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# CEPH: overview

# Agenda

- CEPH Highligth
- CEPH Features
- CEPH Architecture
- CEPH Installation

# CEPH highlight

- Ceph was initially created by Sage Weil for his doctoral dissertation
- On March 19, 2010, Linus Torvalds merged the Ceph client into Linux kernel version 2.6.34
- In 2012, Weil created Inktank Storage for professional services and support for Ceph
- In April of 2014 Red Hat purchased Inktank bringing the majority of Ceph development in-house

# CEPH highlight

- Project started in 2007
- An object based parallel file-system
- Open source project (LGPL licensed )
- Written in C++ and C
- kernel level
- Posix compliant
- No SPOF
- Both data and metadata could be replicated dynamically
- Configuration is config file based
- Flexible striping strategies and object sizes
  - Could be configured “per file”

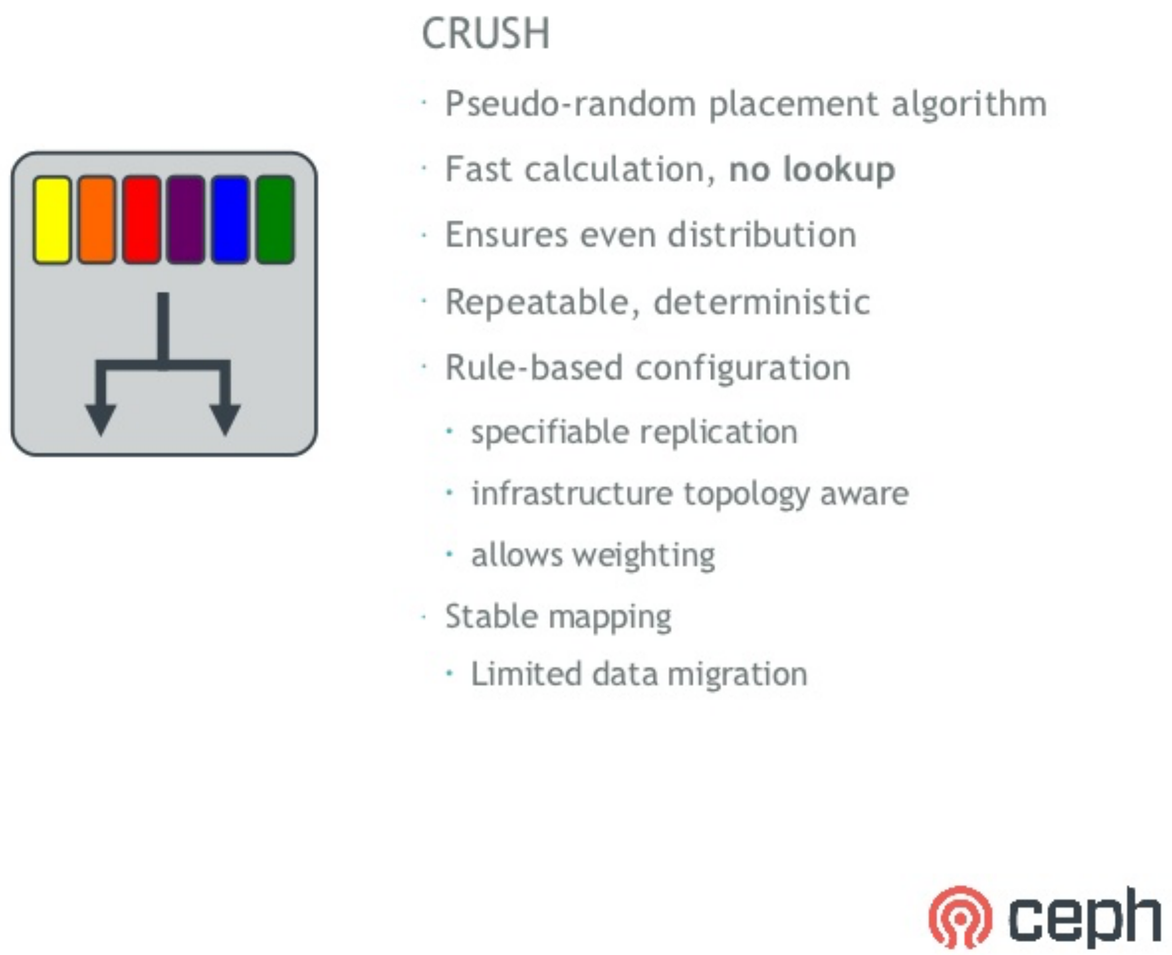
# CEPH Features

- In CEPH tutto è un oggetto
- Non esiste il database per indicare la disposizione degli oggetti nel cluster
- http://ceph.com/papers/weil-crush-sc06.pdf
- Esiste una "regola" per scegliere dove memorizzare i vari oggetti:
  - ogni singolo nodo del cluster può calcolare la disposizione
  - NOSPOF

# CEPH Features

- Why start with Object
  - more useful than (disk) blocks
    - names in a single flat namespace
    - variable size
    - simple API with rich semantics
  - more scalable than files
    - no hard-to-distribute hierarchy
    - update semantics do not span objects
    - workload is trivially parallel

# CEPH Features



CRUSH

- Pseudo-random placement algorithm
- Fast calculation, **no lookup**
- Ensures even distribution
- Repeatable, deterministic
- Rule-based configuration
  - specifiable replication
  - infrastructure topology aware
  - allows weighting
- Stable mapping
  - Limited data migration

ceph

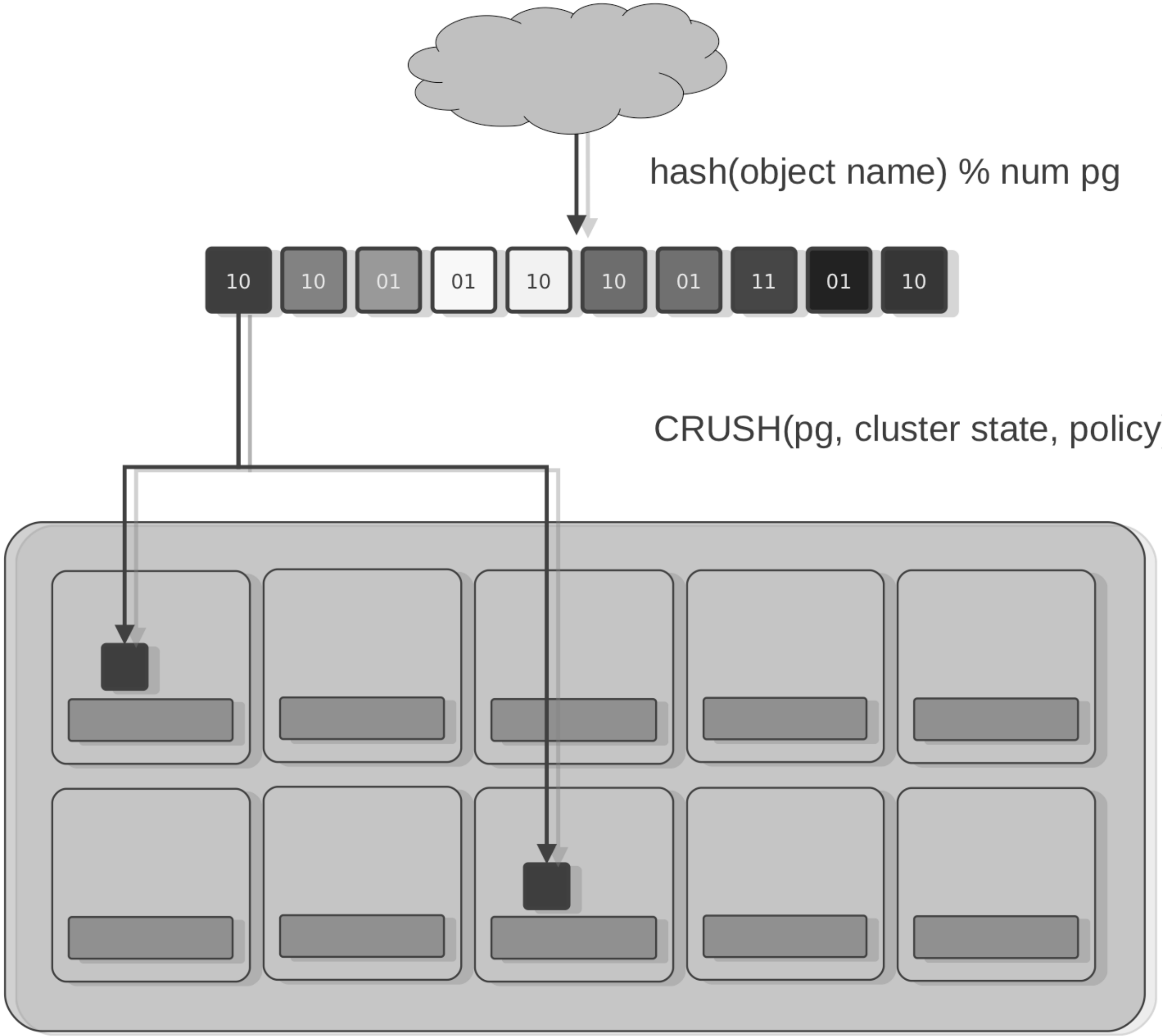
# Distributed object storage

- CRUSH tells us where data should go
    - small "osd map" records cluster state at point in time
    - ceph-osd node status (up/down, weight, IP)
    - CRUSH function specifying desired data distribution
- object storage daemons (RADOS)
    - store it there
    - migrate it as the cluster changes
- decentralized, distributed approach allows
    - massive scales (10,000s of servers or more)
    - efficient data access
    - the illusion of a single copy with consistent behavior

# Distributed object storage

- dynamic cluster
  - nodes are added, removed; nodes reboot, fail, recover
  - recovery is the norm
- osd maps are versioned
  - shared via gossip
- any map update potentially triggers data migration
  - ceph-osds monitor peers for failure
  - new nodes register with monitor
  - administrator adjusts weights, mark out old hardware, etc.

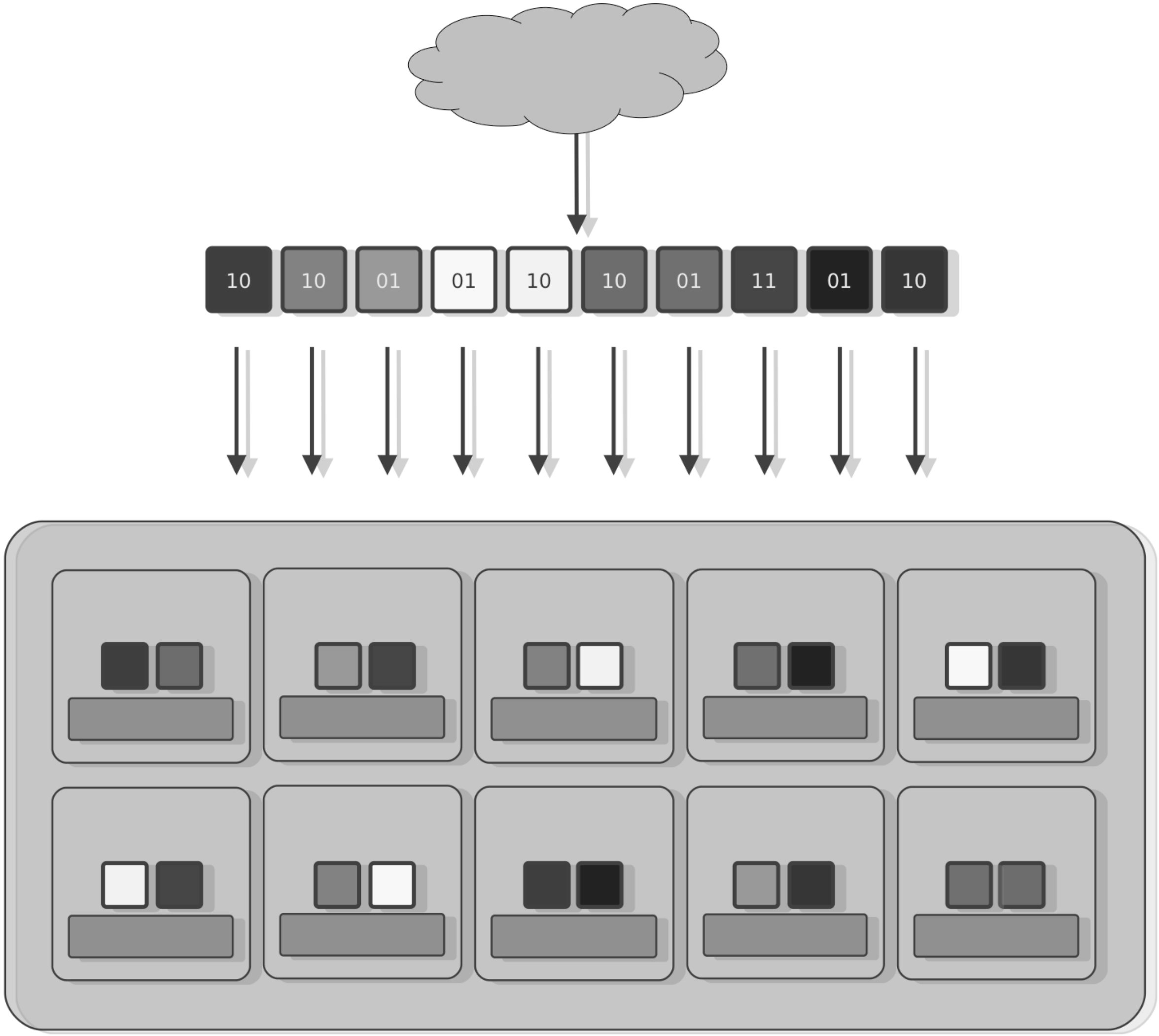
# CEPH Features



hash(object name) % num pg

CRUSH(pg, cluster state, policy)

# CEPH Features



# CEPH Features

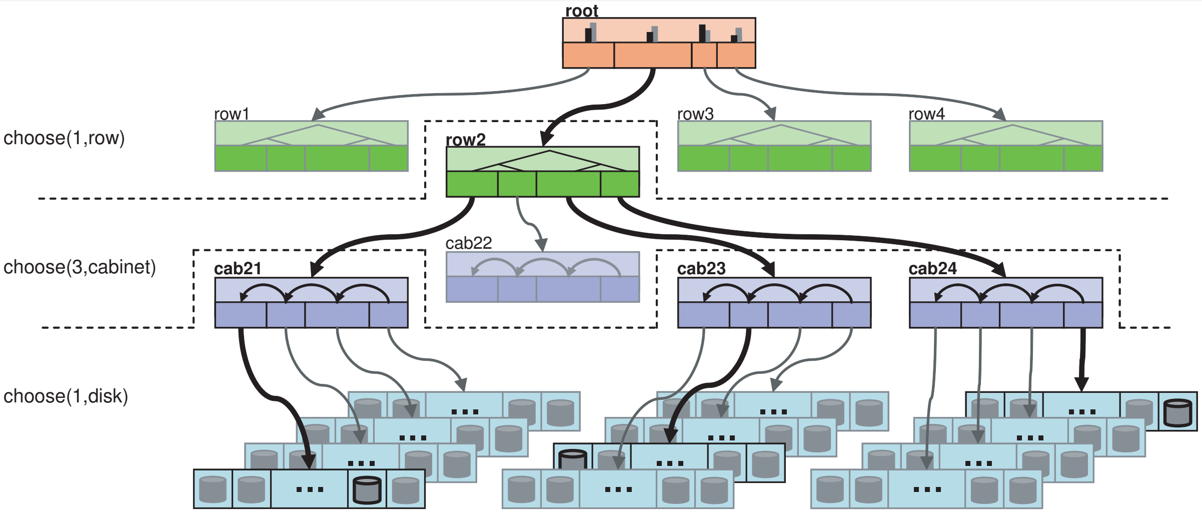
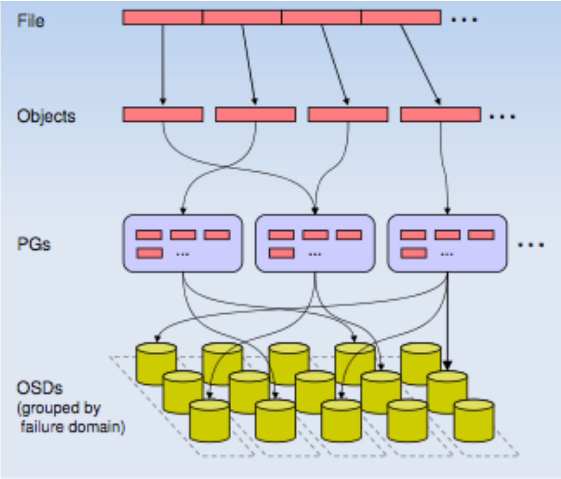
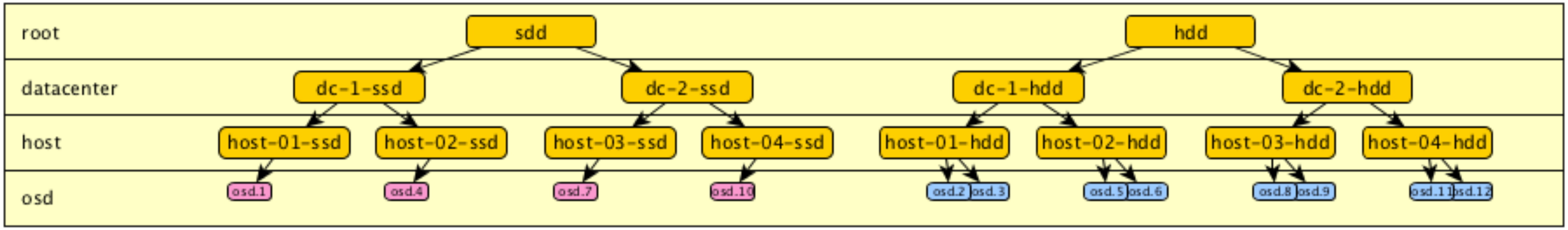


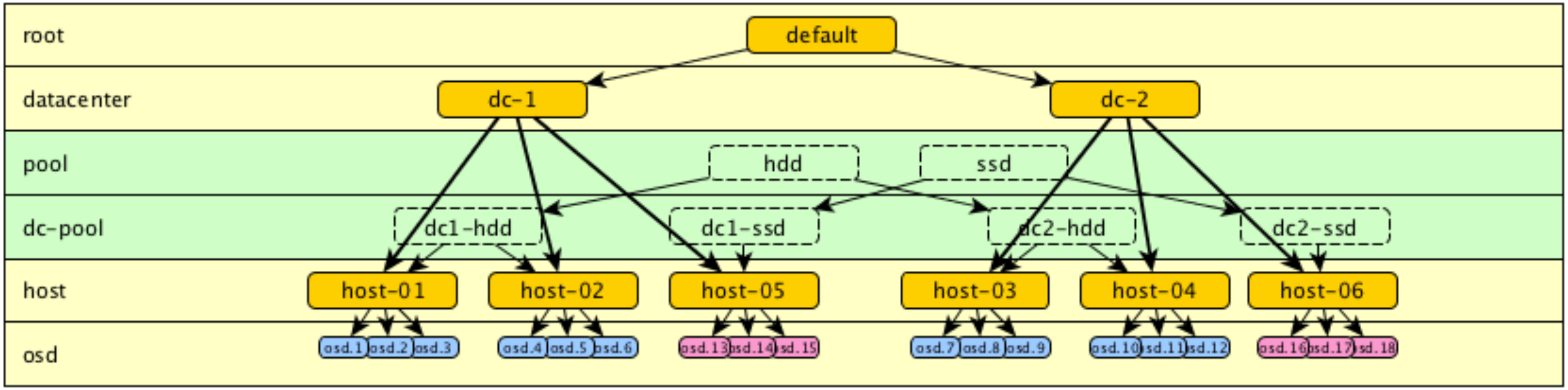
**Figure 1: A partial view of a four-level cluster map hierarchy consisting of rows, cabinets, and shelves of disks. Bold lines illustrate items selected by each *select* operation in the placement rule and fictitious mapping described by Table 1.**

By default these include *root*, *datacenter*, *room*, *row*, *pod*, *pdu*, *rack*, *chassis* and *host*



# CEPH Features





# CEPH Features

- È in grado di fornire Block/Object/Posix storage
- File system supportati come back-end
  - Non-Production
    - btrfs
    - ZFS (On Linux)
  - Production
    - ext4 (small scale)
    - xfs (enterprise deployments)

# CEPH Features

- Intelligent server: replicate data, migrate object, detect node failures
  - this could happen because everyone know where object belongs
- inodes are stored together with the directory object: you can load complete directory and inodes with a single I/O (“find” or “du” are greatly faster)

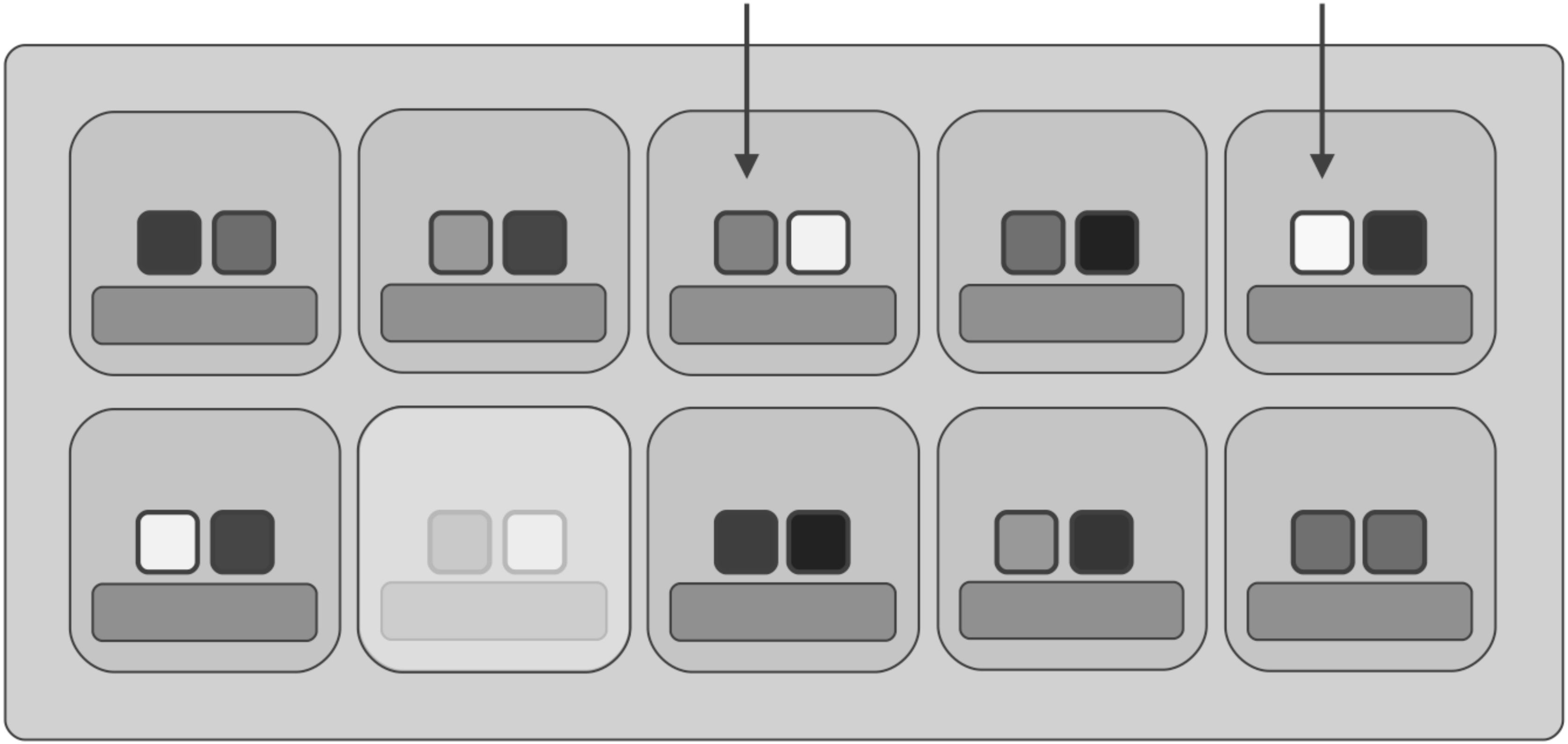
# CEPH Features

## recursive accounting

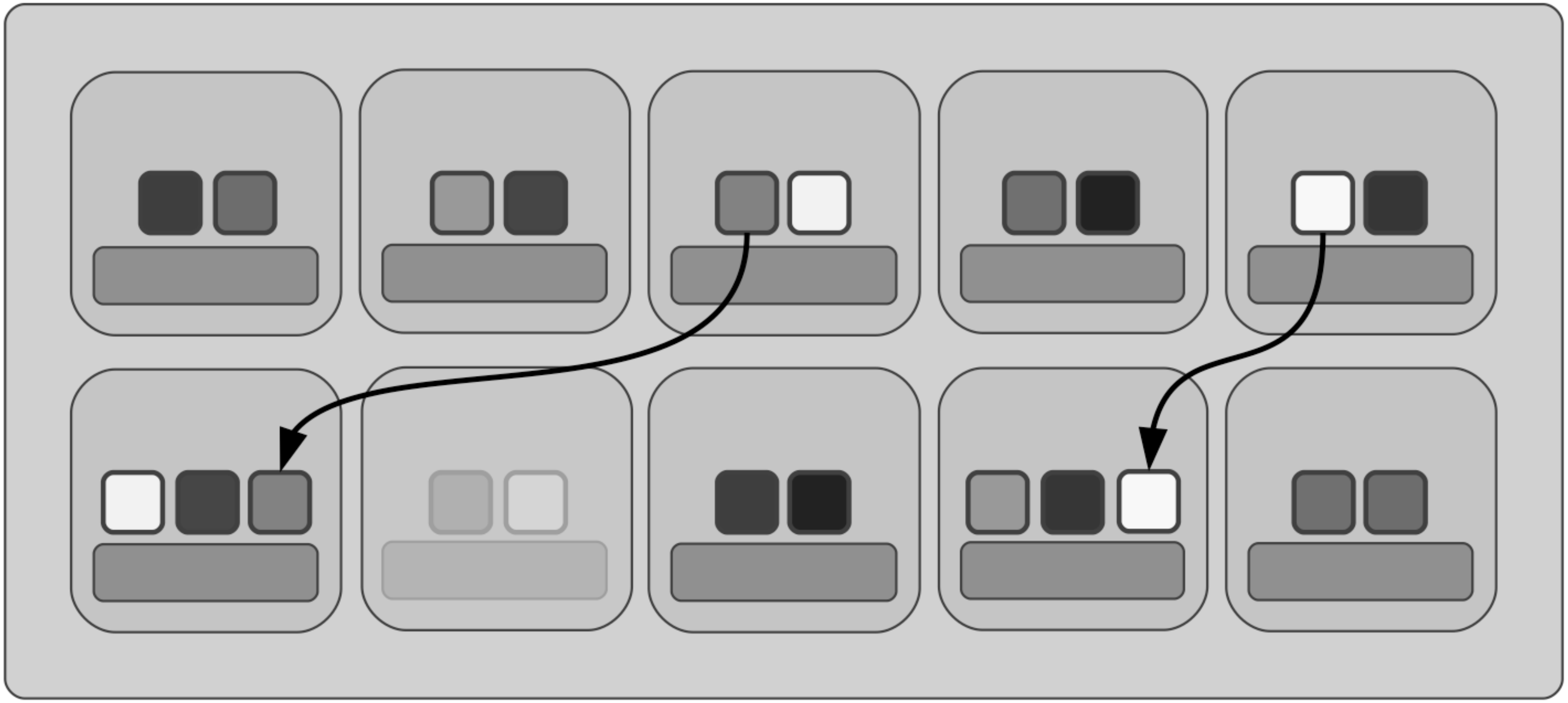
- ceph-mds tracks recursive directory stats
  - file sizes
  - file and directory counts
  - modification time
- virtual xattrs present full stats
- efficient

```
$ ls -alSh | head
total 0
drwxr-xr-x 1 root            root       9.7T 2011-02-04 15:51 .
drwxr-xr-x 1 root            root       9.7T 2010-12-16 15:06 ..
drwxr-xr-x 1 pomceph         pg4194980  9.6T 2011-02-24 08:25 pomceph
drwxr-xr-x 1 mcg_test1       pg2419992   23G 2011-02-02 08:57 mcg_test1
drwx--x--- 1 luko            adm         19G 2011-01-21 12:17 luko
drwx--x--- 1 eest            adm         14G 2011-02-04 16:29 eest
drwxr-xr-x 1 mcg_test2       pg2419992  3.0G 2011-02-02 09:34 mcg_test2
drwx--x--- 1 fuzyceph        adm        1.5G 2011-01-18 10:46 fuzyceph
drwxr-xr-x 1 dallasceph      pg275      596M 2011-01-14 10:06 dallasceph
```

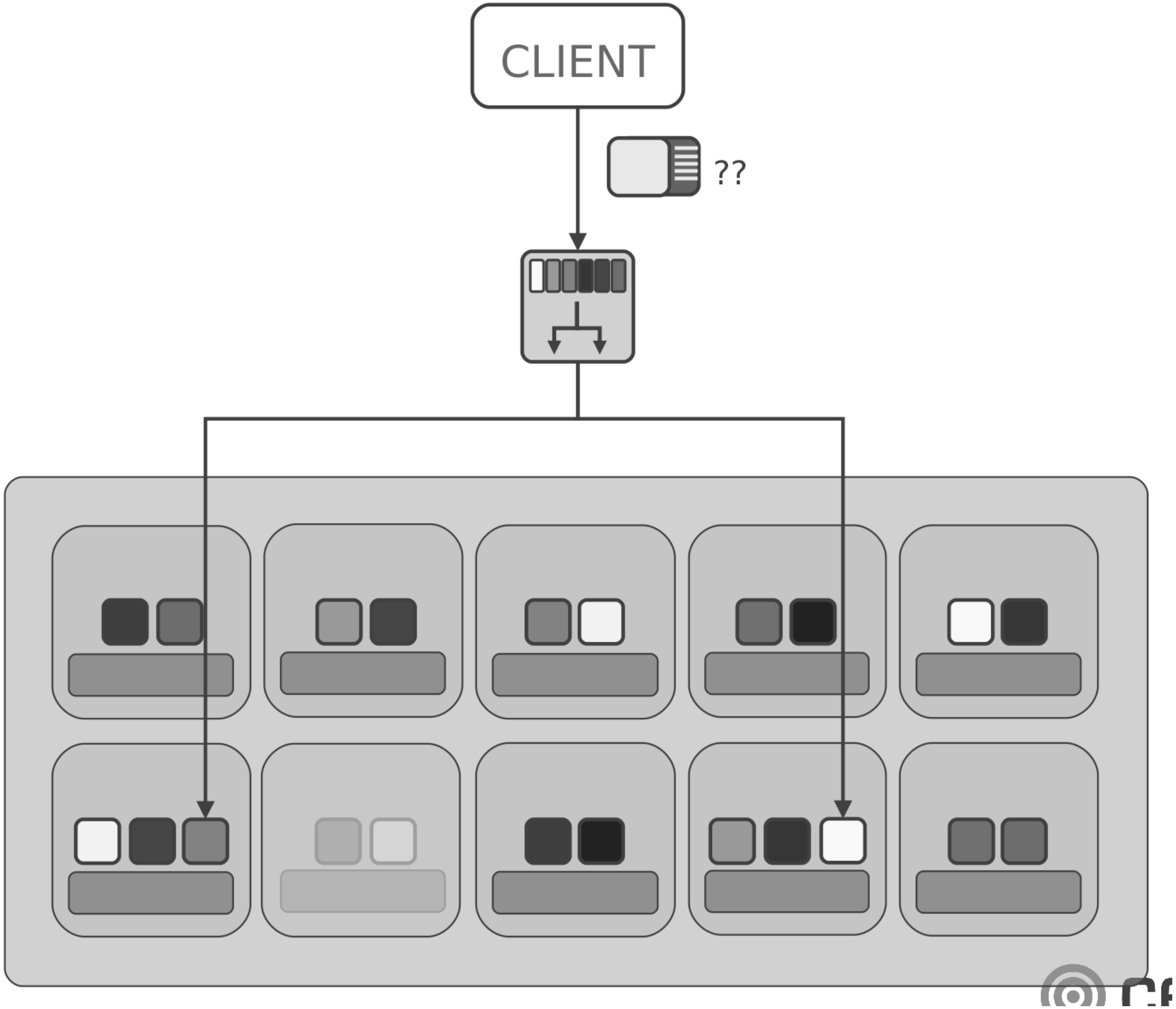
# CEPH Features (Replication)



# CEPH Features (Replication)



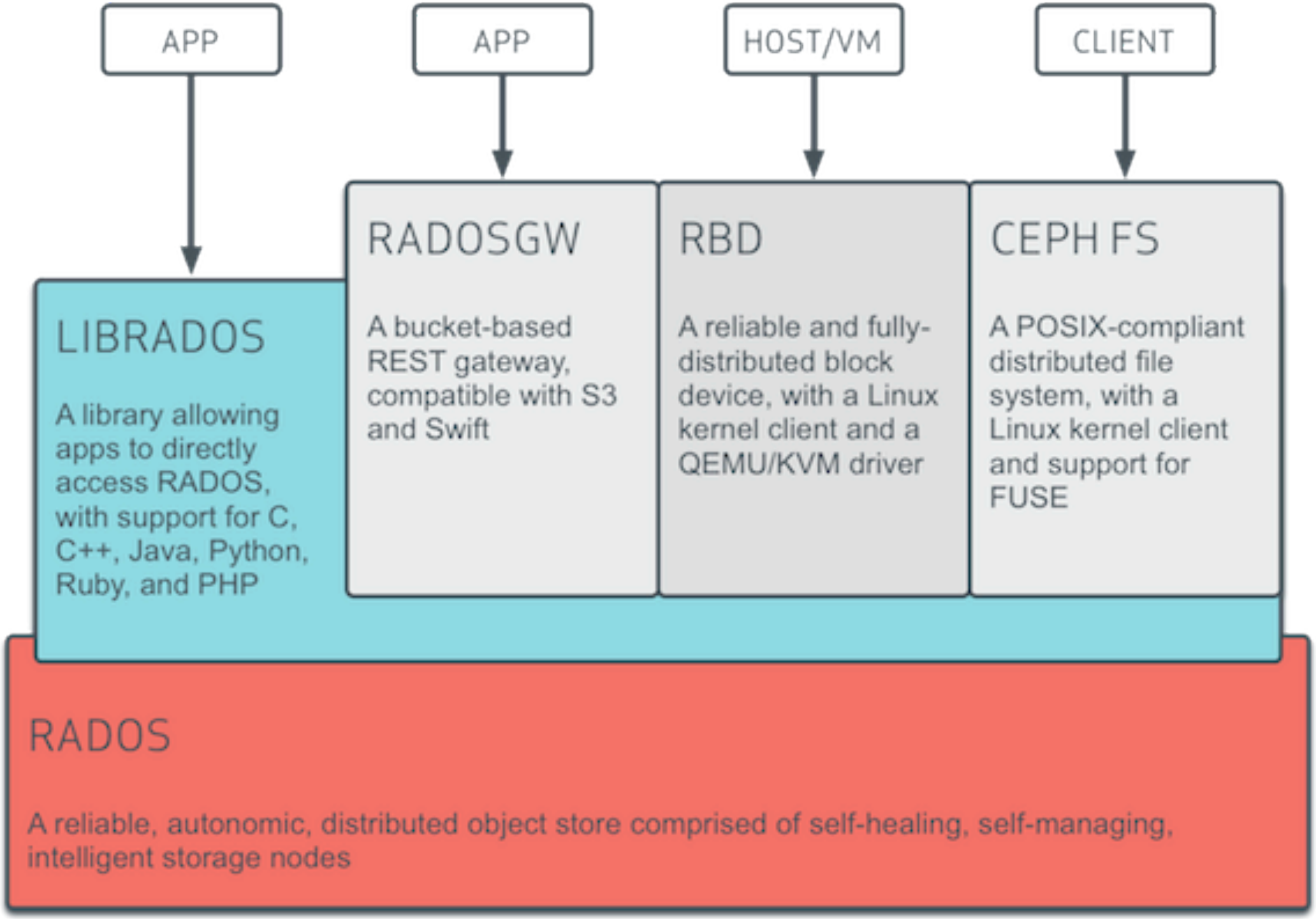
# CEPH Features (Striping)



# CEPH Features

- SAN (shared) disk is not needed to achieve HA
- Support snapshots
- Support quotas (per directory sub-tree)
- The RADOS Gateway also exposes the object store as aRESTful interface which can present as both native Amazon S3 and OpenStack Swift APIs.
- Ceph RBD interfaces with object storage system that provides the librados interface and the CephFS file system
- stores block device images as objects. Since RBD is built on top of librados, RBD inherits librados's capabilities, including read-only snapshots and revert to snapshot

# CEPH Architecture



APP

APP

HOST/VM

CLIENT

LIBRADOS

A library allowing apps to directly access RADOS, with support for C, C++, Java, Python, Ruby, and PHP

RADOSGW

A bucket-based REST gateway, compatible with S3 and Swift

RBD

A reliable and fully-distributed block device, with a Linux kernel client and a QEMU/KVM driver

CEPH FS

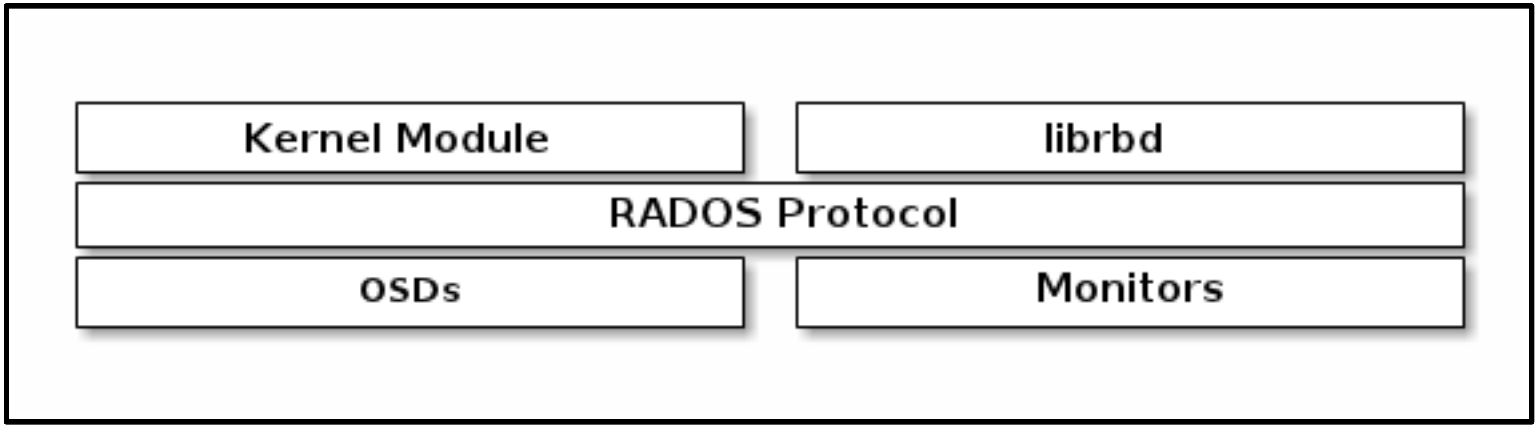
A POSIX-compliant distributed file system, with a Linux kernel client and support for FUSE

RADOS

A reliable, autonomic, distributed object store comprised of self-healing, self-managing, intelligent storage nodes

# CEPH Architecture

Ceph block devices are thin-provisioned, resizable and store data striped over multiple OSDs in a Ceph cluster



Kernel Module

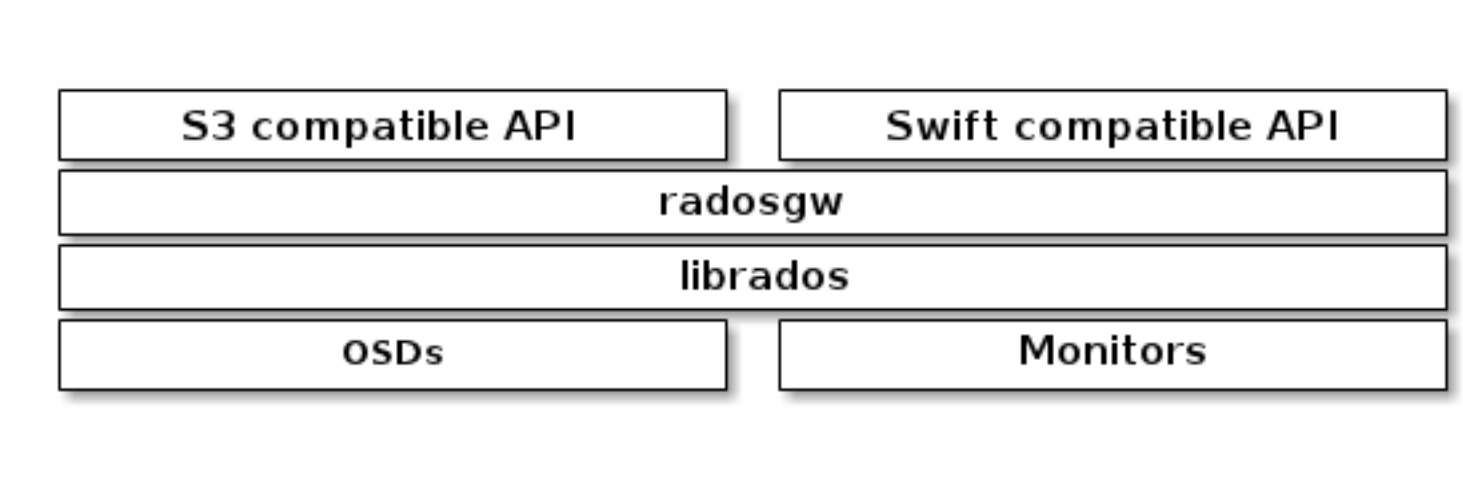
librbd

RADOS Protocol

OSDs

Monitors

# CEPH Architecture



S3 compatible API

Swift compatible API

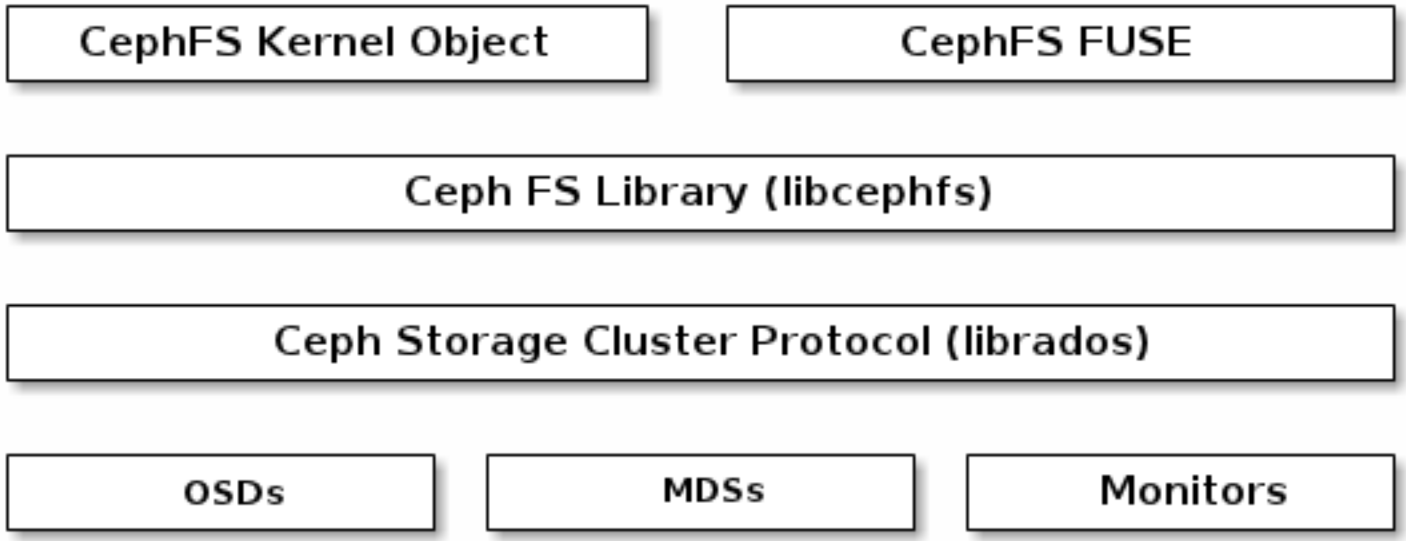
radosgw

librados

OSDs

Monitors

# CEPH Architecture



CephFS Kernel Object

CephFS FUSE

Ceph FS Library (libcephfs)

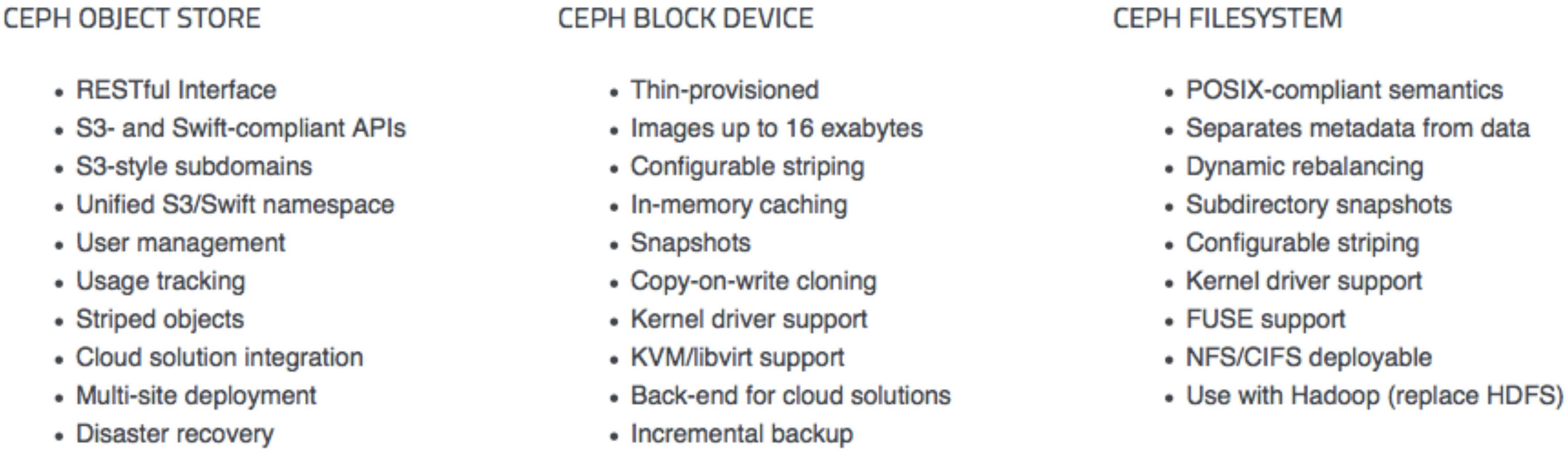
Ceph Storage Cluster Protocol (librados)

OSDs

MDSs

Monitors

# CEPH Features Summary



CEPH OBJECT STORE

- RESTful Interface
- S3- and Swift-compliant APIs
- S3-style subdomains
- Unified S3/Swift namespace
- User management
- Usage tracking
- Striped objects
- Cloud solution integration
- Multi-site deployment
- Disaster recovery

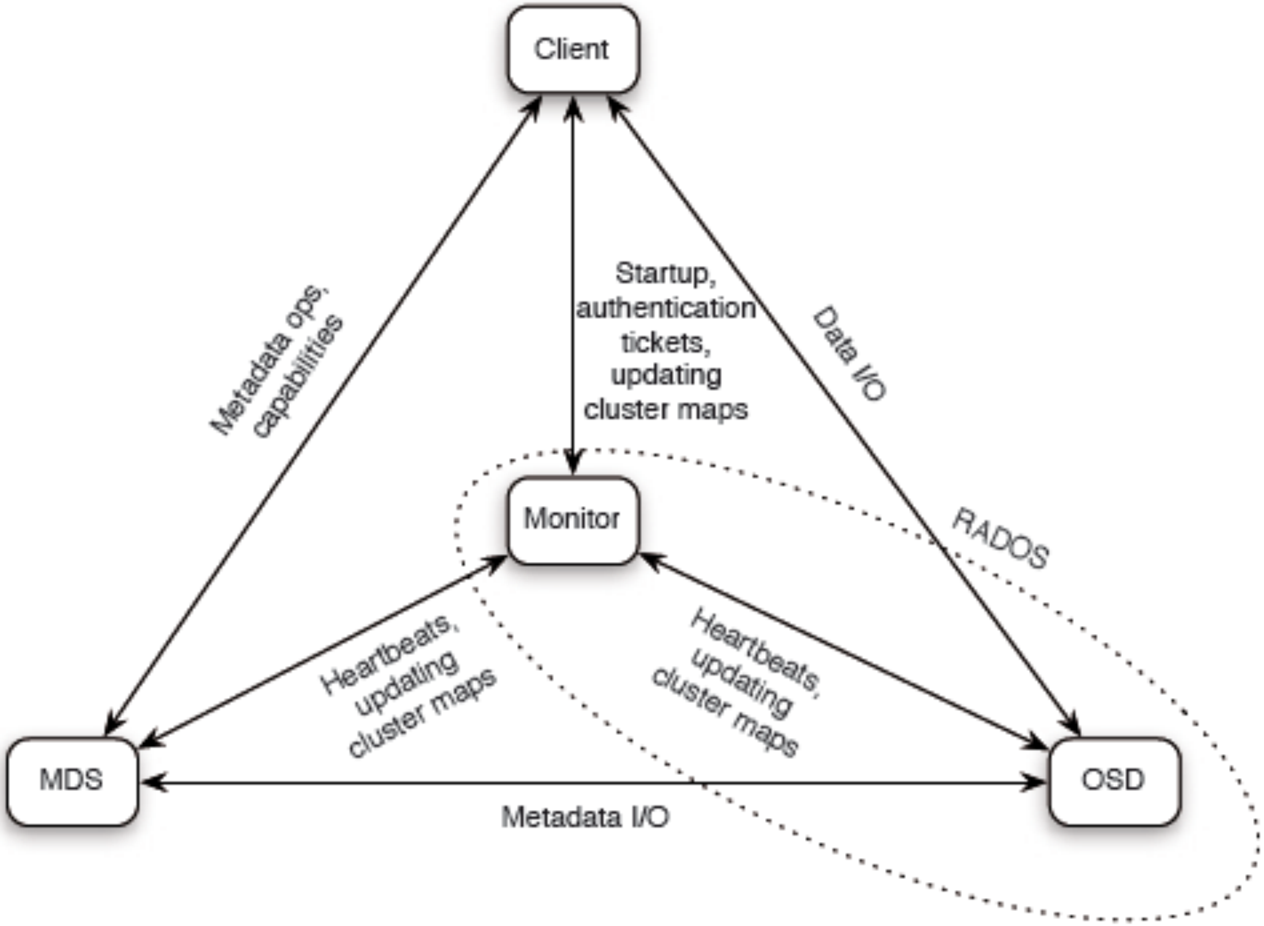
CEPH BLOCK DEVICE

- Thin-provisioned
- Images up to 16 exabytes
- Configurable striping
- In-memory caching
- Snapshots
- Copy-on-write cloning
- Kernel driver support
- KVM/libvirt support
- Back-end for cloud solutions
- Incremental backup

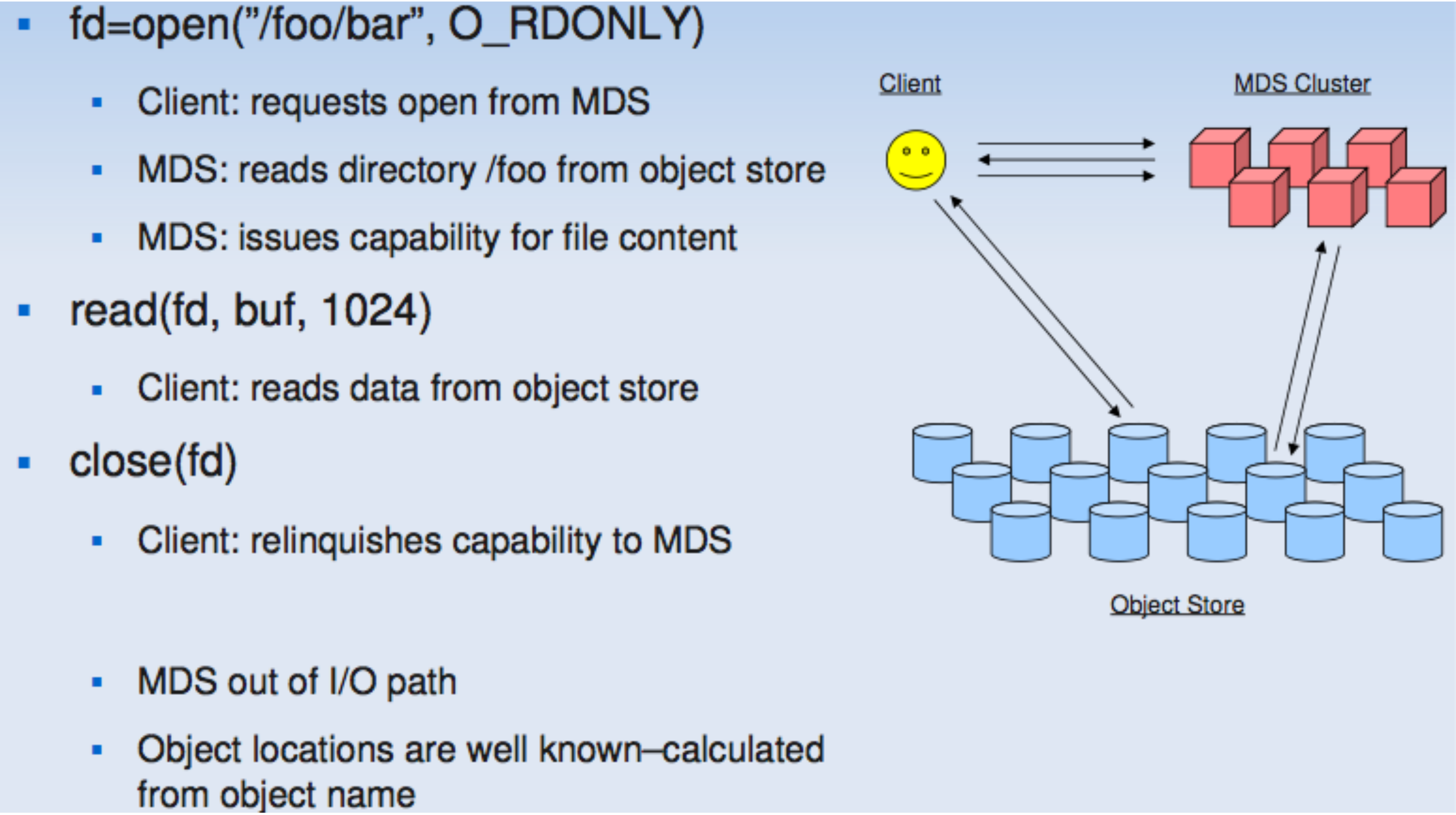
CEPH FILESYSTEM

- POSIX-compliant semantics
- Separates metadata from data
- Dynamic rebalancing
- Subdirectory snapshots
- Configurable striping
- Kernel driver support
- FUSE support
- NFS/CIFS deployable
- Use with Hadoop (replace HDFS)

# CEPH Architecture


Client
Metadata ops, capabilities
Startup, authentication tickets, updating cluster maps
Data I/O
Monitor
RADOS
Heartbeats, updating cluster maps
Heartbeats, updating cluster maps
MDS
OSD
Metadata I/O

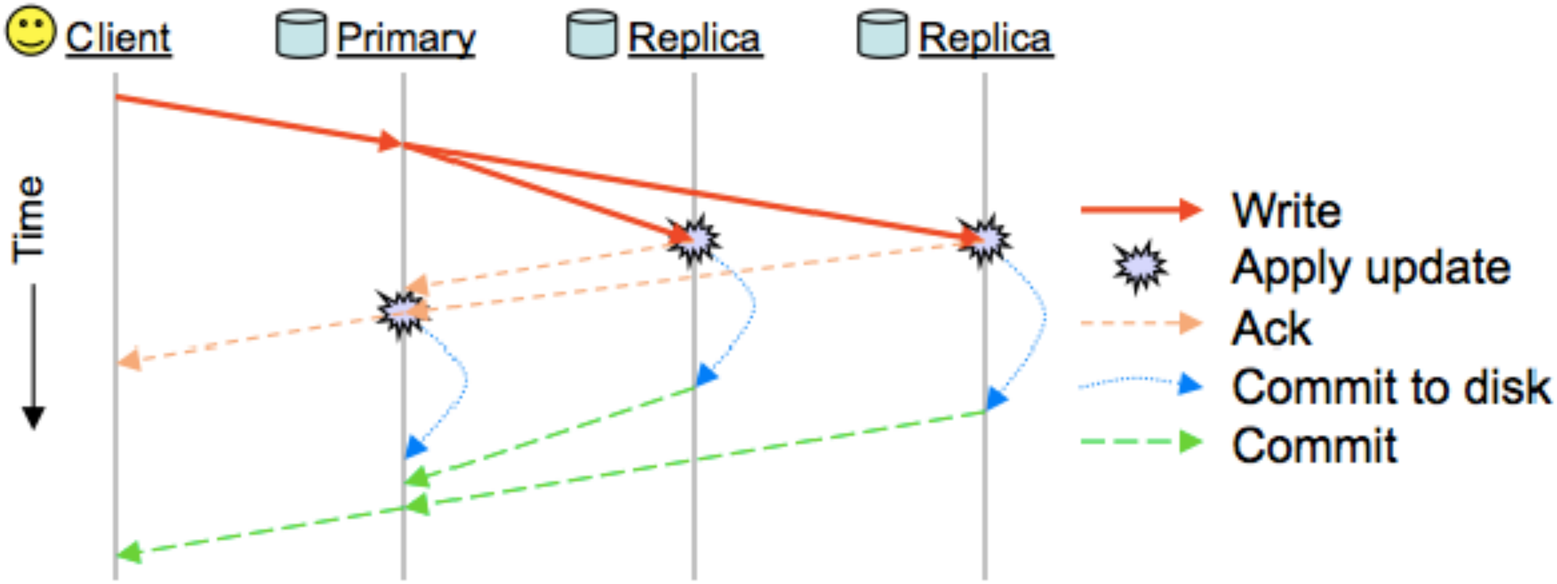
# CEPH Architecture



- fd=open("/foo/bar", O_RDONLY)
  - Client: requests open from MDS
  - MDS: reads directory /foo from object store
  - MDS: issues capability for file content
- read(fd, buf, 1024)
  - Client: reads data from object store
- close(fd)
  - Client: relinquishes capability to MDS

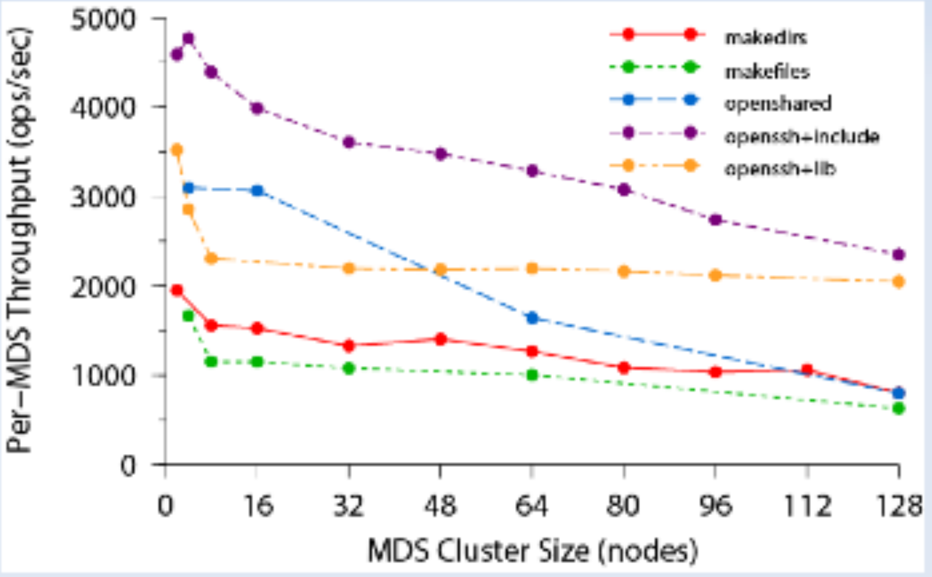
  - MDS out of I/O path
  - Object locations are well known–calculated from object name

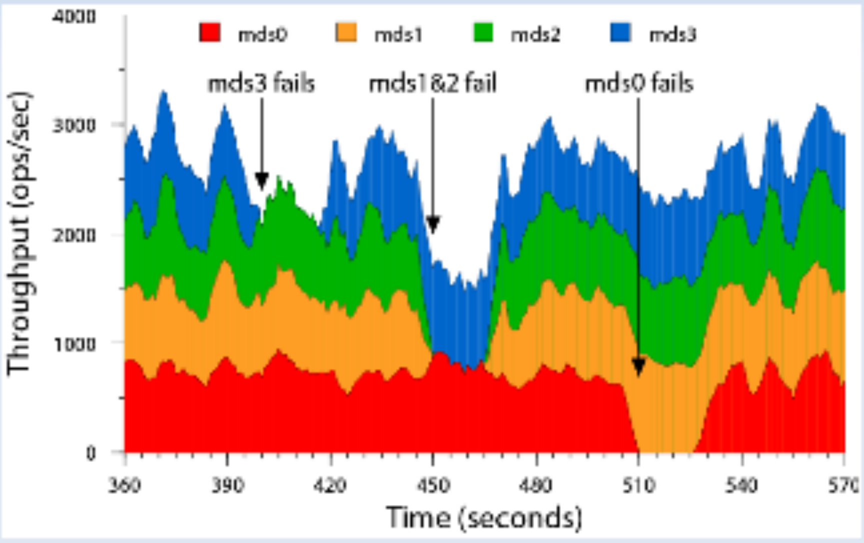
# CEPH Architecture

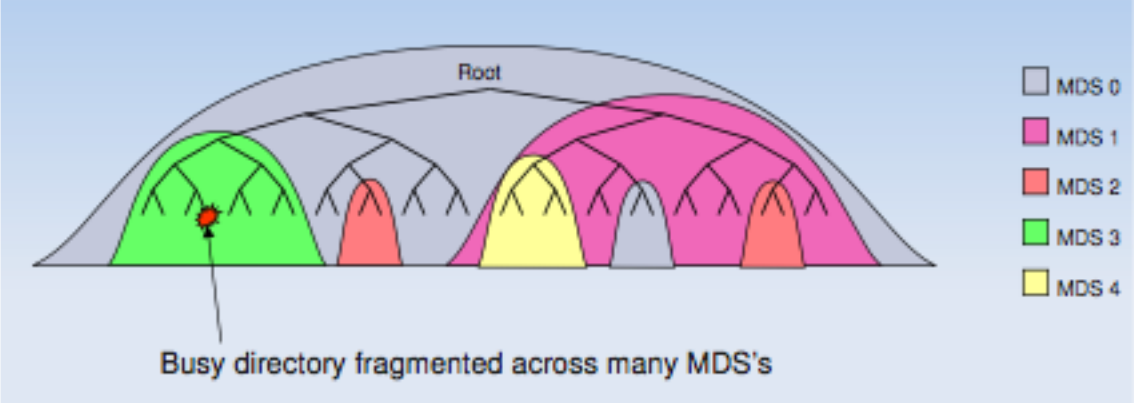


If, OSDs use Btrfs as their local file system, data is written asynchronously using copy-on-write, so that unsuccessful write operations can be fully rolled back.

# CEPH Architecture

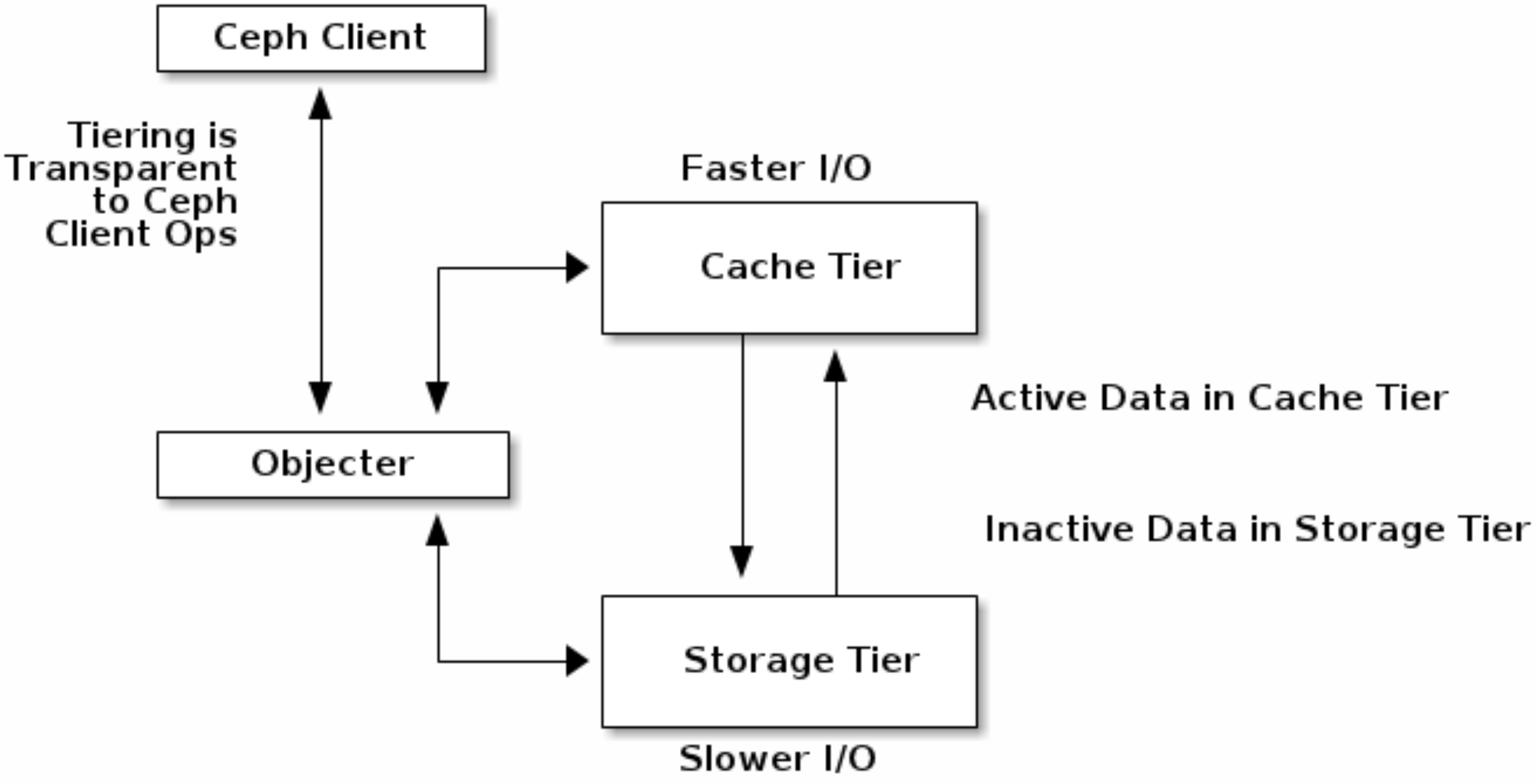






Busy directory fragmented across many MDS's

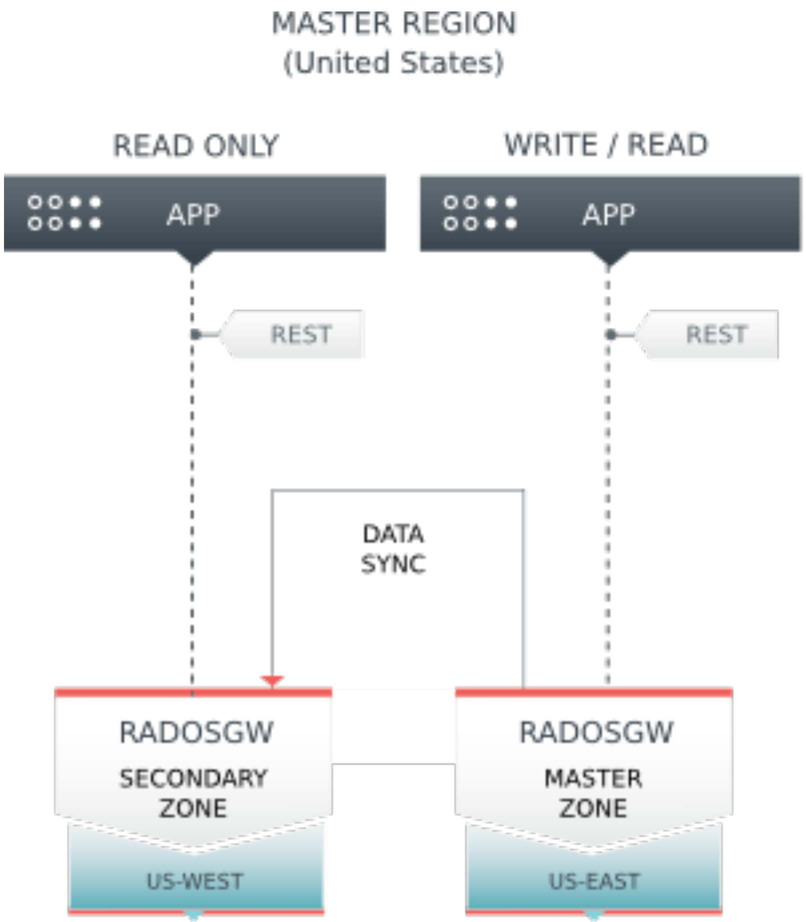
# CEPH Architecture


Ceph Client
Tiering is Transparent to Ceph Client Ops
Faster I/O
Cache Tier
Active Data in Cache Tier
Objecter
Inactive Data in Storage Tier
Storage Tier
Slower I/O

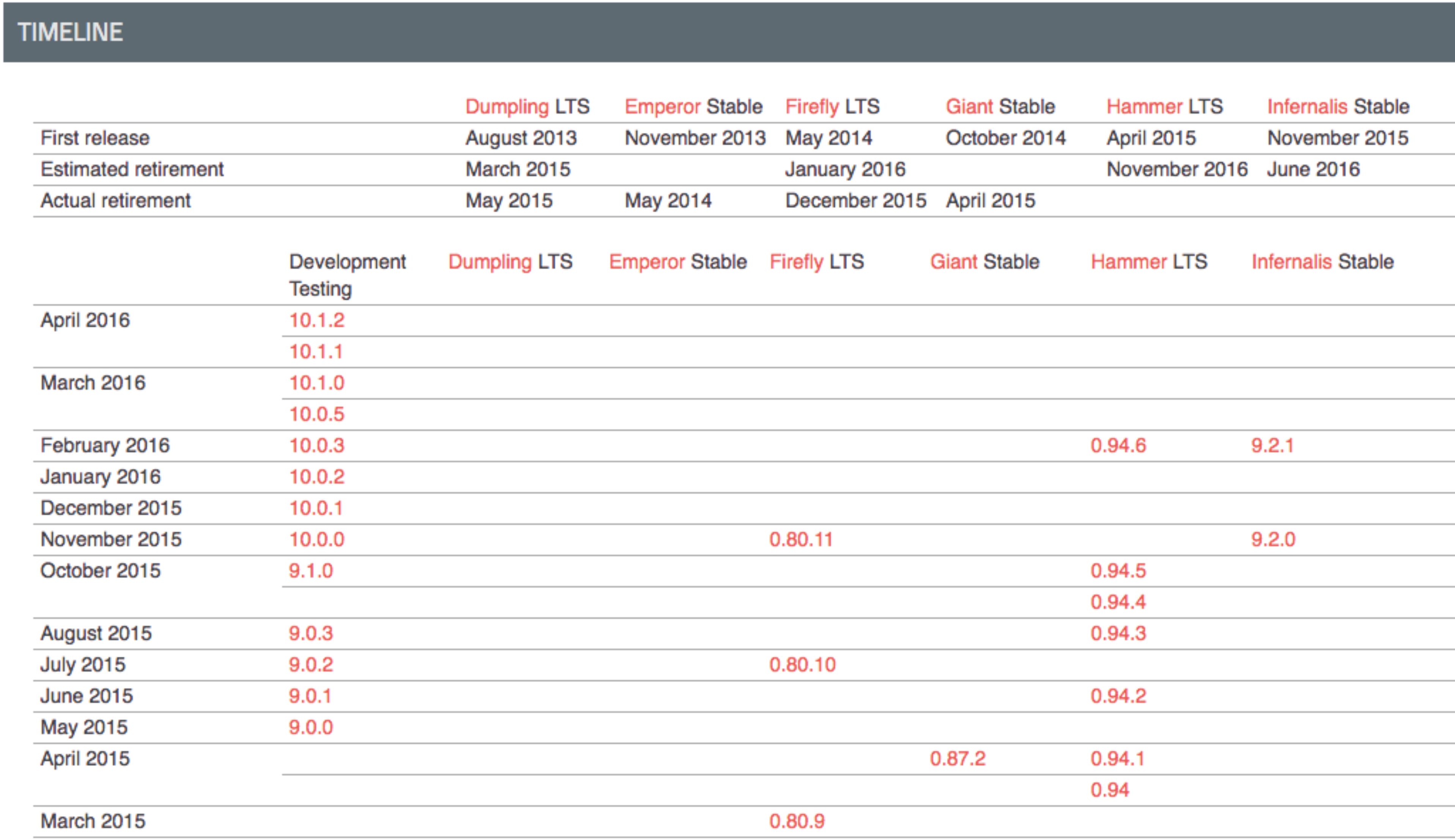
# CEPH Architecture

**Region**: A region represents a *logical* geographic area and contains one or more zones. A cluster with multiple regions must specify a master region.
**Zone**: A zone is a *logical* grouping of one or more Ceph Object Gateway instance(s). A region has a master zone that processes client requests.

**Important** Only write objects to the master zone in a region. You may read objects from secondary zones. Currently, the Gateway does not prevent you from writing to a secondary zone, but **DON'T DO IT**.



# CEPH last releases



TIMELINE

| | Dumpling LTS | Emperor Stable | Firefly LTS | Giant Stable | Hammer LTS | Infernalis Stable |
|---|---|---|---|---|---|---|
| First release | August 2013 | November 2013 | May 2014 | October 2014 | April 2015 | November 2015 |
| Estimated retirement | March 2015 | | January 2016 | | November 2016 | June 2016 |
| Actual retirement | May 2015 | May 2014 | December 2015 | April 2015 | | |

| | Development Testing | Dumpling LTS | Emperor Stable | Firefly LTS | Giant Stable | Hammer LTS | Infernalis Stable |
|---|---|---|---|---|---|---|---|
| April 2016 | 10.1.2 | | | | | | |
| | 10.1.1 | | | | | | |
| March 2016 | 10.1.0 | | | | | | |
| | 10.0.5 | | | | | | |
| February 2016 | 10.0.3 | | | | | 0.94.6 | 9.2.1 |
| January 2016 | 10.0.2 | | | | | | |
| December 2015 | 10.0.1 | | | | | | |
| November 2015 | 10.0.0 | | | 0.80.11 | | | 9.2.0 |
| October 2015 | 9.1.0 | | | | | 0.94.5 | |
| | | | | | | 0.94.4 | |
| August 2015 | 9.0.3 | | | | | 0.94.3 | |
| July 2015 | 9.0.2 | | | 0.80.10 | | | |
| June 2015 | 9.0.1 | | | | | 0.94.2 | |
| May 2015 | 9.0.0 | | | | | | |
| April 2015 | | | | | 0.87.2 | 0.94.1 | |
| | | | | | | 0.94 | |
| March 2015 | | | | 0.80.9 | | | |

# CEPH last releases

- Improved automatic rebalancing logic, which prioritizes degraded over misplaced objects
- Rebalancing operations can be temporarily disabled so they don’t impact performance
- Time-scheduled scrubbing, to avoid disruption during peak times
- Sharing of object buckets to avoid hot-spots
- Optimizations for Flash storage devices increases Ceph’s topline speed
- Read ahead caching accelerates virtual machine booting in OpenStack
- Allocation hinting reduces XFS fragmentation to avoid performance degradation over time
- Caching hinting preserves the cache’s advantages and improves performance
- S3 Object Expiration
- Swift Storage Policies

# CEPH last releases

- Erasure code:
  - Jerasure erasure code plugin
  - ISA erasure code plugin
  - Locally repairable erasure code plugin
  - SHEC erasure code plugin
- Affidabilità più che adeguata (resistenza alle failure di un numero arbitrario di OSD) ma con una ridotta perdita di spazio disco.
- *CephFS*: This is the first release in which CephFS is declared stable and production ready! Several features are disabled by default, including snapshots and multiple active MDS servers.
- A new cephfs-volume-manager module is included that provides a high-level interface for creating "shares" for OpenStack Manila and similar projects
- There is now experimental support for multiple CephFS file systems within a single cluster.

# CEPH future

- More intelligent scrubbing policies and improved peering logic to reduce impact of common operations on overall cluster performance.
- More information about objects will be provided to help administrators perform repair operations on corrupted data.
- New backend for OSDs to provide performance benefits on existing and modern drives (SSD, K/V).
- Introduction of a highly-available iSCSI interface for the Ceph Block Device, allowing integration with legacy systems
- Capabilities for managing virtual block devices in multiple regions, maintaining consistency through automated mirroring of incremental changes
- Access to objects stored in the Ceph Object Gateway via standard Network File System (NFS) endpoints, providing storage for legacy systems and applications
- Support for deployment of the Ceph Object Gateway across multiple sites in an active/active configuration (in addition to the currently-available active/passive configuration)

# Architectural considerations – Redundancy and replication considerations

- Tradeoff between Cost vs. Reliability (use-case dependent)
- Use the Crush configs to map out your failures domains and performance pools
- Failure domains
  - Disk (OSD and OS)
  - SSD journals
  - Node
  - Rack
  - Site (replication at the RADOS level, Block replication, consider latencies)
- Storage pools
  - SSD pool for higher performance
  - Capacity pool
- Plan for failure domains of the monitor nodes
- Consider failure replacement scenarios, lowered redundancies, and performance impacts

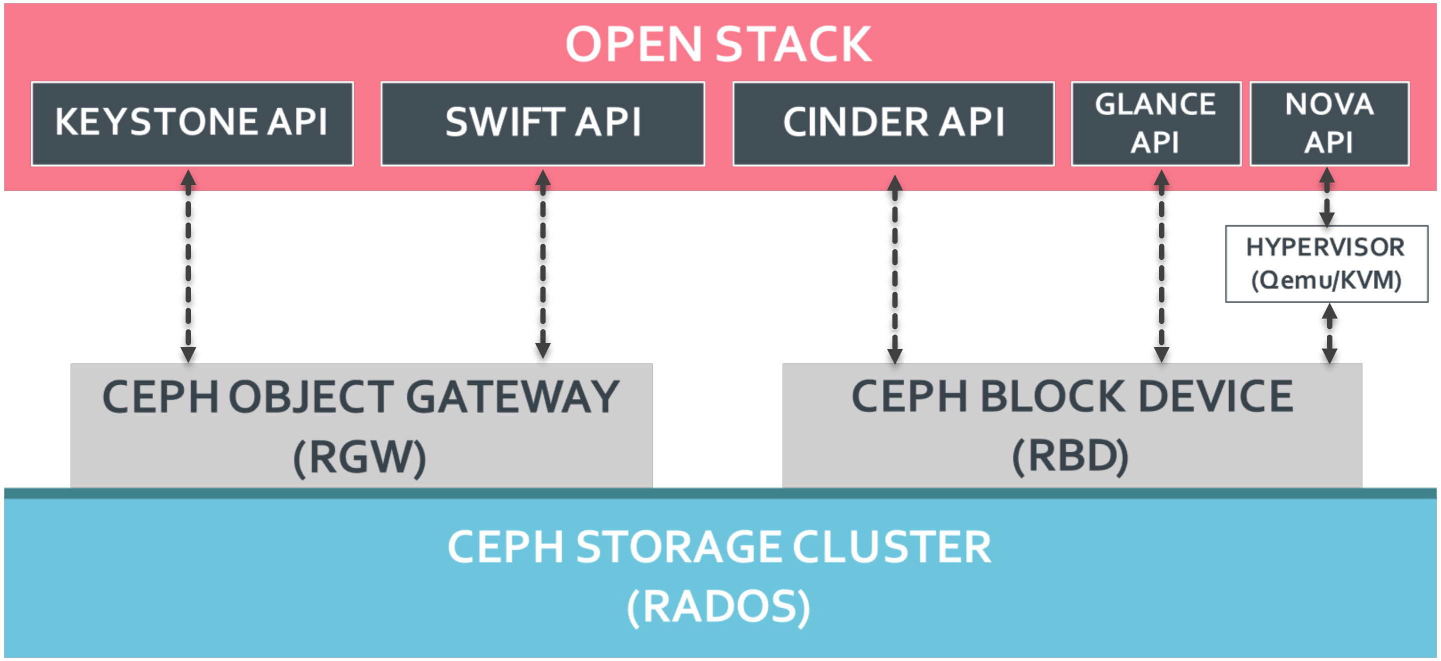
# Server Considerations

- **Storage Node:**
  - one OSD per HDD, 1 – 2 GB ram, and 1 Gz/core/OSD,
  - SSD's for journaling and for using the tiering feature in Firefly
  - Erasure coding will increase useable capacity at the expense of additional compute load
  - SAS JBOD expanders for extra capacity (beware of extra latency and oversubscribed SAS lanes)
- **Monitor nodes (MON):** odd number for quorum, services can be hosted on the storage node for smaller deployments, but will need dedicated nodes larger installations
- **Dedicated RADOS Gateway nodes** for large object store deployments and for federated gateways for multi-site

# Networking Considerations

- **Dedicated or Shared network**
  - Be sure to involve the networking and security teams early when design your networking options
  - Network redundancy considerations
  - Dedicated client and OSD networks
  - VLAN's vs. Dedicated switches
  - 1 Gbs vs 10 Gbs vs 40 Gbs!
- **Networking design**
  - Spine and Leaf
  - Multi-rack
  - Core fabric connectivity
  - WAN connectivity and latency issues for multi-site deployments

# CEPH & OpenStack


OPEN STACK

KEYSTONE API

SWIFT API

CINDER API

GLANCE API

NOVA API

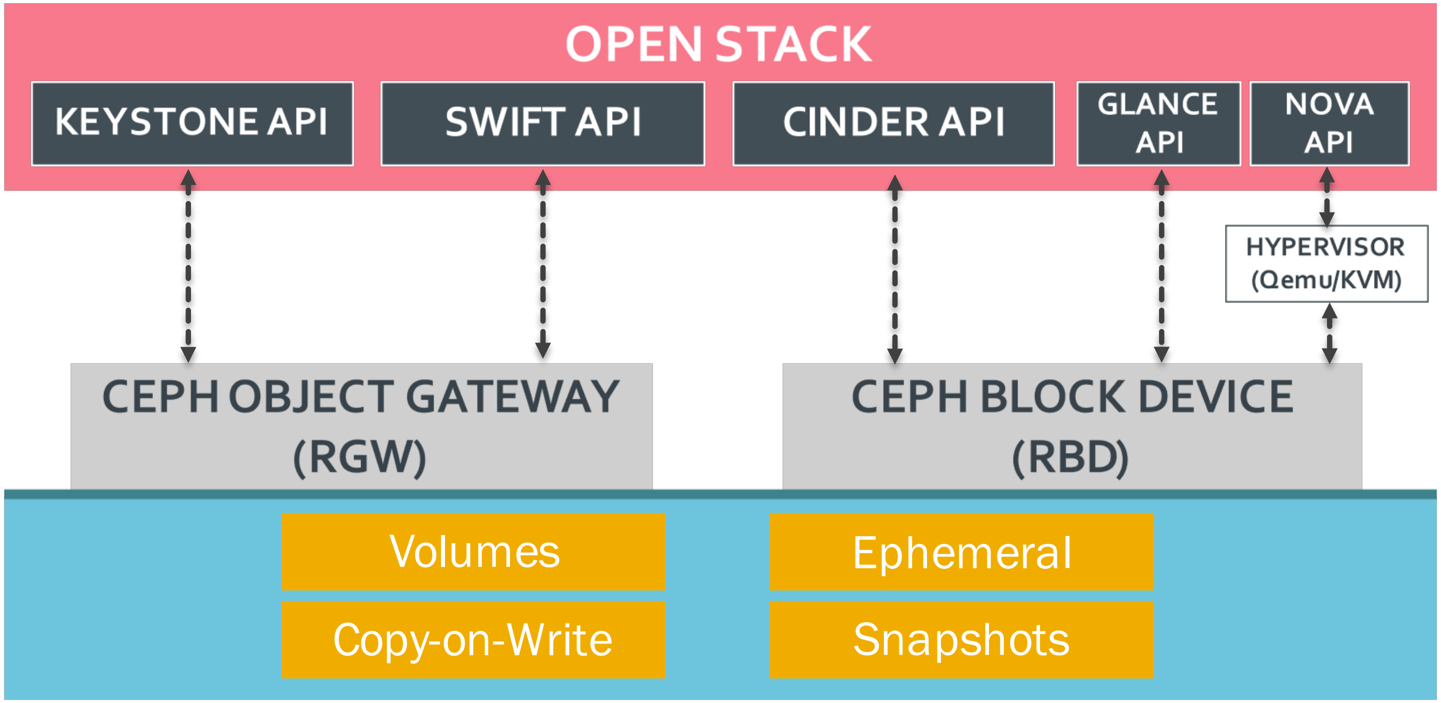
HYPERVISOR (Qemu/KVM)

CEPH OBJECT GATEWAY (RGW)

CEPH BLOCK DEVICE (RBD)

CEPH STORAGE CLUSTER (RADOS)

# CEPH & OpenStack



OPEN STACK

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CEPH BLOCK DEVICE (RBD)

Volumes

Copy-on-Write

Ephemeral

Snapshots

# Link Utili

- https://ceph.com/docs/master/architecture/
- http://ceph.com/docs/master/start/intro/
- http://ceph.com/docs/master/release-notes/
- http://cephnotes.ksperis.com/blog/2015/02/02/crushmap-example-of-a-hierarchical-cluster-map
- http://ceph.com/papers/weil-crush-sc06.pdf