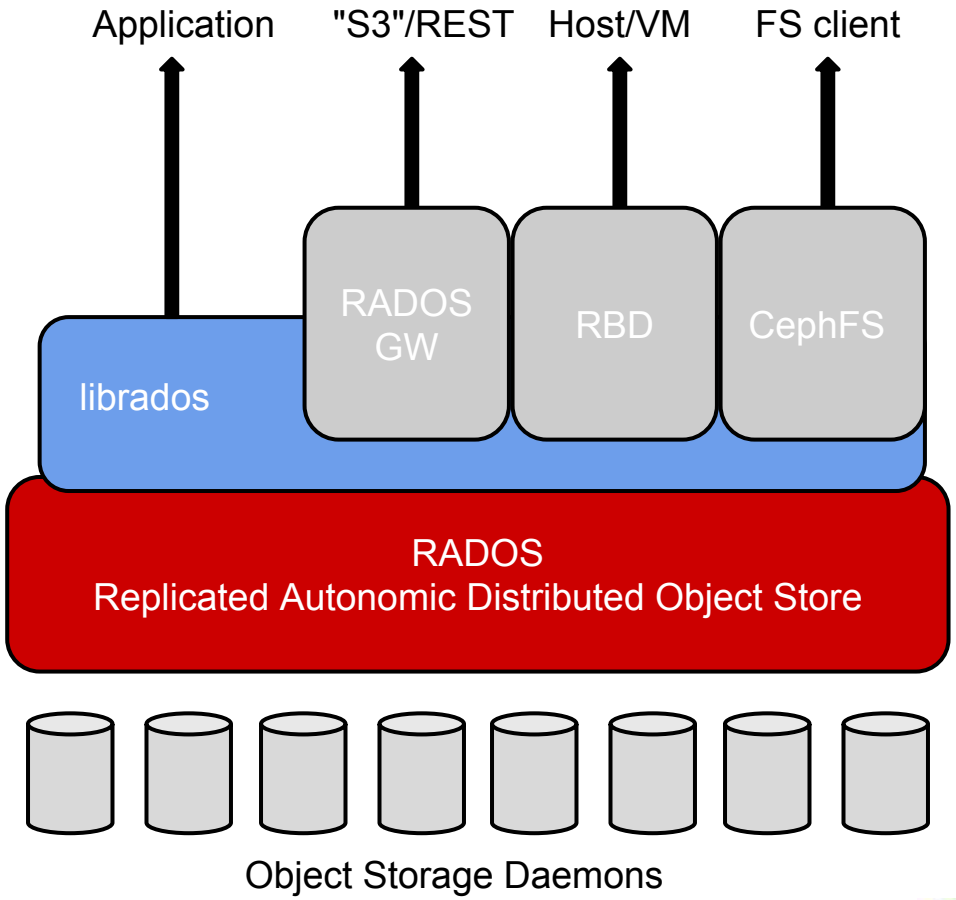
Ceph's architecture

POSIX-compliant distributed file system that ships with the Linux kernel since 2.6.34; usable via kernel module (FUSE available as well).

Each of the grey boxes stripe their data for performance

... break large files into xMB objects and distribute across many disks



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CRUSH ...

Controlled Replication Under Scalable Hashing

- algorithmic data placement
  - no central meta data server
  - clients compute where data is
  - based on CRUSH map (which is "gossip'ed")
  - stable mapping
- infrastructure-aware
  - centers, buildings, rooms, row-of-racks, racks, hosts
  - define placement rules (e.g. each replica in a different rack)
  - address correlated failures
  - allows weighting OSDs

Read more about CRUSH: http://ceph.com/papers/weil-crush-sc06.pdf

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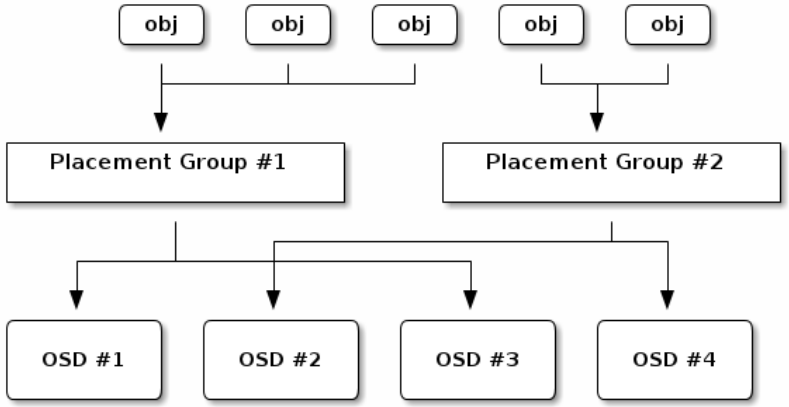
Data placement

- **A Placement Group (PG) aggregates a series of objects into a group, and maps the group to a series of OSDs**
- Data is organized in pools; each pool has M replicas, N placement groups (PGs)
  - e.g. pool "data" with ID 1, 2 replicas, 512 PGs
- Placement groups are physically stored as a directory on an OSD
  - e.g. /osd.1/1.fe0/ and /osd.3/1.fe0/
- Object name is hashed to a PG
  - e.g. object "myfile" -> PG 1.fe0
- *CRUSH* map is used to lookup which servers/OSDs hold that PG



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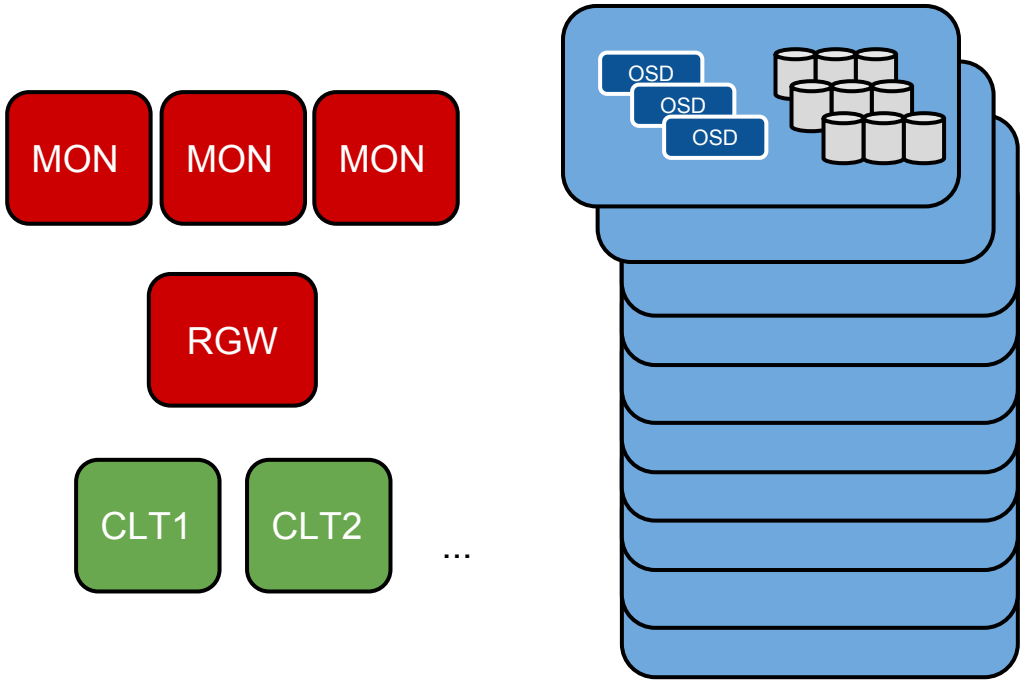
First steps

- **Set up a small scale test cluster**
  - 3 MON servers, 1 RADOS gateway (all VMs)
  - 8 OSD hosts with 4-5 disks each (ex-CASTOR)
  - Ceph 0.56.4 installed via *yum install ceph* on SLC6.4
  - Various clients: kernel rbd driver, OpenStack, AI monitoring, ...



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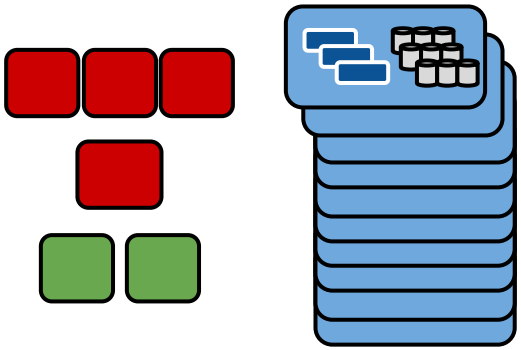
Early testing

- **Setup was easy**
  - ~2 days for our 250TB testbed
- **Passed our (simple) interface tests**
  - RADOS, RBD, RADOS GW, CephFS
- **Passed our first functional tests**
  - remove OSD, change replication size, delete object in PG, corrupt object in PG, …
  - OpenStack/Cinder
- **Passed our performance tests**
  - rados bench
- **Passed our community expectations**
  - very quick and helpful responses to issues we encountered



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Early testing

- **Setup was easy**
  - ~2 days for our 50TB testbed
- **P**
- **I**
- **Passed our performance tests**
  - rados bench
- **Passed our community expectations**
  - very quick and helpful responses to issues we encountered

The results of this initial testing allowed us to convince management to support a more serious Ceph prototype ...

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DSS 12 racks of disk server quads

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DSS Our 3PB Ceph Cluster

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48 OSD servers

Dual Intel Xeon E5-2650
32 threads incl. HT
Dual 10Gig-E NICs
Only one connected
24x 3TB Hitachi disks
Eco drive, ~5900 RPM
3x 2TB Hitachi system disks
Triple mirror
64GB RAM

5 monitors

Dual Intel Xeon L5640
24 threads incl. HT
Dual 1Gig-E NICs
Only one connected
3x 2TB Hitachi system disks
Triple mirror
48GB RAM

```
[root@p01001532971954 ~]# ceph osd tree | head -n2
# id weight    type name up/down   reweight
-1   2883 root default
```

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Ceph Configuration

11 data pools with 3 replicas each

- mostly test pools for a few different use-cases
- 1-4k pgs per pool; 19584 pgs total

Room/Rack in ceph.conf:

```
osd crush location = room=0513-R-0050
                     rack=RJ35
```

Rack-wise replication:

```
rule data {
  ruleset 0
  type replicated
  min_size 1
  max_size 10
  step take 0513-R-0050
  step chooseleaf firstn 0 type
rack
  step emit
}
```

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11 data pools with 3 replicas each

- mostly test pools for a few different use-cases
- 1-4k pgs per pool; 19584 pgs total

Room/Rack in ceph.conf:

```
osd crush location = room=0513-R-0050
                     rack=RJ35
```

```
-1   2883 root default
-2   2883      room 0513-R-0050
-3   262.1               rack RJ35
-15  65.52                    host p05151113471870
-16  65.52                    host p05151113489275
-17  65.52                    host p05151113479552
-18  65.52                    host p05151113498803
-4   262.1               rack RJ37
-23  65.52                    host p05151113507373
-24  65.52                    host p05151113508409
-25  65.52                    host p05151113521447
-26  65.52                    host p05151113525886
...
```

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Fully Puppetized Deployment

Fully puppetized deployed

- Big thanks to eNovance for their module!
  https://github.com/enovance/puppet-ceph/

Automated machine commissioning

- Add a server to the hostgroup (osd, mon, radosgw)
- OSD disks are detected, formatted, prepared, auth'd
- Auto-generated ceph.conf
- Last step is manual/controlled: service ceph start

We use mcollective for bulk operations on the servers

- Ceph rpm upgrades
- daemon restarts

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DSS Service Monitoring

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Service information

full name: **Ceph Storage Service**
short name: Ceph
group: IT/DSS
site: CERN

email: **ceph-admins@cern.ch**
web site: https://twiki.cern.ch/twiki/bin/viewauth/DSSGroup/CephP...
alarms page: http://cern.ch/ceph/alarms.html

service managers: Arne Wiebalck, Dan van der Ster

Part of (subservice of):

IT/DSS services

Subservices

none / not declared

Clusters, subclusters and nodes

cluster ceph_beesly_mon
cluster ceph_beesly_osd

Depends on

none / not declared

Depended on by

services that depend on this service:
Cloud Infrastructure

Service availability (more)

availability:
percentage: 100%
status: **available**

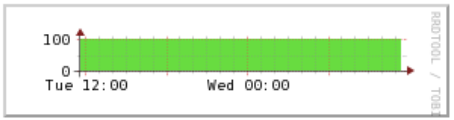
last update: 11:16:09, 2 Oct 2013 (13 minutes ago)
expires after: 15 minutes

rss feed with status changes

how is availability measured or estimated:

Availability is 100% when Ceph reports HEALTH_OK, otherwise it is the percentage placement groups which can actively accept IOs.

availability in the last 24 hours (more):



Additional service information (more)

Num Mons:	5
Num Mons in Quorum:	5
Num Pools:	12
Num OSDs:	1,056
Num OSDs Up:	1,056
Num OSDs In:	1,056
Num PGs:	19,584
Num PGs Active:	19,584
OSD Gigabytes Total:	2,949,955
OSD Gigabytes Used:	13,371
OSD Gigabytes Avail:	2,936,583
PG Gigabytes:	762
Num Objects:	134,787
Num Object Copies:	404,359
Num Objects Degraded:	0
Num Objects Unfound:	0
Total Read (GB):	3,501
Total Write (GB):	6,064

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DSS Initial Benchmarks

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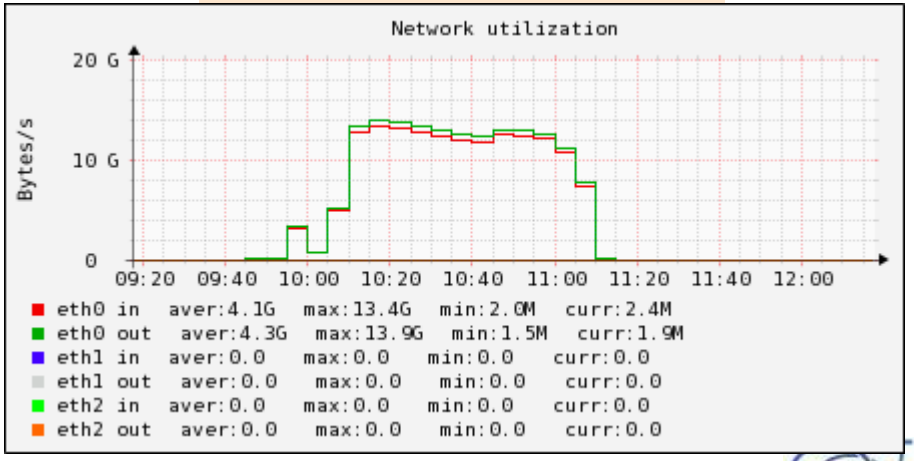
basic rados bench - *saturate the network*

```
[root@p05151113471870 ~]# rados bench 30 -p test write -t 100
Total writes made:      7596
Write size:             4194304
Bandwidth (MB/sec):     997.560
Average Latency:        0.395118
[root@p05151113471870 ~]# rados bench 30 -p test seq -t 100
Total reads made:     7312
Read size:            4194304
Bandwidth (MB/sec):    962.649
Average Latency:       0.411129
```

120M file test

Wrote 120 million tiny files into RADOS to measure scalability by that dimension. No problems observed. Then we added one OSD server, and the rebalance took ages (~24hrs) which is probably to be expected.

all-to-all rados bench



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Our Users

A few early adopters are helping us evaluate Ceph:

- **OpenStack**: usage for Glance images and Cinder volumes
- **AFS/NFS**: backend RBD storage for these commonly used fs's
- **CASTOR**: high performance buffer of objects to be written to tape
- **DPM**: backend RBD storage for this high-energy-physics fs
- **OwnCloud**: S3 or CephFS backend for desktop synchronisation
- **Zenodo**: backend storage for data and publications sharing service

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Looking forward...

librados is very powerful:

- could be interesting for physics data

The killer app for Ceph at CERN would be to build upon it a general purpose network file system

- Would help us get rid of NetApp boxes
- Dare we dream that it may one day replace AFS?!

CephFS is advertised as not yet production quality, so we don't yet advertise it to our users

- "Nearly Awesome" -- Sage Weil

To be generally usable we'd need:

- HA and load balanced (for AFS we get accessed at 75kHz)
- All the goodies we get from AFS: quotas, ACLs, krb5, ...

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Conclusions

We are attracting various use-cases

- OpenStack images and volumes
- RBD backends for other storage services (AFS/NFS/DPM)
- Object storage for novel applications: (tape buffer, Zenodo, OwnCloud)

We have very high hopes for Ceph at CERN!

- the design is *interesting*
- the performance so far is adequate
- operationally it is very attractive

Everybody wants a filesystem: CephFS will be crucial

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BACKUP SLIDES

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Our puppet-ceph changes

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- Yum repository support
- Don't export the admin key
  - *our puppet env is shared across CERN*
  - *(get the key via k5 auth'd scp instead)*
- New options:
  - *osd default pool size, mon osd down out interval, osd crush location*
- RADOS GW support (RHEL only)
  - *https to be completed*
- /dev/disk/by-path OSDs
  - *better handle disk replacements*
- Unmanaged osd service
  - *manual control of the daemon*
- Other OSD fixes: delay mkfs, don't mount the disks, …

Needs some cleanup before pushing back to enovance

https://github.com/cernceph/puppet-ceph/

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Puppet-ceph TODO/Wish-list

We have some further puppet work in mind:

- Add arbitrary ceph.conf options
- Move the OSD journal to a separate partition
- SSD OSD journals
- Use the udev triggers for OSD creation

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Current Issues

Latency:

- Our best case write latency is presently 50ms
  - 1 replica, journal as a file on the OSD
- We tested an in-memory OSD and saw ~1ms latency
  - So our high latency comes from our journal
- We need to put our journals on the blockdev directly (should get ~12ms writes) or use SSDs (but we're worried they'll wear out)

ulimits:

- With more than >1024 OSDs, we're getting various errors where clients cannot create enough processes to connect to the OSDs
  - failed ceph tell, failed glance image uploads
- Our clients have been informed to increase ulimit -u to 4096, but it would useful if ceph was somehow less process greedy.

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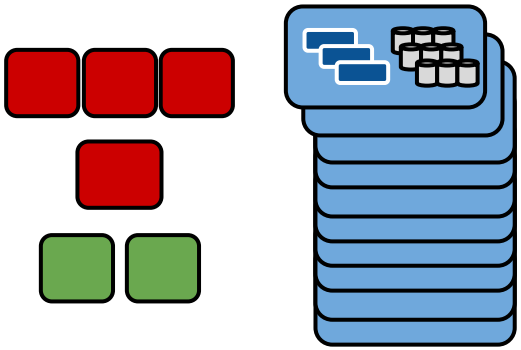
Issues during early testing

- **ceph-deploy did not work for us at the time**
- **“2 rooms - 3 replicas - problem”**
- **“re-weight apocalypse”**
  - wrong ratio of RAM to OSDs



- **“flaky” server caused Ceph timeouts and constant re-balancing**
  - taking out the server “fixed” the problem
  - root cause not understood (can slow server slow down the cluster?)
- **qemu-kvm RPM on RHEL derivative SLC needs patching**
  - RPM provided by Inktank

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Openstack / Ceph Testing

We are still validating the OpenStack / Ceph integration

- Being a RedHat shop, we require the version of qemu-kvm patched by Inktank to support RBD
- Our workloads benefit from striping:
  - Gary McGilvary developed and pushed some patches to allow configurable striping via the OpenStack UI
- Our grizzly cluster is using RBD
  - Small problem related to ulimit, see coming slide...
- For Cinder usage we are currently blocked:
  - Deployed Grizzly with *cells* to divide our large facilities
  - Grizzly cells don't support Cinder
  - Belmiro Moreira backported the Havana code for Cinder/Cells; currently under test

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Ceph as a Tape Buffer?

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CASTOR holds much of our physics data

- 90PB total, 75PB on TAPE

Tapes write at 250MB/s; without striping CASTOR diskservers cannot supply data at that rate.

Idea: put a Ceph buffer between the disk servers and tape drives

but… single threaded read performance

```
[root@p05151113471870 ~]# rados bench 10 -p test seq -t 1
Total reads made:     612
Read size:            4194304
Bandwidth (MB/sec):    244.118
Average Latency:       0.0163772
```

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Ceph as a Tape Buffer?

So our colleage Andreas Peters prototyped a striping RADOS object client: **cephcp**

```
Upload:
[root@p05151113471870 ~]# ./cephcp -p test -i admin -n 64 file:
/root/1G.dat ceph:/root/1G.dat
[cephcp] 1073741824 bytes copied in 1137.89 ms [ 943.63 MB/s ]
```

```
Download
[root@p05151113471870 ~]# ./cephcp -p test -i admin -n 64 ceph:
/root/1G.dat file:/dev/null
[cephcp] 1073741824 bytes copied in 1022.40 ms [ 1050.22 MB/s ]
```

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Service Monitoring

A few monitoring helper scripts

https://github.com/cernceph/ceph-scripts

`ceph-health-cron`:

- report on the ceph health hourly

`cephinfo`:

- python API to the ceph JSON dumps

`cern-sls`:

- example usage of cephinfo.py
- compute and publish ceph availability and statistics

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