Introduction To Ceph

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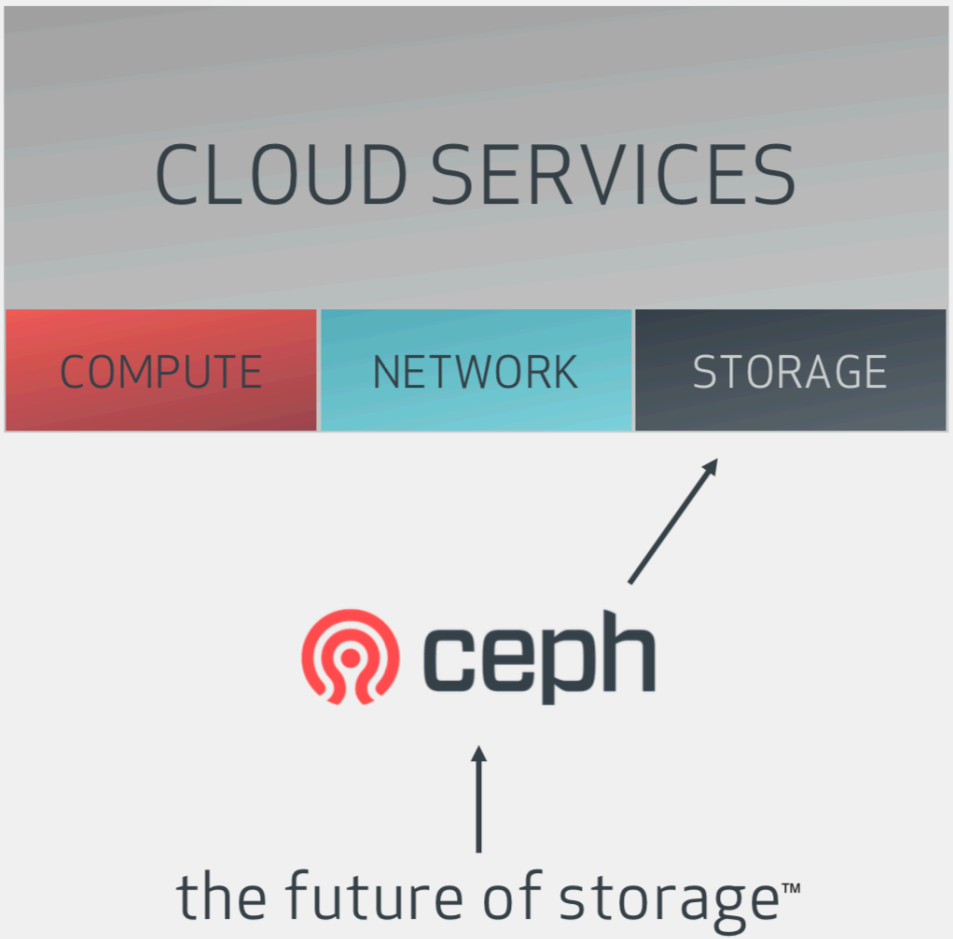
Infrastructure @ Shannon

January 3, 2019


CLOUD SERVICES
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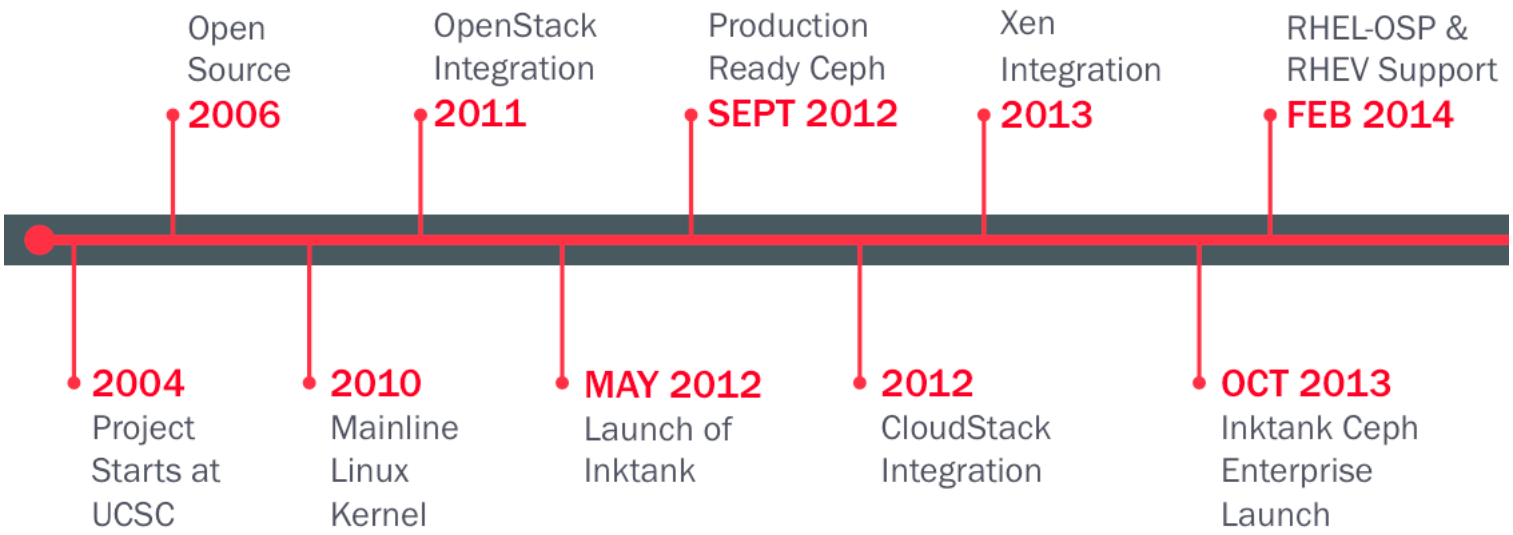
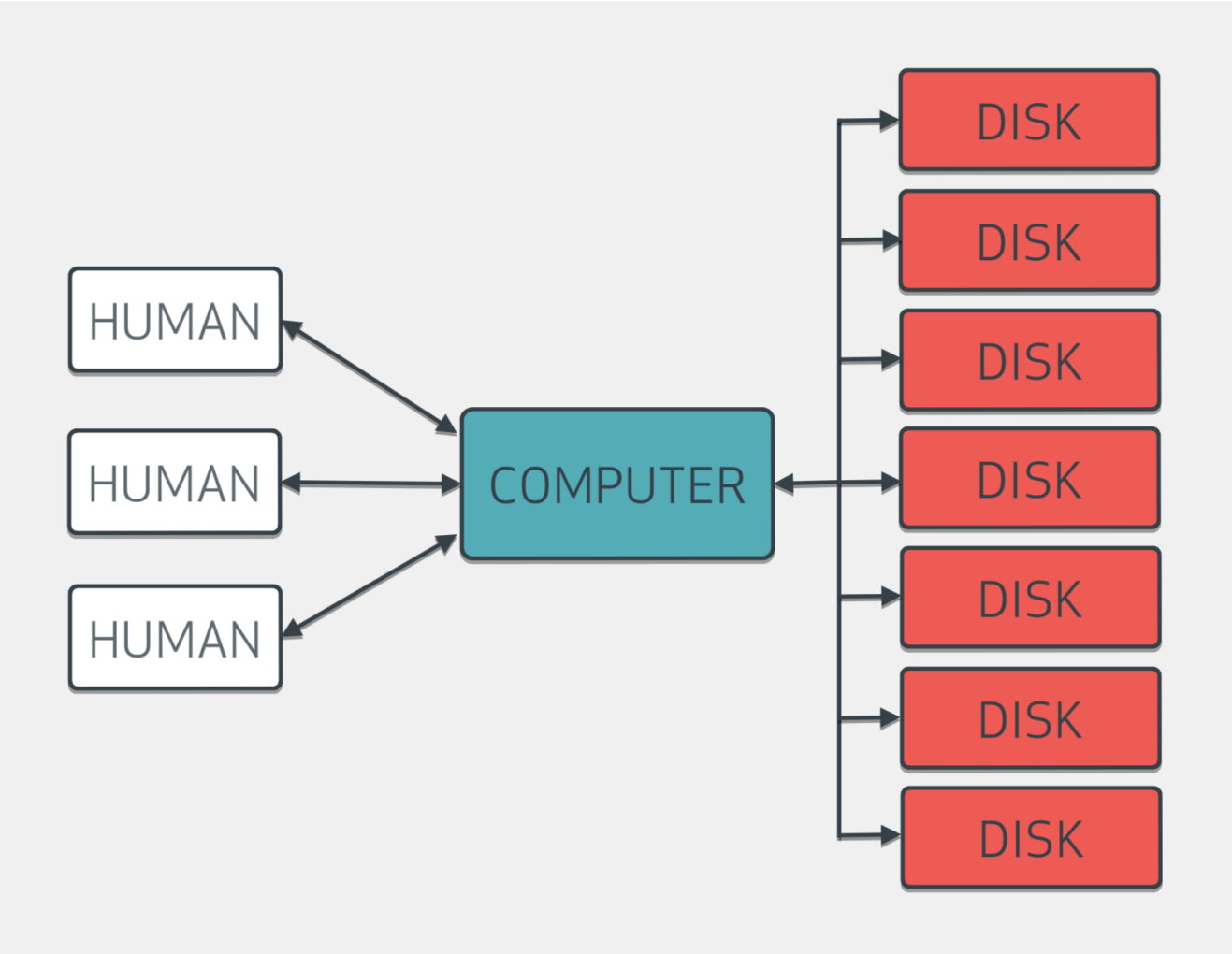
NETWORK
STORAGE
ceph
the future of storage™

Timeline of Ceph

Original author: **sage weil**

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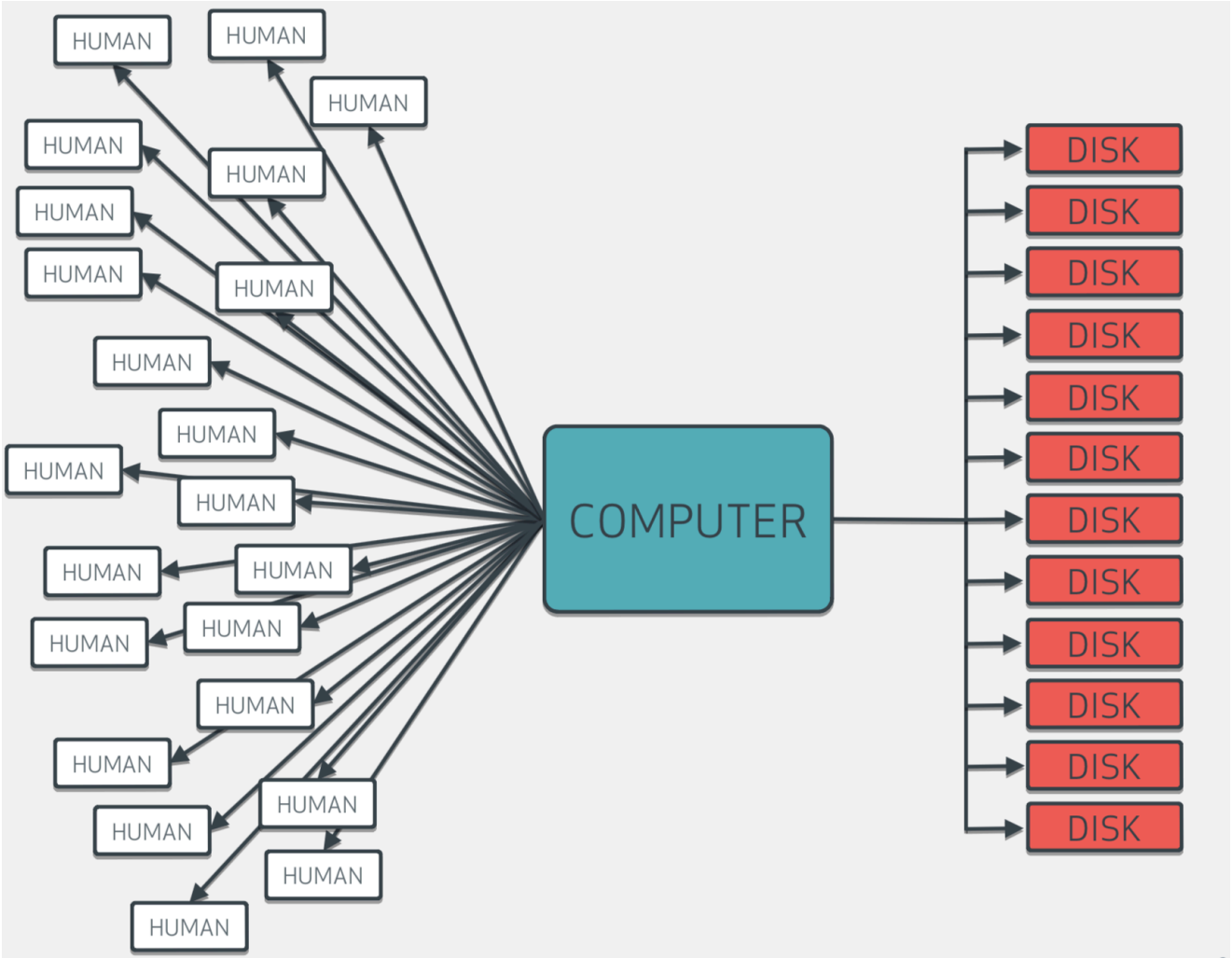
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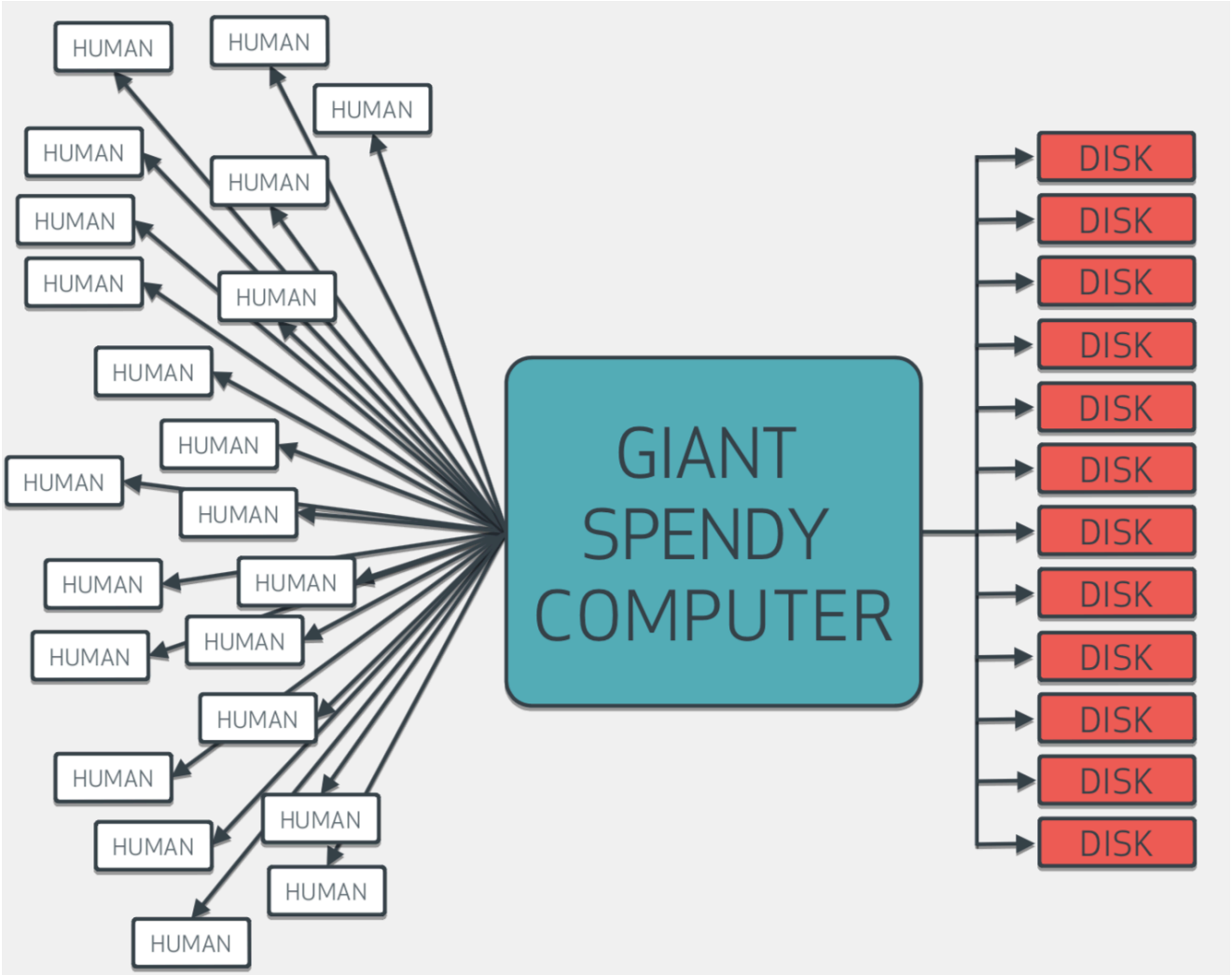
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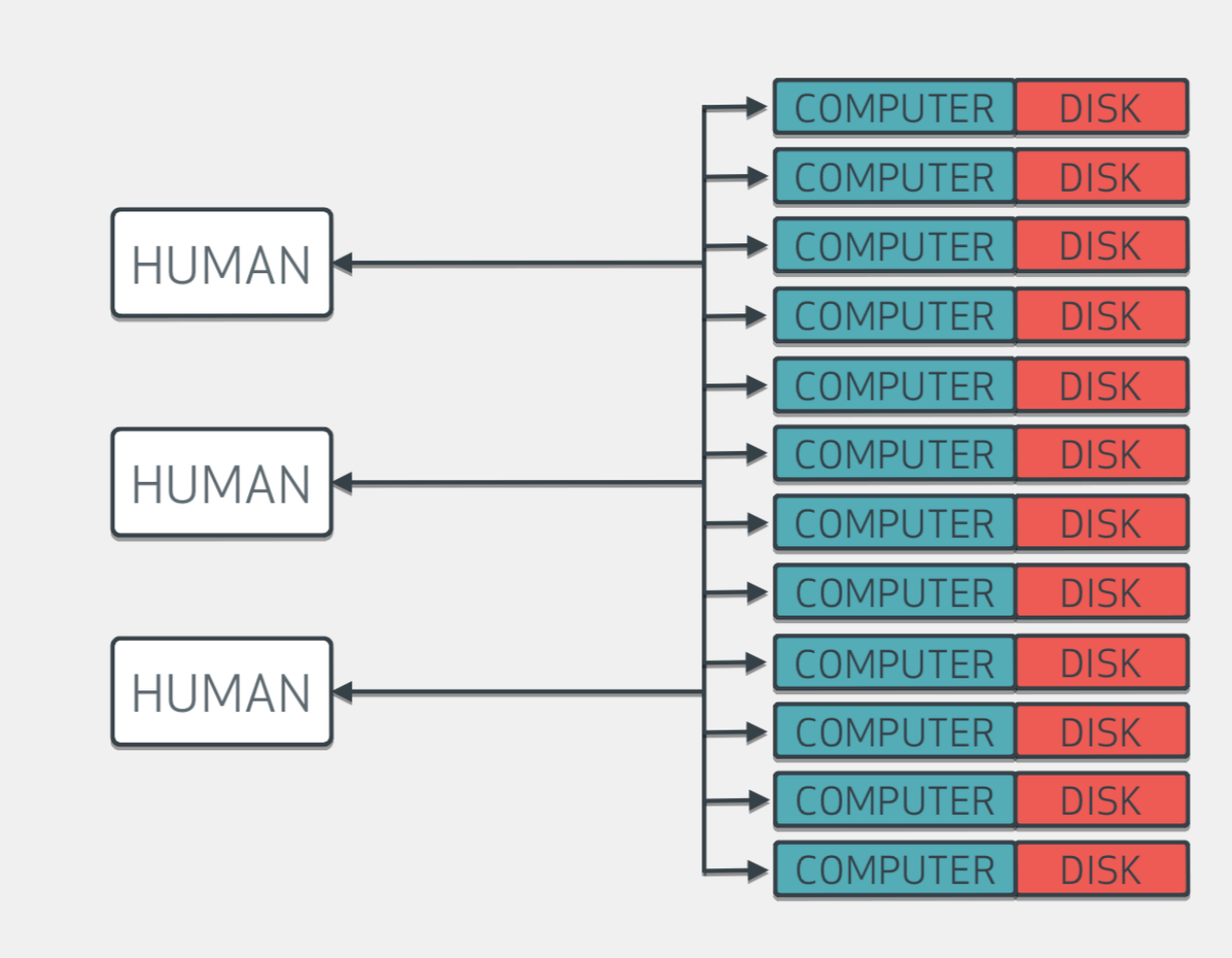
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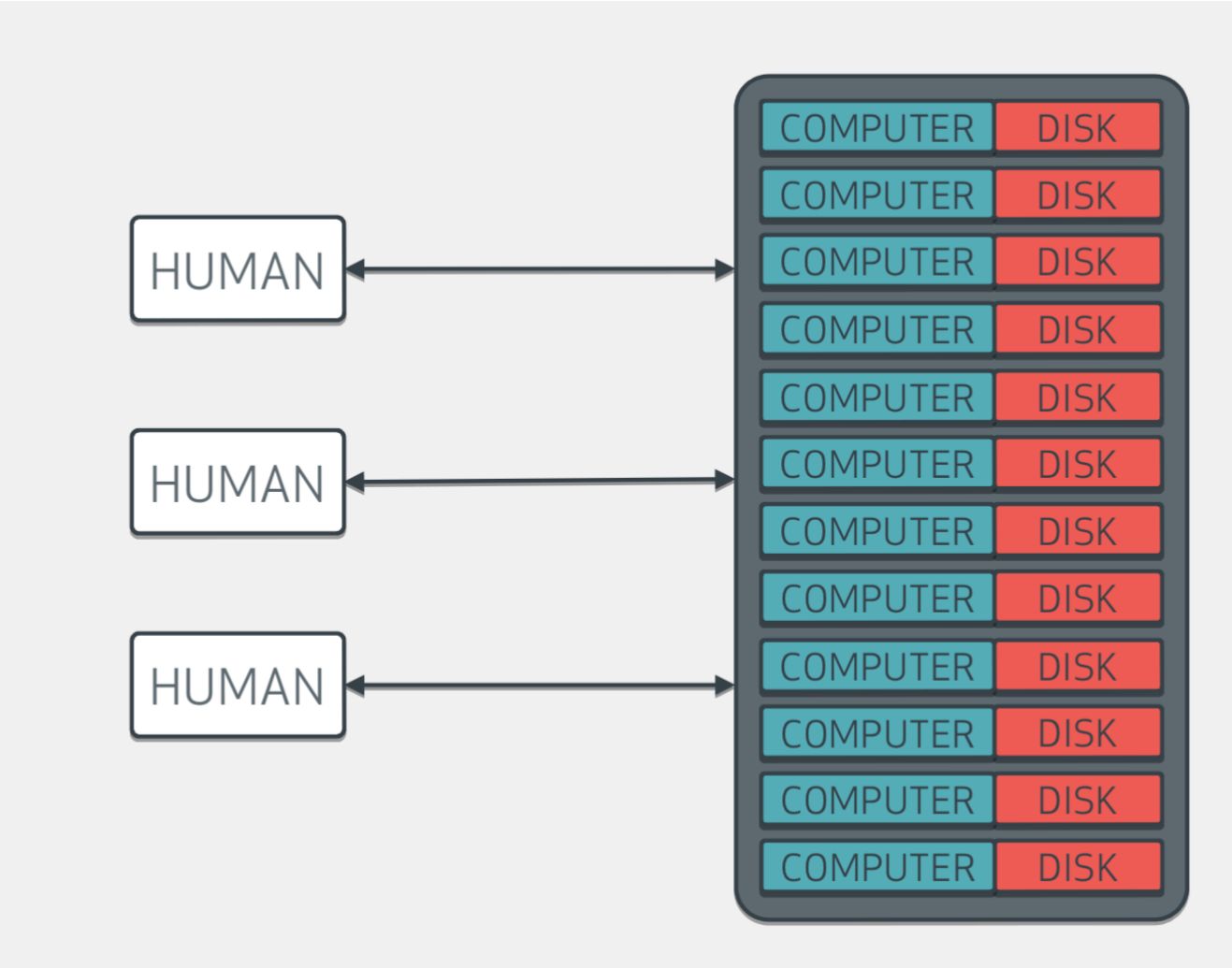
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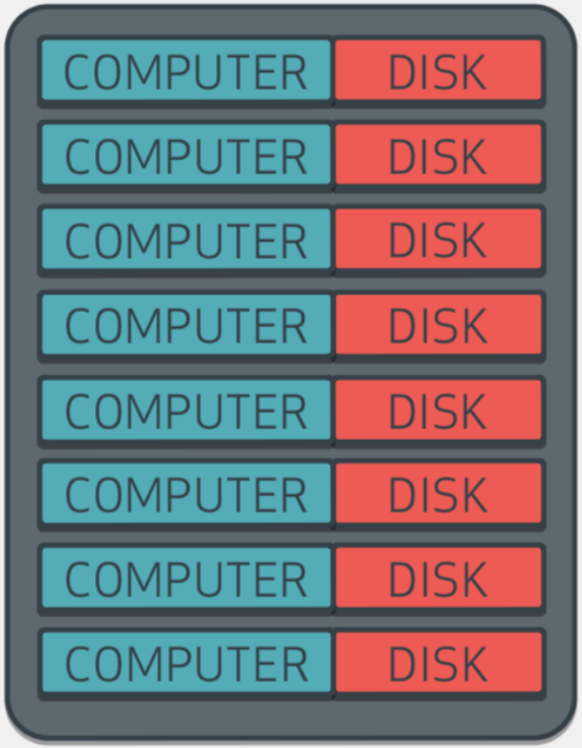
"STORAGE APPLIANCE"



Storage Challenges

- **Must Support Current Infrastructures**
  - Block storage with snapshots, cloning
  - File storage with POSIX support
- **Must plan for integration of emerging technologies**
  - Cloud infrastructures and SDNs
- **Must Support New Challenges**
  - Object storage to support massive influx of unstructured data
- All this while supporting:
  - **Massive data growth -> scalability**
  - **Mixed hardware that must work heterogeneously**
  - **Maintain reliability and fault tolerance**
  - **Performance!**

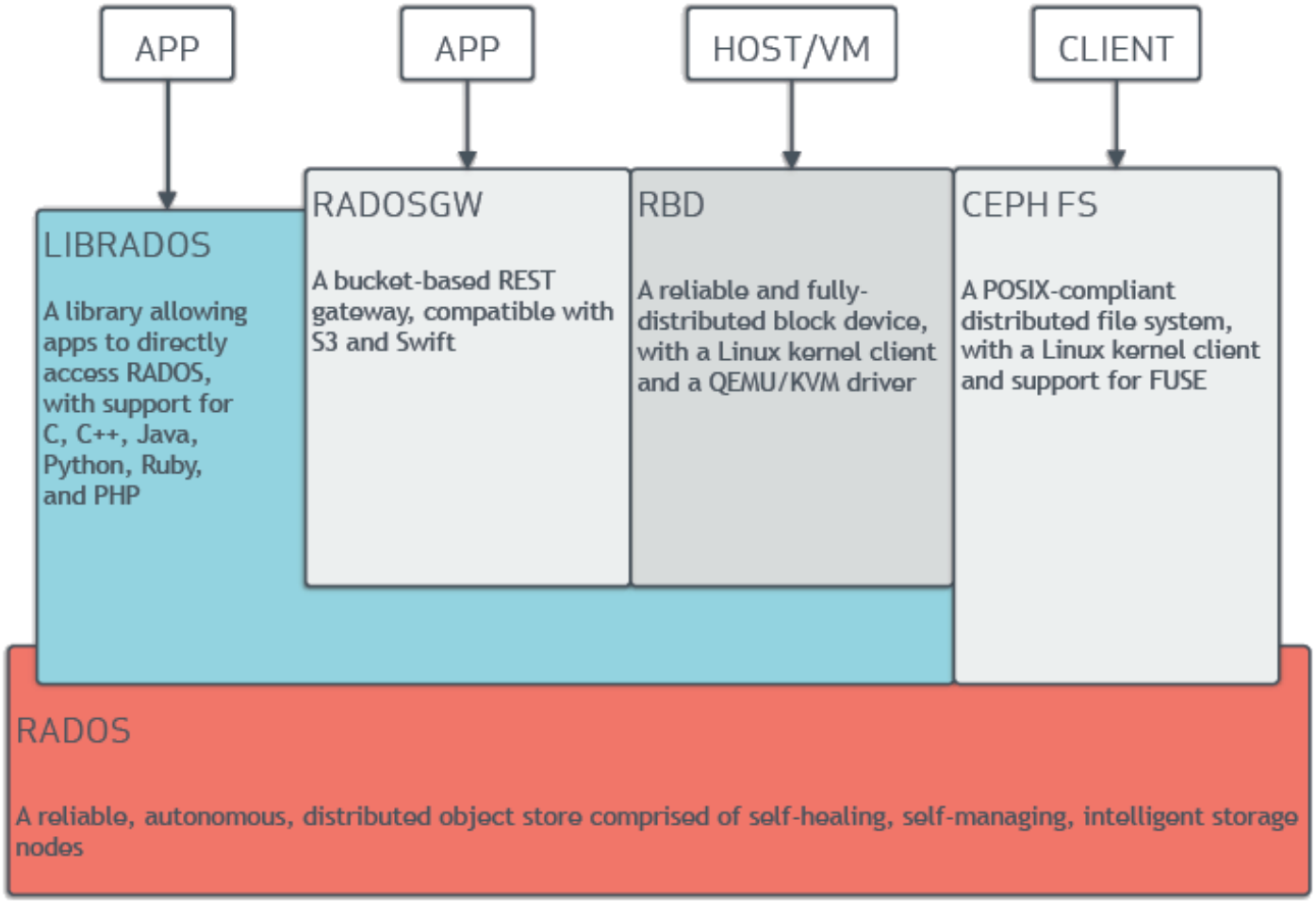
Ceph Features

- **Hardware Agnostic**
  Runs on commodity servers with directly attached storage. Not locked in a specified hardware platform.
- **Flexible**
  Can define pools of storage with differenct redundancy rules, disk types, geographic placement, depending on user requirements.
- **Scalable**
  In both bandwidth and capacity. No metadata servers. Silent clients do not generate network traffic/cluster load.
- **Self-Healing**
  Recovers automatically after disk or server failures.

Ceph: Unified File Storage

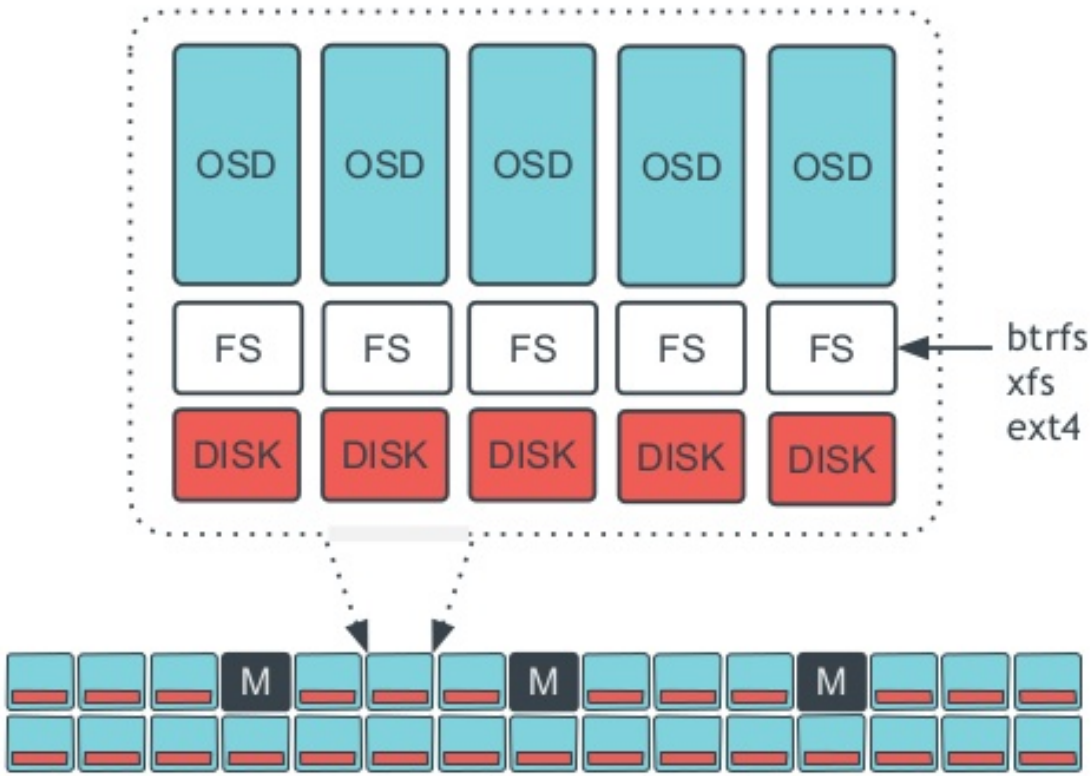
- **Object**
  - Native LIBRADOS (Reliable Autonomic Distributed Object Store)
  - RADOS Gateway provides S3/Swift REST API compatibility
- **Block**
  - Linux kernel (krbd) and KVM(librbd) support
  - provides snapshotting and cloning capabilities
- **File**
  - CephFS support file system

Ceph Stack


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, autonomous, distributed object store comprised of self-healing, self-managing, intelligent storage nodes

Outline

Ceph Cluster



Monitors

- **Maintain the cluster map**
  - MON map
  - OSD map
  - MDS map
  - PG map
  - CRUSH map
- **Provide consensus for distributed decision making**
  - Each MON knows about all the other MONs in the cluster
  - First establish a quorum of more than half of MONs so an odd number of MONs is needed in the cluster
  - MONs in a quorum can distribute maps to OSDs and clients. Clients request cluster maps from a MON only when the primary OSD fails
- **Monitors are not in data path**

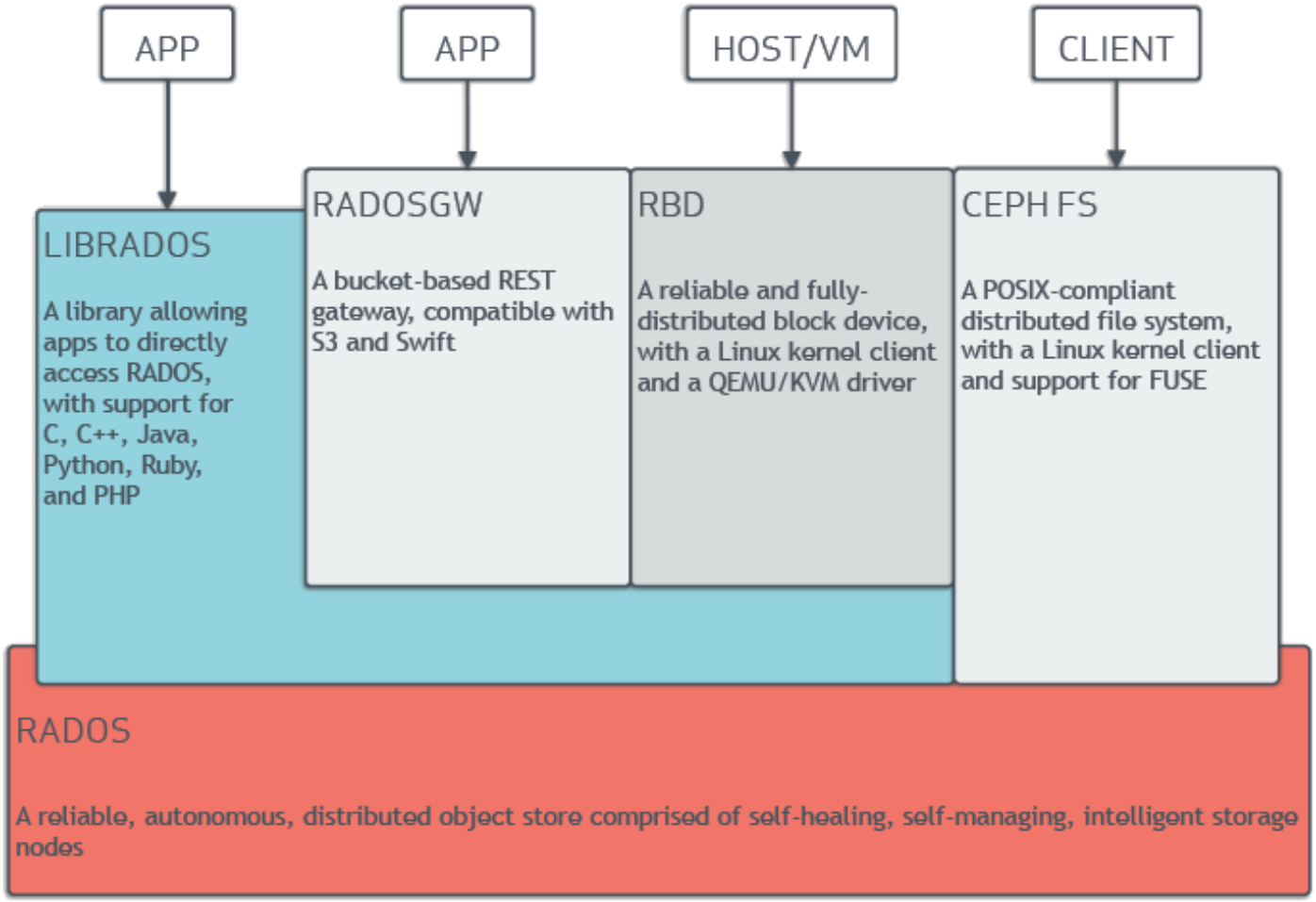
Object Storage Node

- **Object Storage Device (OSD)**
  - Building block of Ceph Storage Cluster
  - One hard disk
  - One Linux File System
  - One Ceph OSD Daemon
- **File System:**
  - File system must be btrfs, xfs or ext4
  - Have the XATTRs enabled

Ceph OSD Daemon

- **Ceph Object Storage Device Daemon**
  - Serve stored objects to clients
- **OSD is primary for some objects**
  - Responsible for replication
  - Responsible for coherency
  - Responsible for re-balancing
  - Responsible for recovery
- **OSD is secondary for some objects**
  - Under the control of the primary
  - Capable of becoming primary
- **Supports extended objects classes**
  - Atomic transactions
  - Synchronization and notifications

Ceph Stack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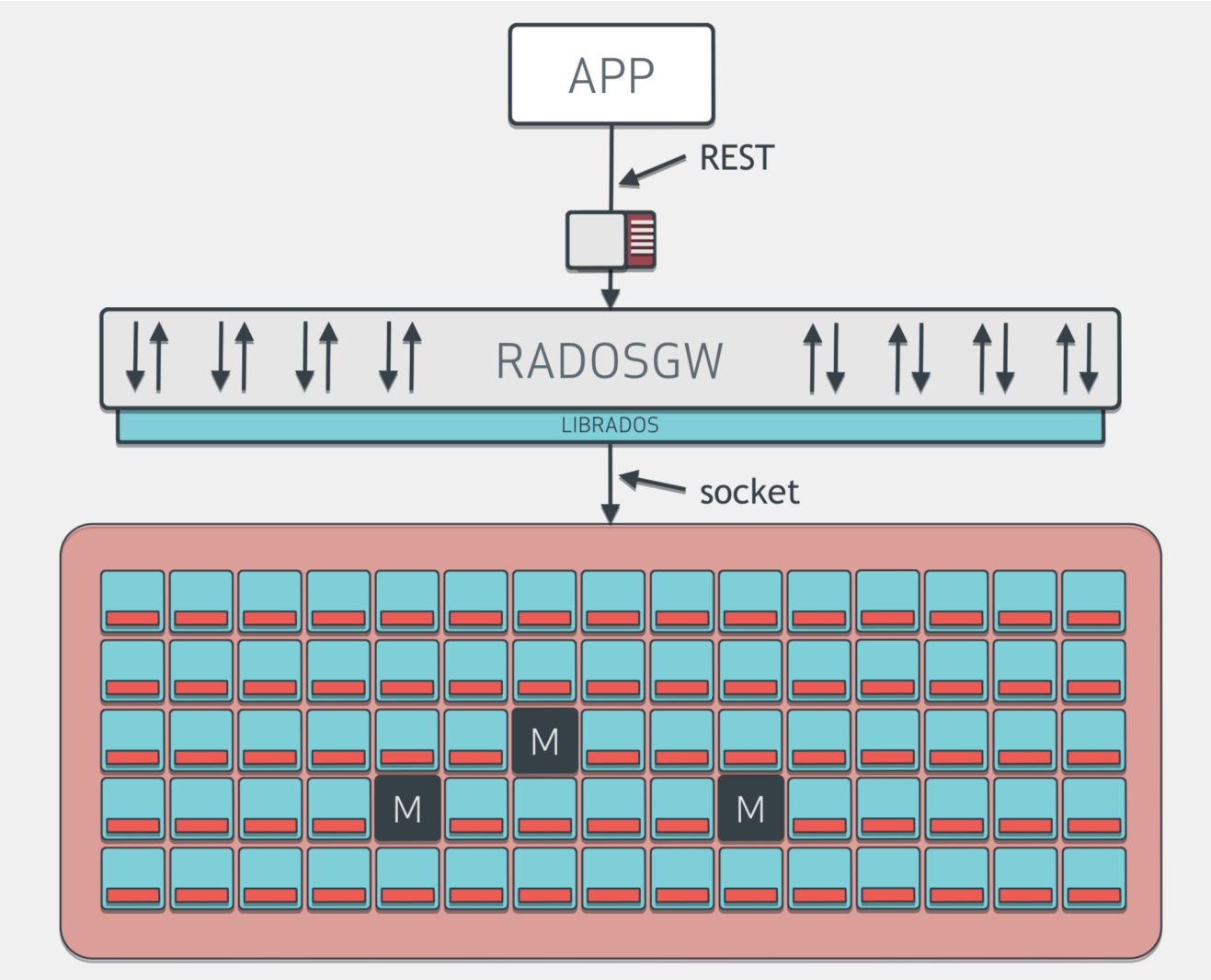
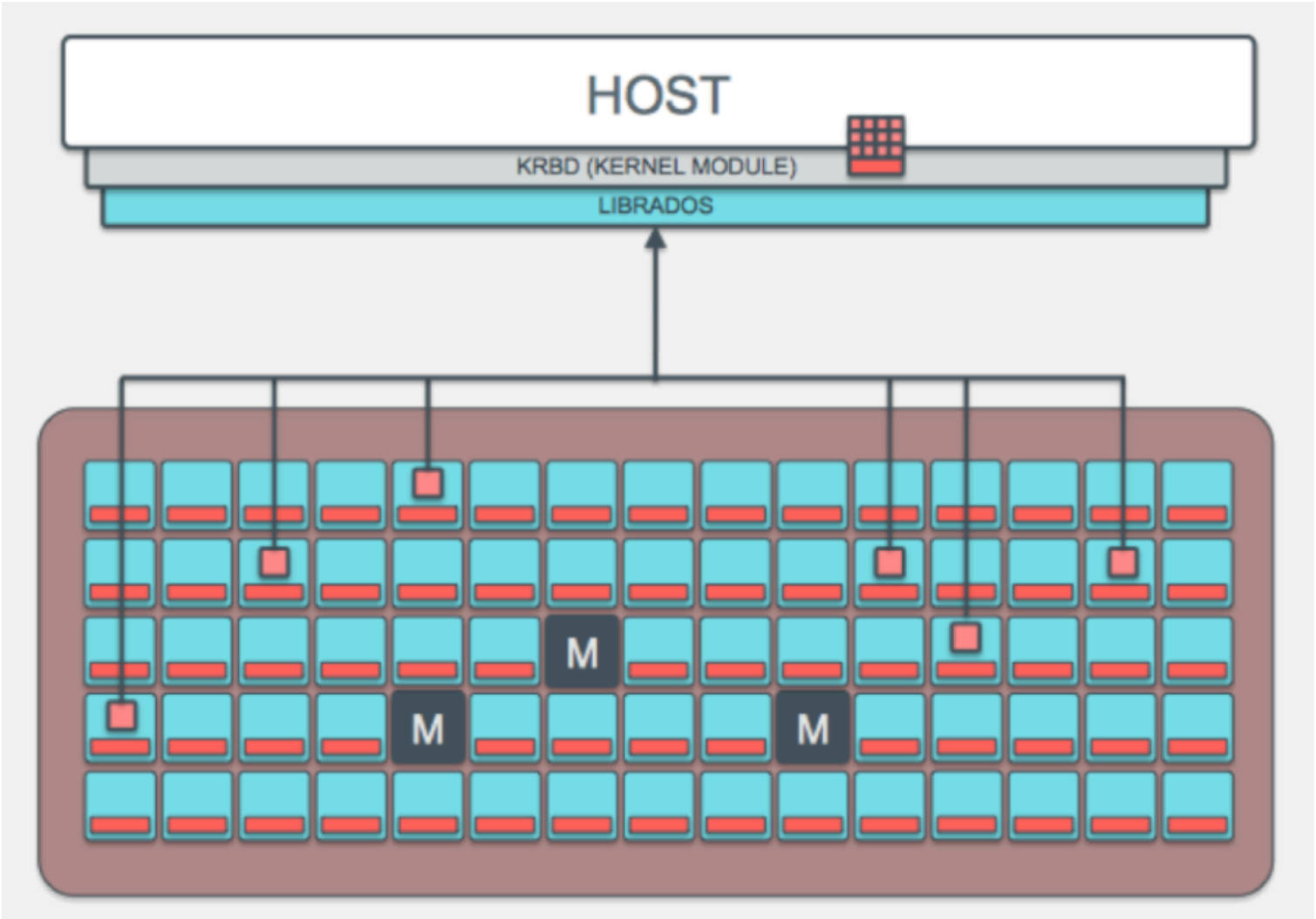
Communication Methods

Ceph Service	Method	Description
N/A	*librados*	Library that provides direct access to RADOS for applications
Ceph Object Gateway	*radosgw*	RESTful APIs for S3 and Swift compatibility
Ceph File System	*libcephfs*	Library that provides access to Ceph Cluster via a POSIX-like interface
Ceph Block Device	*librbd*	Python module, provides file-like access to RBD images

RADOSGW



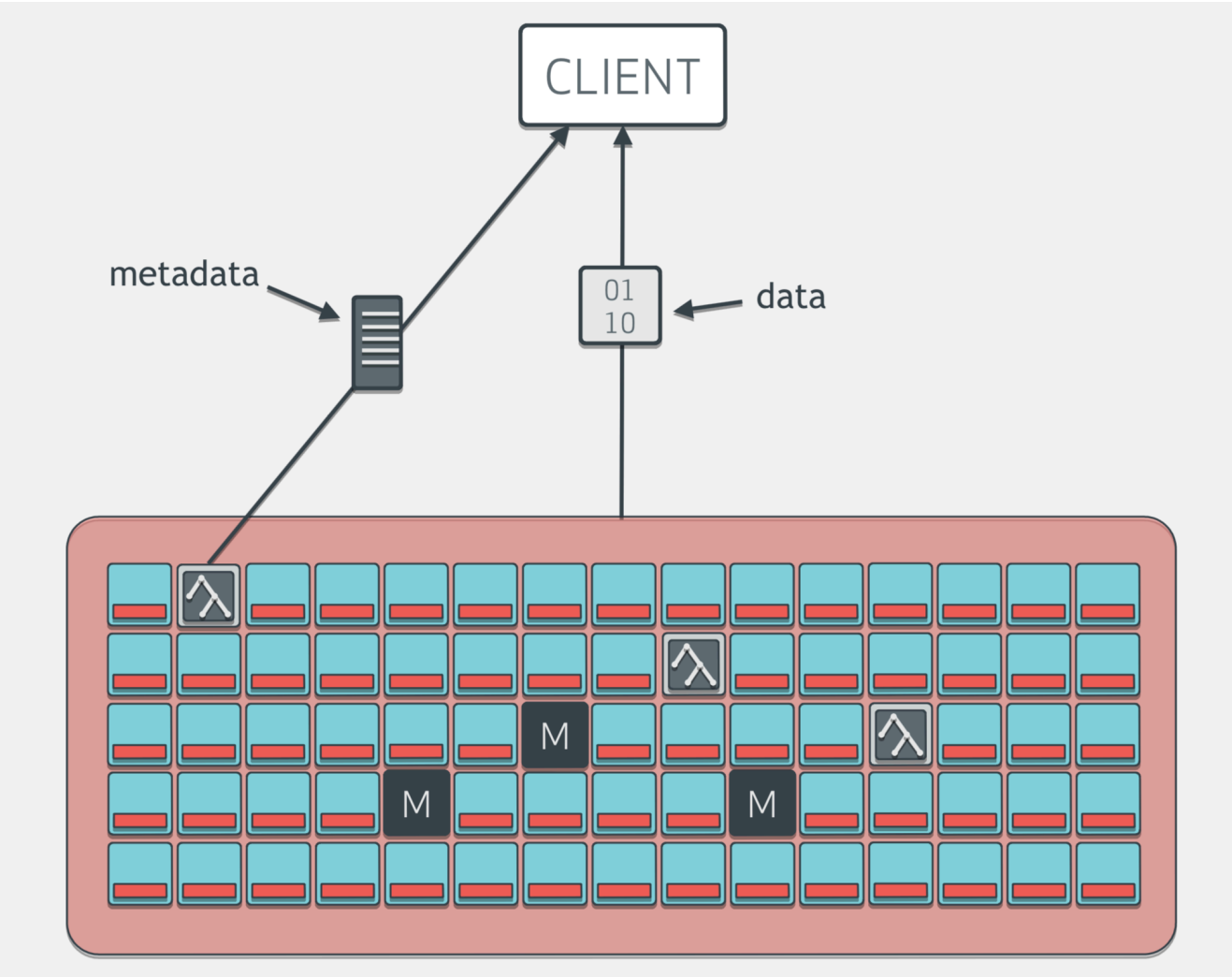
RBD



Metadata Server(MDS)

- **Manages metadata for a POSIX-compliant shared file system**
  - Directory Hierarchy
  - File Metadata(owner, timestamps, mode, etc)
  - Stores metadata in Rados
  - Does not access file content
  - Only required for shared file system
- **The Ceph Metadata Server daemon**
  - Provides the POSIX information needed by file systems that enables CephFS to interact with the Ceph Object Store
  - It remembers where data lives within a tree
  - Client accessing CephFS data first make a request to an MDS, which provides what they need to get files from the right OSDs
- If you aren't running CephFS, MDS daemons do not need to be deployed.

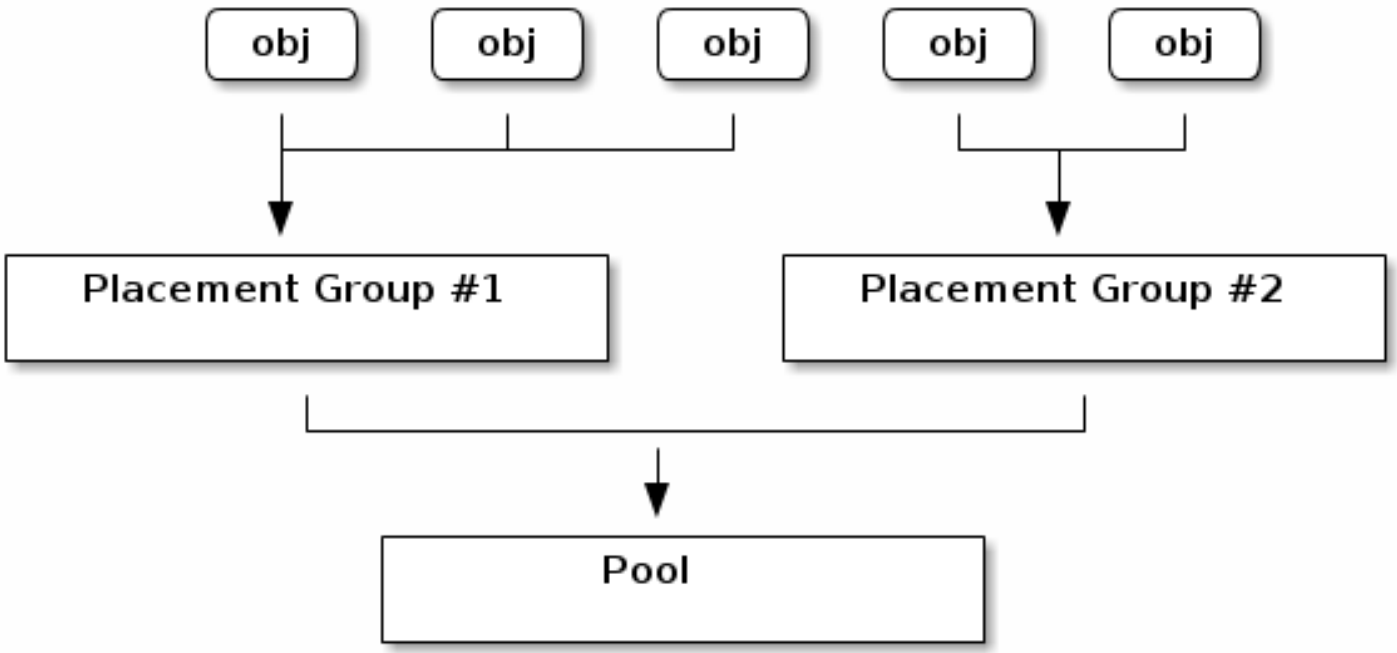
CephFS



Ceph Cluster

```
ubuntu@ip-172-31-58-195:~# ceph -s
  cluster:
    id:     ccb00027-ca55-48cc-bf5a-b6cbf79c9b99
    health: HEALTH_OK

  services:
    mon: 3 daemons, quorum ip-172-31-56-105,ip-172-31-57-232,ip-172-31-58-195
    mgr: ip-172-31-56-105(active), standbys: ip-172-31-57-232, ip-172-31-58-195
    mds: cephfs-1/1/1 up  {0=ip-172-31-58-195=up:active}, 2 up:standby
    osd: 4 osds: 3 up, 3 in
    rgw: 1 daemon active

  data:
    pools:   8 pools, 184 pgs
    objects: 268  objects, 37 MiB
    usage:   3.1 GiB used, 87 GiB / 90 GiB avail
    pgs:     184 active+clean
```

Pools and Placement Groups



Pools

- **What are pools?**
  - Pools are logical partitions for storing object data
- **Pools have the following attributes:**
  - Set ownership/access
  - Set number of object replicas
  - Set number of placement groups
  - Set the CRUSH rule set to use
- **The PGs within a pool are dynamically mapped to OSDs**

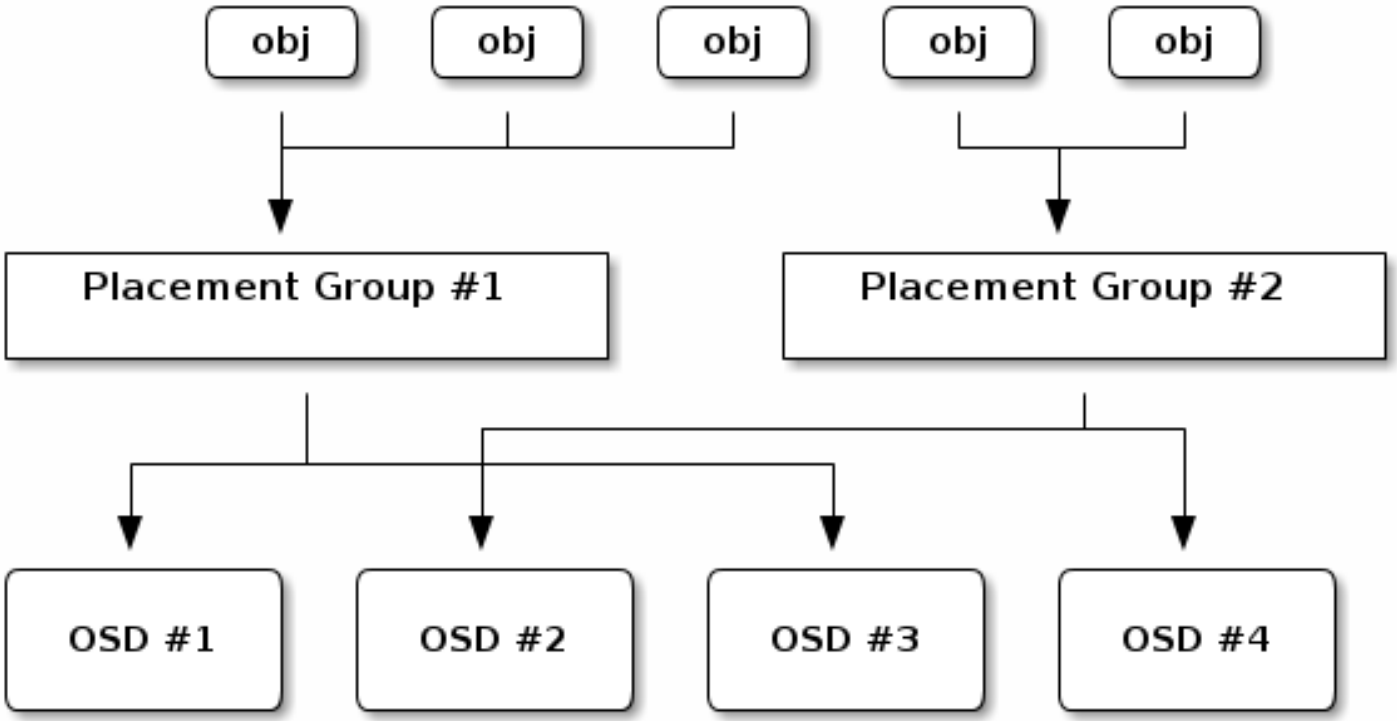
Pools

```
ubuntu@ip-172-31-58-195:~# ceph osd lspools
1 .rgw.root
2 default.rgw.control
3 default.rgw.meta
4 default.rgw.log
5 cephfs_data
6 cephfs_metadata
7 rbd
8 default.rgw.buckets.index
ubuntu@ip-172-31-58-195:~# rados df
POOL_NAME                  USED OBJECTS CLONES COPIES ... RD_OPS       RD WR_OPS      WR
cephfs_data                 28 B       2      0      6 ...      2    1 KiB      2  2 KiB
cephfs_metadata            13 KiB      22      0     66 ...      5    5 KiB     91 46 KiB
...
rbd                        37 MiB      19      0     57 ...   2522 5.3 MiB   1313 81 MiB

total_objects    268
total_used       3.1 GiB
total_avail      87 GiB
total_space      90 GiB
ubuntu@ip-172-31-58-195:~#  ceph osd pool create {pool-name} {pg-num} [{pgp-num}]
```

Placement Groups (PGs)

- **What is a PG?**
  - A PG is a logical collection of objects
  - Objects within the PG are replicated by the same set of OSDs
- **How to choose the PG?**
  - An object's PG is determined by hashing the object name against the number of PGs in the pool
  - A PG's location is determined by CRUSH according to desired protection and placement strategies

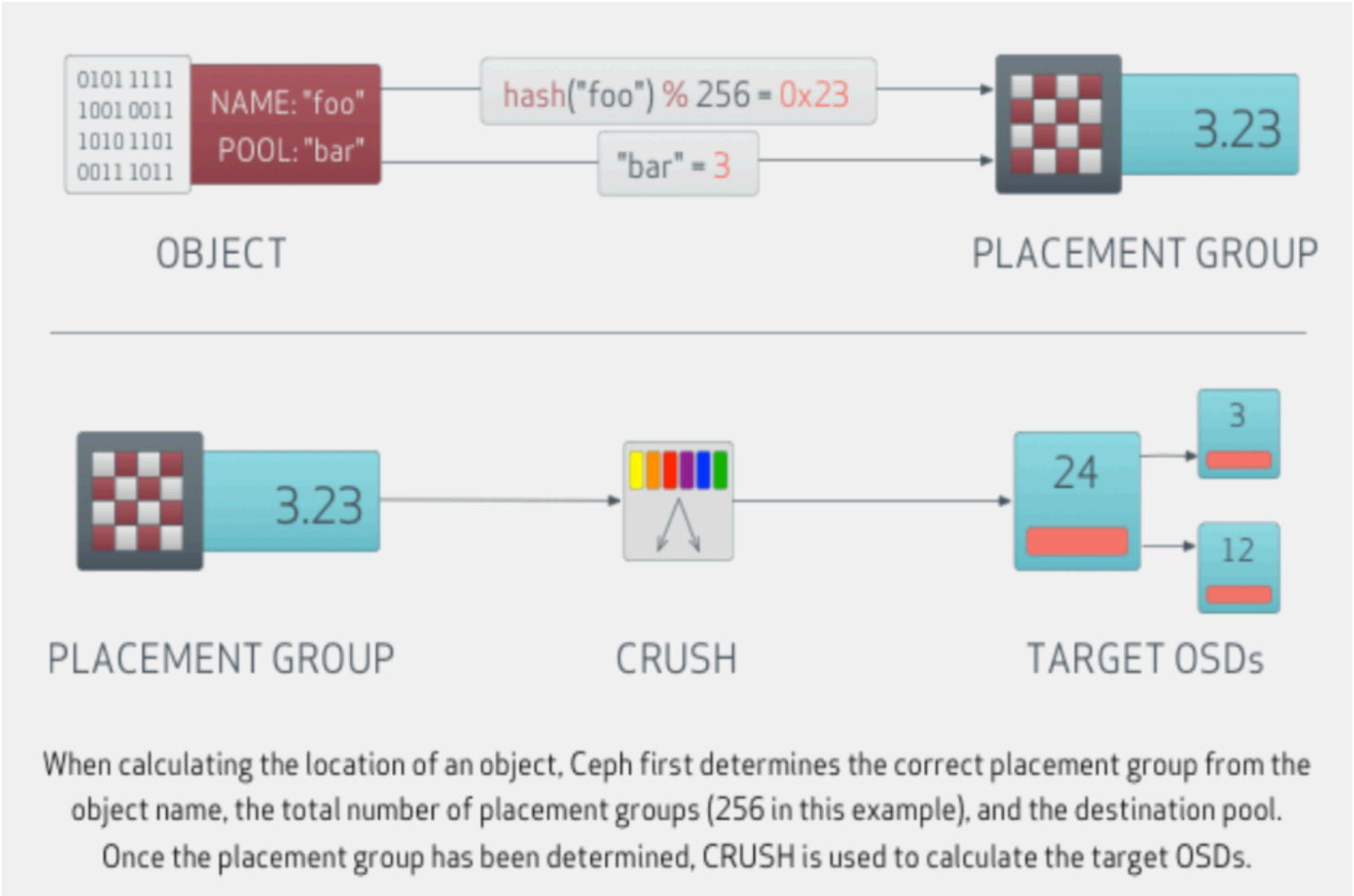
Placement Groups (PGs)



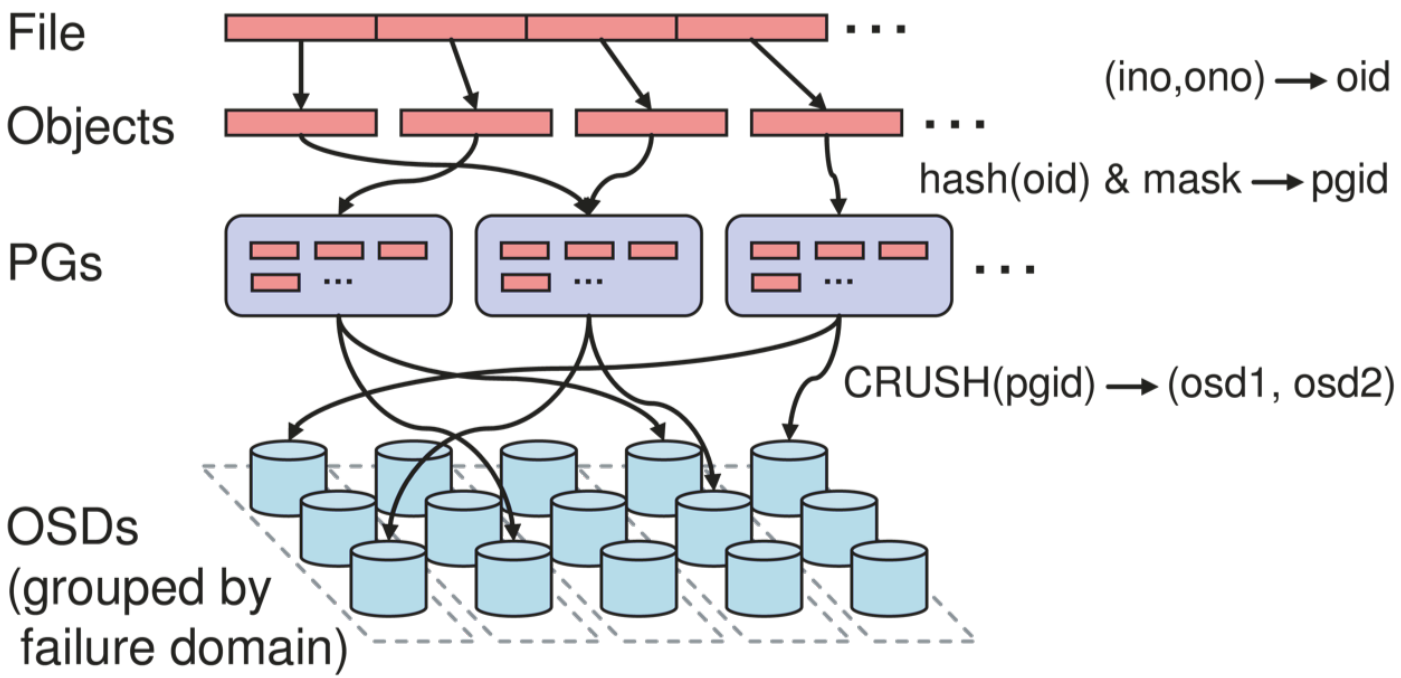
Placement Groups (PGs)

- **Without them**
  - Track placement and metadata on per-object basis
  - Not realistic nor scalable with a million++ objects
- **Extra Benefits**
  - Reduce the number of processes
  - Reduce amount of per object metadata Ceph must track
- **Handling the cluster life cycle**
  - The total number of PGs must be adjusted when growing the cluster
  - As devices leave or join the Ceph cluster, most PGs remain where they are
  - Approximately 50-200 PGs per OSD is recommended -> to balance out memory and CPU requirements and per-OSD load

From Object to OSD



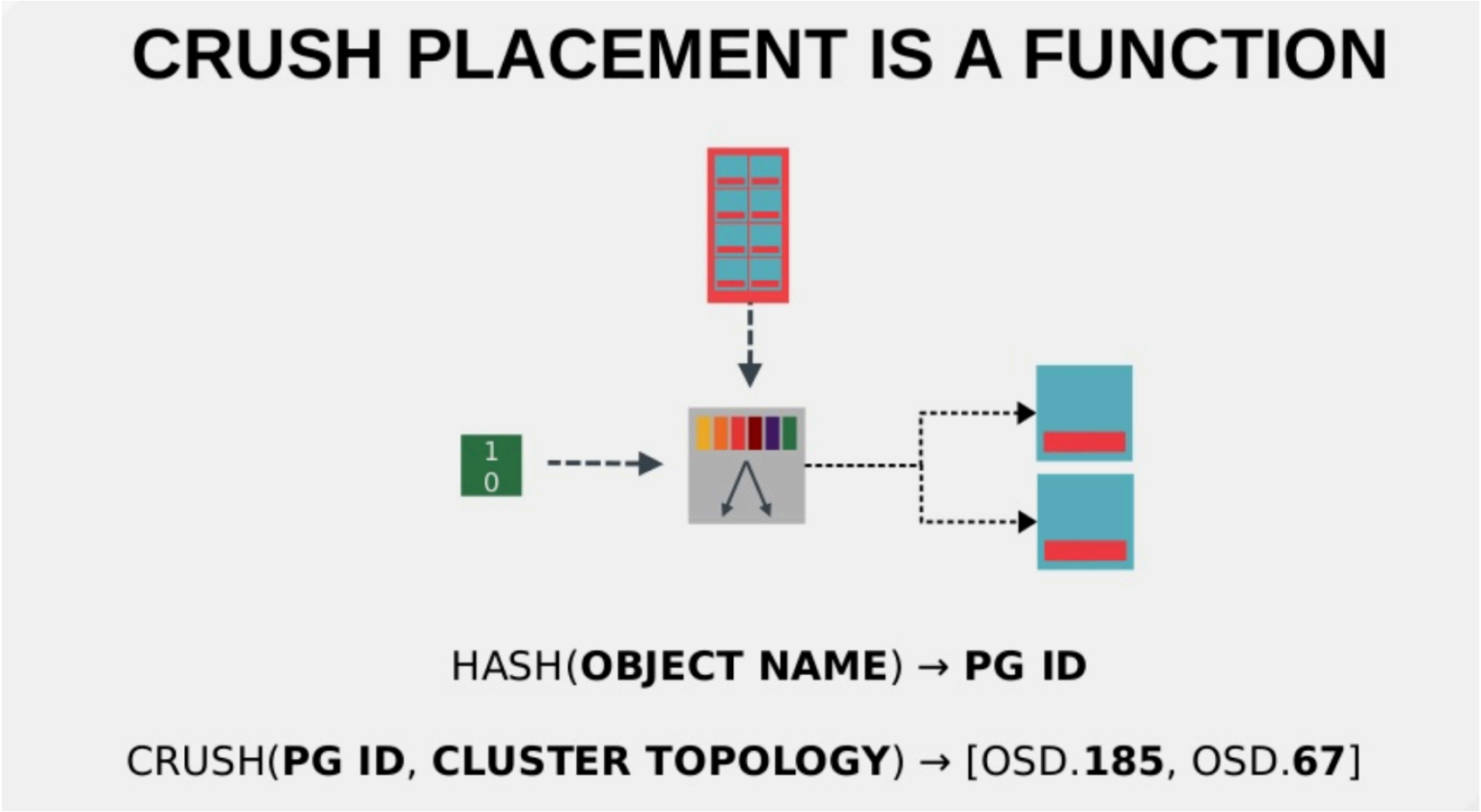
Object Addressing



寻址流程

- **File -> Object**
  - 将用户要操作的 File，映射成 RADOS 能够处理的 Object
  - 本质上是按照 Object 的最大 Size 对 File 进行切分
  - 切分可以使大小不限的 File 变成最大 Size 一致、可以被 RADOS 高效管理的 Object
  - 切分同时也可以让对单一 File 实施的串行处理变成对多个 Object 实施的并行化处理
- **Object -> PG**
  - 将每个 Object 独立的映射到一个 PG 中去
  - 固定的 Hash 算法
- **PG -> OSD**
  - 将作为 Object 的逻辑组织单元的 PG 映射到数据的实际存储单元 OSD
  - 采用 CRUSH 算法

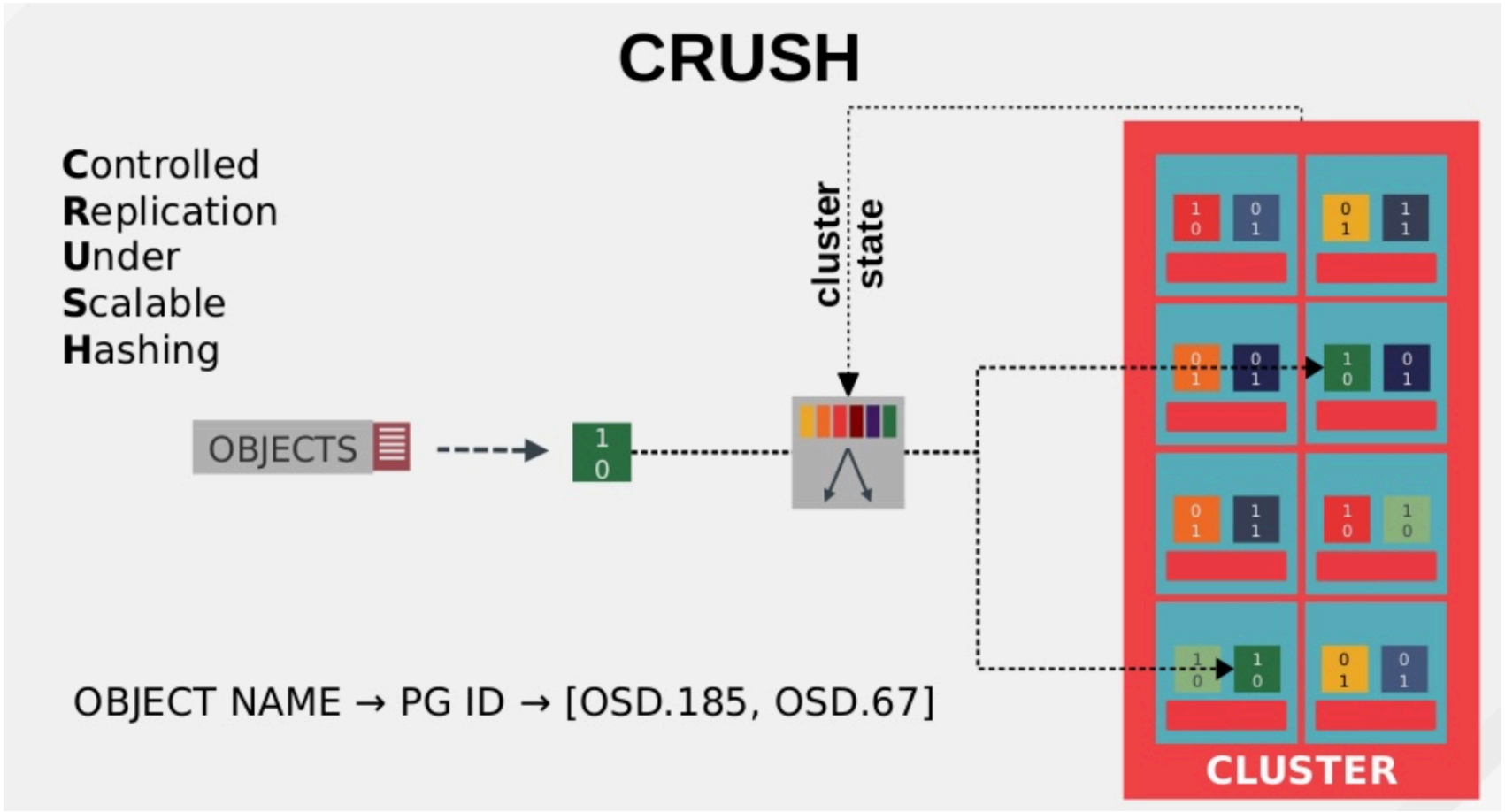
CRUSH Function



CRUSH

- CRUSH(x) -> $(osd_{n1}, osd_{n2}, osd_{n3})$
  - Inputs
    - x is the placement group
    - hierarchical cluster map
    - placement rules
  - Outputs: a list of OSDs
- Advantages
  - Anyone can calculate object location
  - Cluster map infrequently updated

CRUSH


CRUSH
Controlled
Replication
Under
Scalable
Hashing
cluster
state
OBJECTS
1
0
OBJECT NAME → PG ID → [OSD.185, OSD.67]
CLUSTER

CRUSH

CRUSH(Controlled Replication Under Scalable Hashing)

- **Ceph's data distribution mechanism**
- **Pseudo-random placement algorithm**
  - Deterministic function of inputs
  - Clients can compute data location
- **Rule-based configuration**
  - Desired/required replica count
  - Affinity/distribution rules
  - Infrastructure topology
  - Weighting
- **Excellent data distribution**
  - De-clustered placement
  - Excellent data-re-distribution

Key CRUSH Properties

- **No Storage** - Only need to know the cluster topology
- **Fast** - microseconds, even for very large clusters
- **Stable** - very little data movement when topology changes
- **Reliable** - placement is constrained by ***failure domains***
- **Flexible** - replication, erasure codes, complex placement schemes

Hierarchical Cluster Map

- **The cluster map is composed of *device* and *bucket***
  - **device**: basic storage device, OSD
  - **bucket**: container, and contain any number of devices or other buckets
  - **item**: member of bucket, can be device or lower level bucket
  - both device and bucket have numerical identifiers and weight values associated with them
- bucket type:
  - root, region, datacenter, room, row, rack, host
  - you can define your own bucket type and hierarchy relation

Hierarchical Cluster Map

```
# devices
device 0 osd.0 class hdd
device 1 osd.1 class hdd
device 2 osd.2 class hdd
device 3 osd.3 class hdd
```

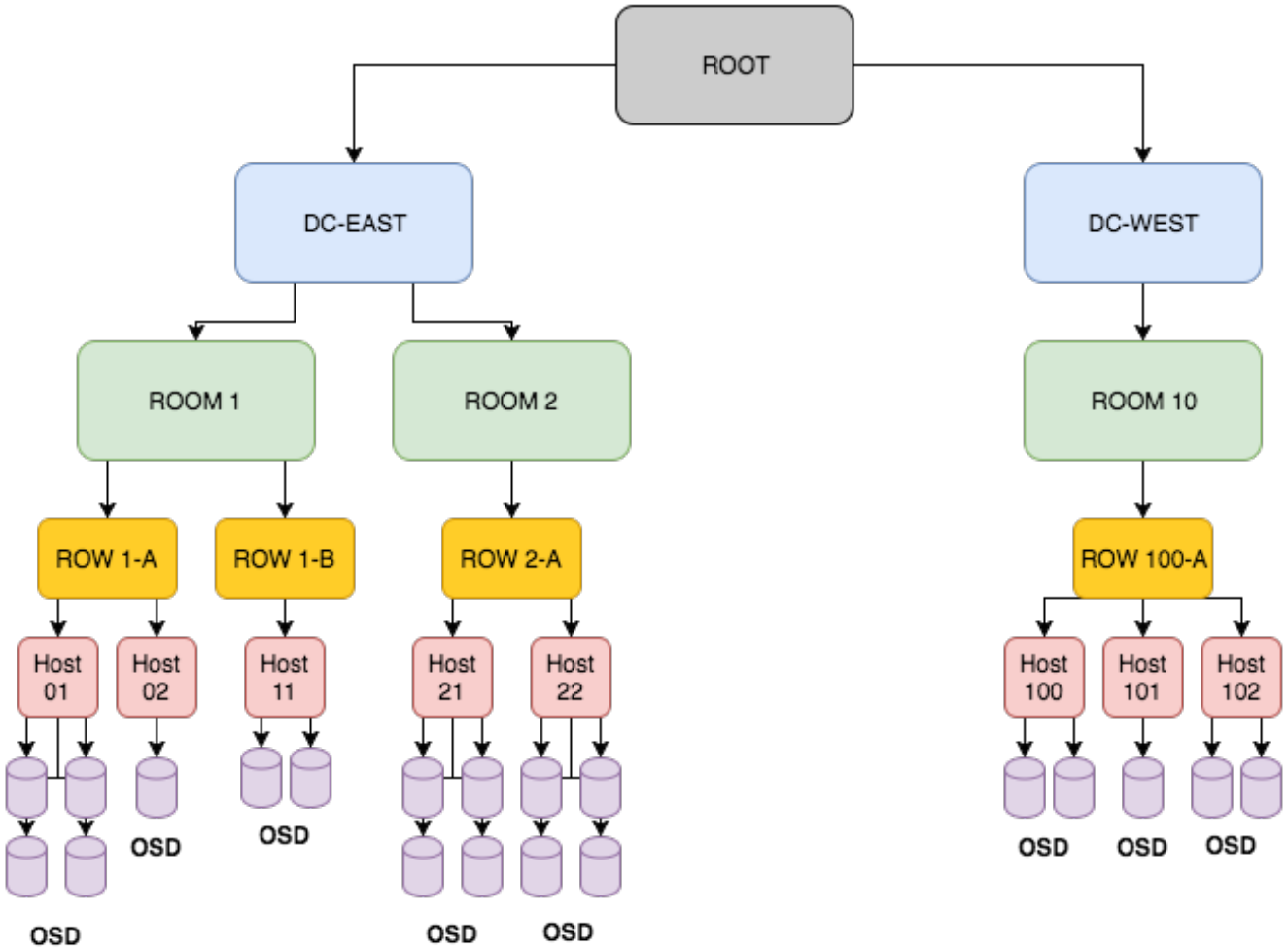
```
# buckets
host node1 {
    id -2
    id -3 class hdd
    # weight 1.000
    alg straw2
    hash 0    # rjenkins1
    item osd.0 weight 1.000
}
```

```
host node2 {
    id -5
    id -6 class hdd
    # weight 1.000
    alg straw2
    hash 0    # rjenkins1
    item osd.1 weight 1.000
}
```

```
host node3 {
    id -7
    id -8 class hdd
    # weight 2.000
    alg straw2
    hash 0    # rjenkins1
    item osd.2 weight 1.000
    item osd.3 weight 1.000
}
```

```
root default {
    id -1    # bucket id, 一般为负数
    # weight 4.000 # sum of item's weight
    alg straw2 # algorithm for random select
    hash 0    # rjenkins1 # hash function type
    item node1 weight 1.000
    item node2 weight 1.000
    item node3 weight 2.000
}
```

Cluster Map Example



Failure Domains

- **CRUSH generates *n* distinct target devices(OSDs)**
  - may be replicas or erasure coding shards
- **Separate replicas across failure domains**
  - single failure should only compromise one replica
  - size of failure domain depends on cluster size
    - disk
    - host(NIC, RAM, PS)
    - rack(ToR switch)
    - row(distribution switch, ...)
    - data center(eletricity...)
  - based on types in CRUSH hierarchy

CRUSH Rules

- **Policy**
  - where to place replicas
  - the failure domain
- **Trivial program**
  - short sequence of imperative commands
  - flexible, extensible
  - not particularly nice for humans

```
1 rule flat {
2     ruleset 0    # ruleset id
3     type replicated
4     min_size 1   # 副本最小数量
5     max_size 10 # 副本最大数量
6     step take root
7     step choose fistn 0 type osd
8     step emit
9 }
```

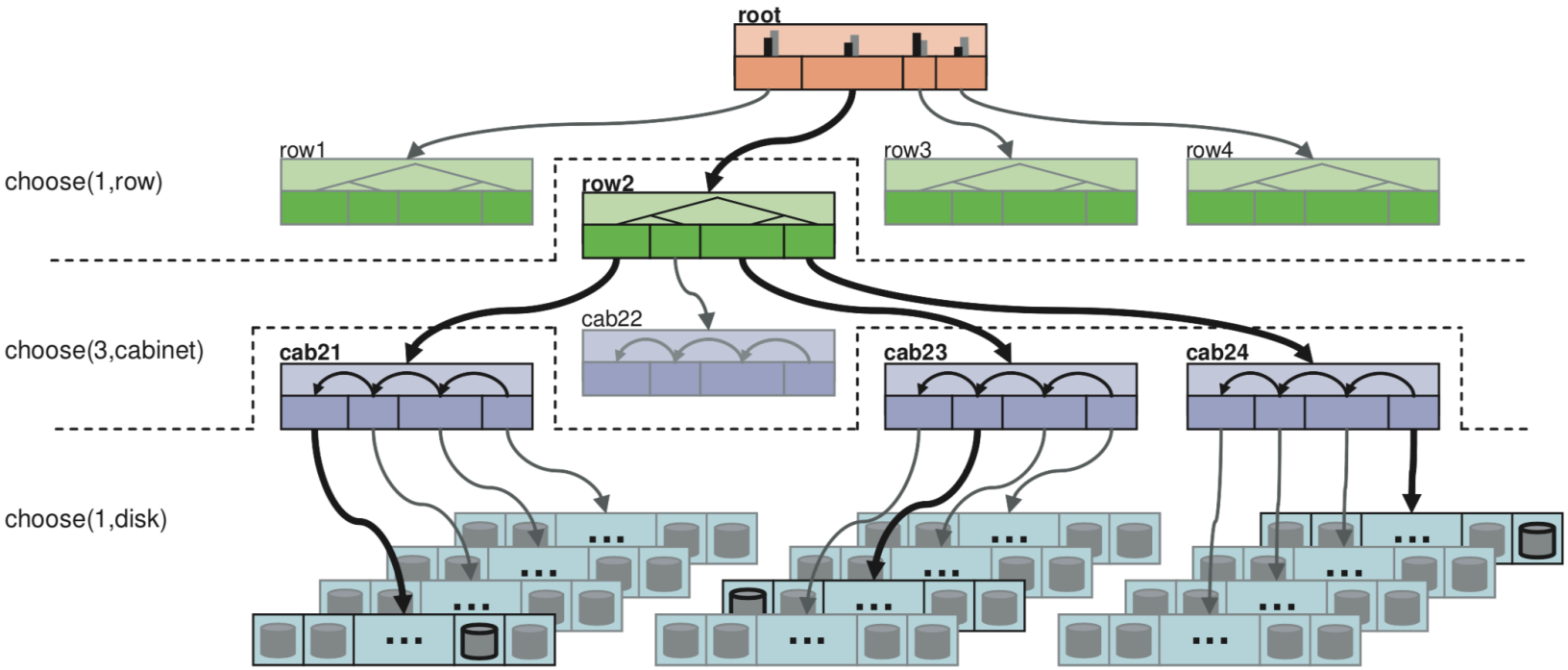
Basic Operation: Step

- **take**: choose a bucket(often root bucket)
- **choose**
  - **choose firstn {num} type {bucket-type}**
    - 选择 num 个 bucket-type 的 item
  - **chooseleaf firstn {num} type {bucket-type}**
    - 先选择 bucket-type 类型的 item，再递归选择叶子节点的 OSD
  - meaning of num parameter
    - if $num == 0$, choose pool-num-replicas buckets(all available)
    - if $num > 0 and < pool - num - replicas$, choose that many buckets
    - if $num < 0$, it means $pool - num - replicas - num$
- **emit**

RuleSet

```
1  rule replicated_ruleset {
2      ruleset 0        # ruleset id
3      type replicated # type replicated or erasure code
4
5      min_size 1
6      max_size 10
7
8      step take root
9      step choose firstn 1 type row
10     step choose firstn 3 type cabinet
11     step choose firstn 1 type osd
12     step emit
13 }
```

CRUSH Rules


root
row1
row2
row3
row4
choose(1,row)
cab22
cab21
cab23
cab24
choose(3,cabinet)
choose(1,disk)

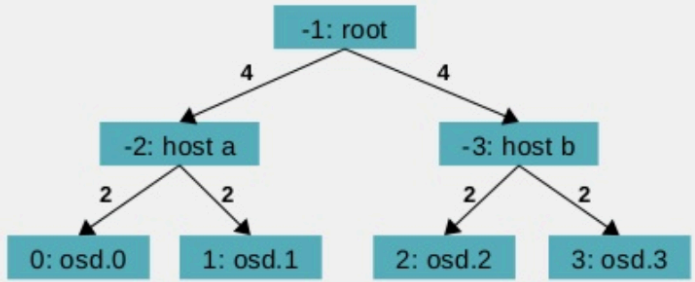
RuleSet Example

```
1  rule ssd-primary {
2      ruleset 5          # ruleset id
3      type replicated # type replicated or erasure code
4
5      min_size 5
6      max_size 10
7
8      step take ssd    # 选择ssd这个root bucket作为输入
9      step chooseleaf firstn 1 type host    # 选择一个host，再递归选择叶子节点的osd
10     step emit
11
12     step take hdd    # 选择hdd这个root bucket作为输入
13     step chooseleaf firstn -1 type host    # 选择总副本数减一个host，再递归选择叶子节点的osd
14     step emit
15 }
```

Bucket Algorithms

- **Goal of CRUSH algorithm**
  - efficiency and scalability of the mapping algorithm
  - minimum data migration to restore a balanced distribution when the cluster changes due to the addition or removal of devices.
- **CRUSH define 4 kinds of buckets to represent internal nodes in the cluster hierarchy**
  - uniform buckets
  - list buckets
  - tree buckets
  - straw buckets
- Each bucket type is based on a **different internal data structure** and utilizes a **different function c(r, x) for pseudo-randomly choosing nested items** during the replica placement process
- Each bucket type represents a different **tradeoff between computation and reorganization efficiency**

How does it work?



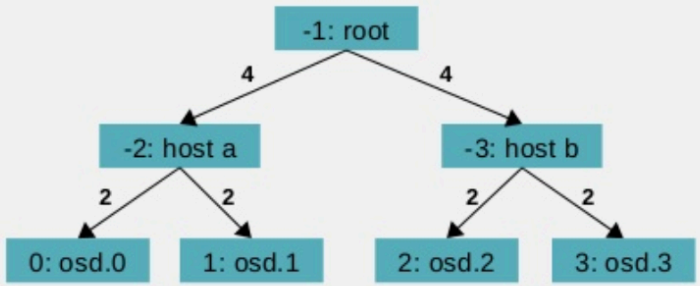
- Weighted tree
- Each node has a unique id

- While CRUSH is executing, it has a "working value" vector → → →

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type host
        step choose firstn 1 type osd
        step emit
}
```

[ ]

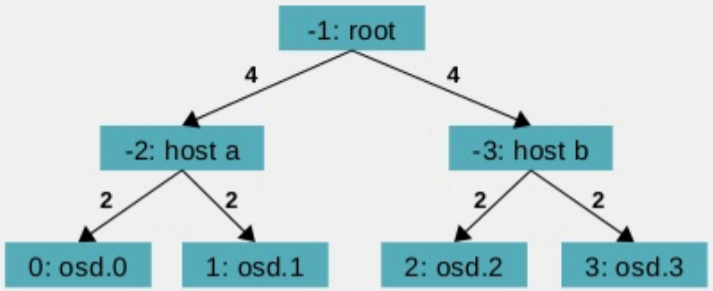
How does it work?



- take root

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type host
        step choose firstn 1 type osd
        step emit
}


[-1]
```

How does it work?

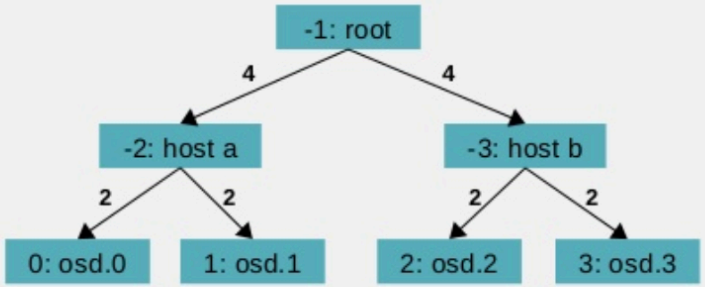


- choose firstn 0 type host
  - nrep=2
- descend from [-1] with
  - x=<whatever>
  - r=0
  - hash(-1, x, 0)
    → -3

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type host
        step choose firstn 1 type osd
        step emit
}
```

```
[-1]
[-3]
```

How does it work?

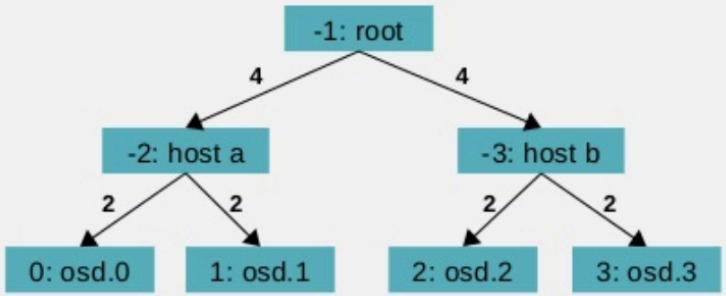


- choose firstn 0 type host
  - nrep=2
- descend from [-1] with
  - x=<whatever>
  - r=**1**
  - hash(-1, x, 1)
    → -3 → dup, reject

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type host
        step choose firstn 1 type osd
        step emit
}
```

```
[-1]
[-3]
```

How does it work?

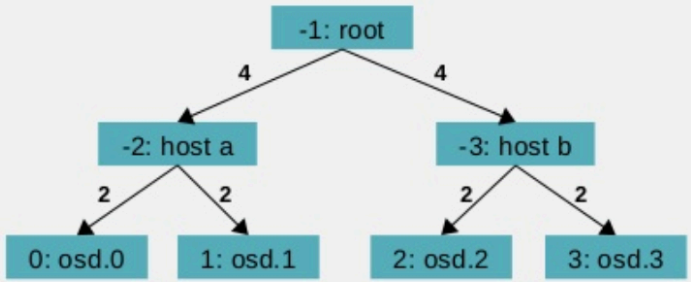


- choose firstn 0 type host
  - nrep=2
- descend from [-1] with
  - x=<whatever>
  - r=2
  - hash(-1, x, 2)
    → -2

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type ho
        step choose firstn 1 type os
        step emit
}
```

```
[-1]
[-3,-2]
```

How does it work?

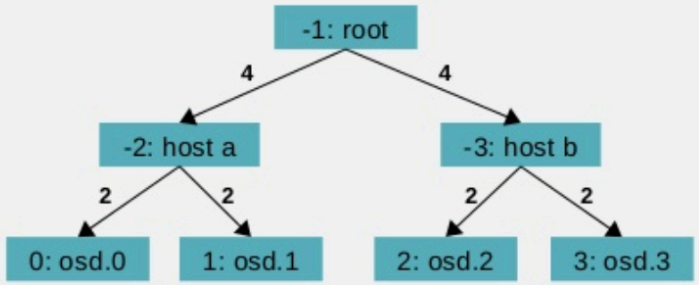


- choose firstn 1 type osd
  - nrep=1
- descend from [**-3**,-2] with
  - x=<whatever>
  - r=0
  - hash(-3, x, 0)
    → 2

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type host
        step choose firstn 1 type osd
        step emit
}
```

```
[-1]
[-3,-2]
[2]
```

How does it work?



- choose firstn 1 type osd
  - nrep=1
- descend from [-3,**-2**] with
  - x=<whatever>
  - r=1
  - hash(-2, x, 1)
    → 1

```
rule by-host {
        ruleset 0
        type replicated
        min_size 1
        max_size 10
        step take root
        step choose firstn 0 type host
        step choose firstn 1 type osd
        step emit
}
```

```
[-1]
[-3,-2]
[2,1]
```

Bucket Algorithms

- **Many algorithms for selecting a child**
  - every internal tree node has a type
  - tradeof between time/computation and rebalancing behavior
  - can mix types within a tree
- **uniform**
  - $hash(nodeid, x, r)\%num_children$
  - fiexed $O(1)$ time
  - addint child shuffles everything
- **straw2**
  - $hash(nodeid, x, r, child)$ for every child
  - scale based on child weight
  - pick the biggest value
  - $O(n)$ time
- **adding or removing child**
  - only moves values to or from that child
  - still fast enough for small n

Cluster Aware

Where should the object be placed

- **Traditional**
  - Centralized interface provides services to the client through a double dispatch
  - Huge bottleneck at petabyte-to-exabyte scale.
- **Ceph**
  - Ceph OSD and Client are *cluster aware*
  - Each OSD knows about other OSD in the cluster
  - OSD can interact directly with other OSD and monitors
  - Client can interact directly with OSD

Cluster Map

Cluster Map indicates the knowledge of the cluster topology.

- **The Monitor Map**
- **The OSD Map**
- **The PG Map**
- **The CRUSH Map**
- **The MDS Map**

Cluster Map: Monoitor Map

```
1 ubuntu@ip-172-31-58-195:~# ceph mon dump
2 dumped monmap epoch 2
3 epoch 2
4 fsid ccb00027-ca55-48cc-bf5a-b6cbf79c9b99
5 last_changed 2018-12-26 18:17:17.540294
6 created 2018-12-26 18:16:44.542161
7 0: 172.31.56.105:6789/0 mon.ip-172-31-56-105
8 1: 172.31.57.232:6789/0 mon.ip-172-31-57-232
9 2: 172.31.58.195:6789/0 mon.ip-172-31-58-195
```

Cluster Map: OSD Map

```
ubuntu@ip-172-31-58-195:~# ceph osd dump
epoch 245
fsid ccb00027-ca55-48cc-bf5a-b6cbf79c9b99
created 2018-12-26 18:17:10.141095
modified 2018-12-29 12:02:43.764006
crush_version 26
...
pool 5 'cephfs_data' replicated size 3 min_size 2 crush_rule 0 object_hash rjenkins pg_num 64
      pgp_num 64 last_change 48 flags hashpspool stripe_width 0 application cephfs
pool 6 'cephfs_metadata' replicated size 3 min_size 2 crush_rule 0 object_hash rjenkins pg_num
      64 pgp_num 64 last_change 48 flags hashpspool stripe_width 0 application cephfs
max_osd 4
osd.0 up   in  weight 1 up_from 98 up_thru 244 down_at 94 last_clean_interval [90,93)
      172.31.56.105:6801/2052 172.31.56.105:6802/2052 172.31.56.105:6803/2052
      172.31.56.105:6804/2052 exists,up 2ee23b61-eca4-41e5-a6b0-277bfd6c48a1
...
```

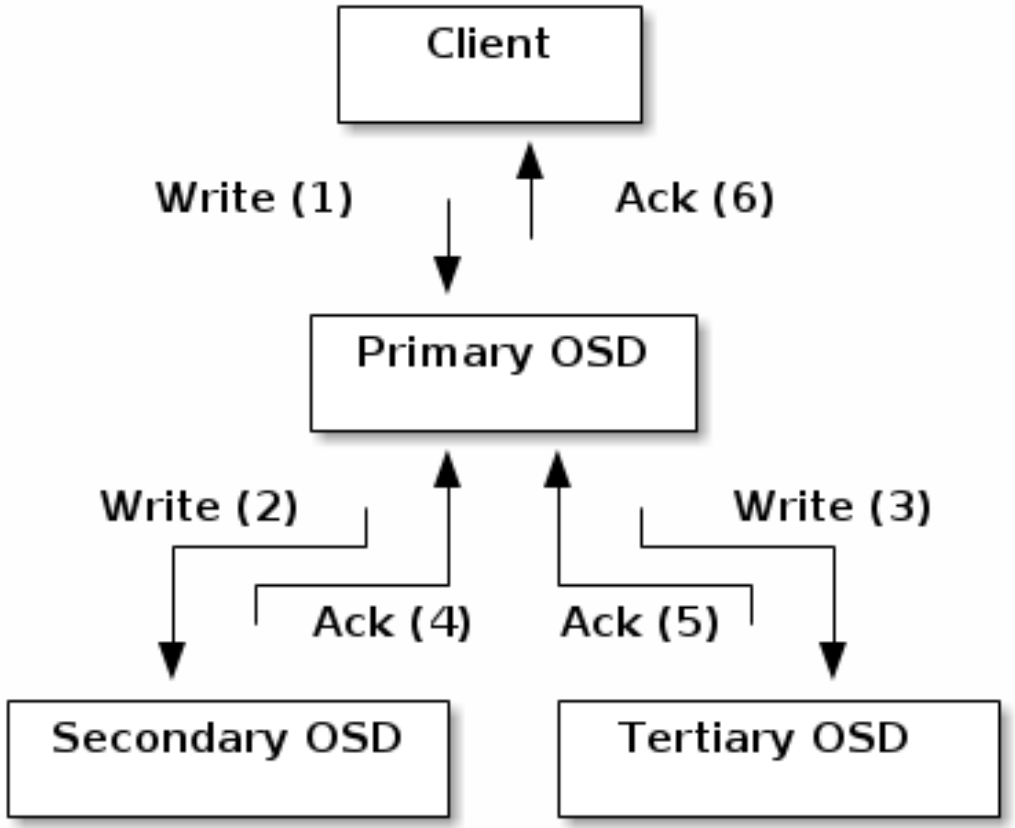
Cluster Map: CRUSH Map

```
ubuntu@ip-172-31-58-195:~# ceph osd tree
ID CLASS WEIGHT  TYPE NAME                 STATUS REWEIGHT PRI-AFF
-1       0.11597 root default
-3       0.02899     host ip-172-31-56-105
 0   ssd 0.02899         osd.0                 up  1.00000 1.00000
-5       0.02899     host ip-172-31-57-232
 1   ssd 0.02899         osd.1                 up  1.00000 1.00000
-7       0.02899     host ip-172-31-58-195
 2   ssd 0.02899         osd.2                 up  1.00000 1.00000
-9       0.02899     host ip-172-31-61-170
 3   ssd 0.02899         osd.3               down        0 1.00000
```

Cluster Map

- 由若干个 monitor 共同负责整个 Ceph 集群中所有的 OSD 状态的发现与记录，并且共同形成 cluster map 的 master 版本，然后扩散到整体 OSD 以及 client
- OSD 使用 cluster map 进行数据的维护，client 使用 cluster 进行数据的寻址
- monitor 并不主动轮询各个 OSD 的当前状态。正相反，OSD 需要向 monitor 上报状态信息。常见的上报有两种情况
  - 新的 OSD 被加入集群
  - 某个 OSD 发现自身或者其他 OSD 发生异常
- 在收到这些上报信息后，monitor 将更新 cluster map 信息并加以扩散

Data Operation Procedure

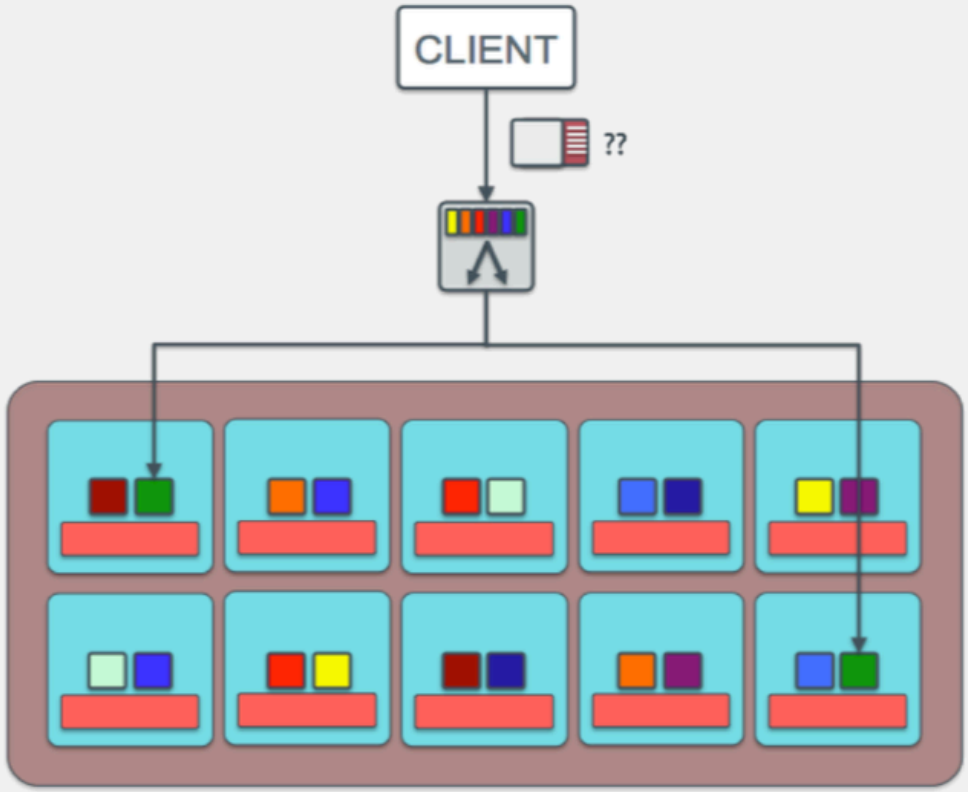


Peering and Recovery

The Ceph Object Store is dynamic

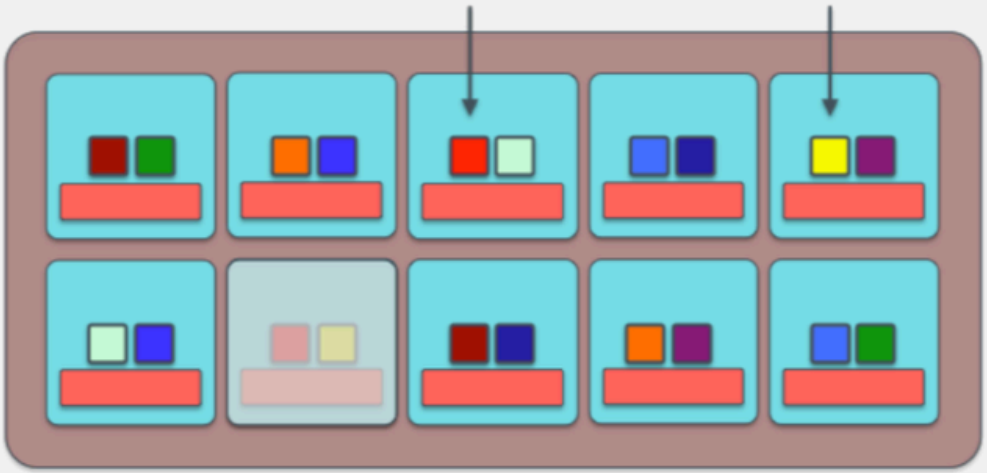
- **Failure is the norm rather than the exception**
- **The cluster map records cluster state at a point in time**
- **The cluster map contains the OSDs status(up/down, weight, IP)**
  - OSDs cooperatively migrate data
  - They do so to achieve recovery based on CRUSH rules
  - Any cluster map update potentially triggers data migration

CRUSH



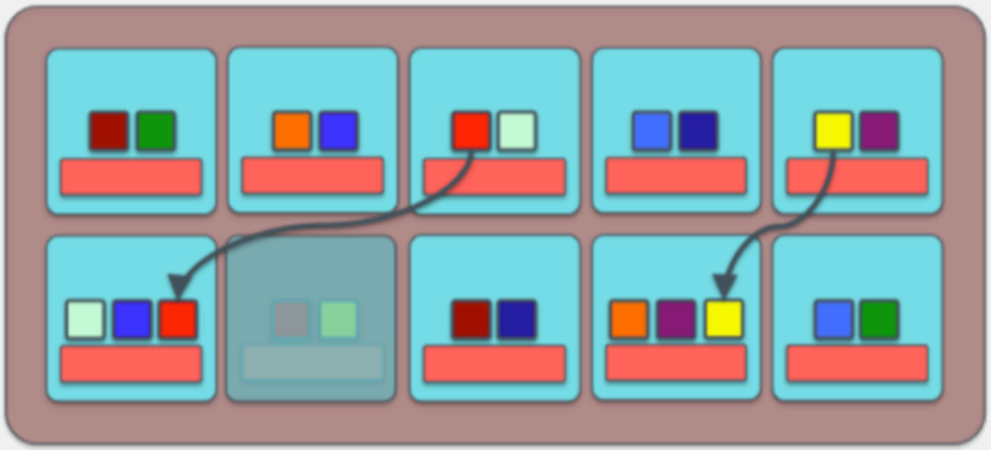
When it comes time to store an object in the cluster (or retrieve one), the client calculates where it belongs.

CRUSH



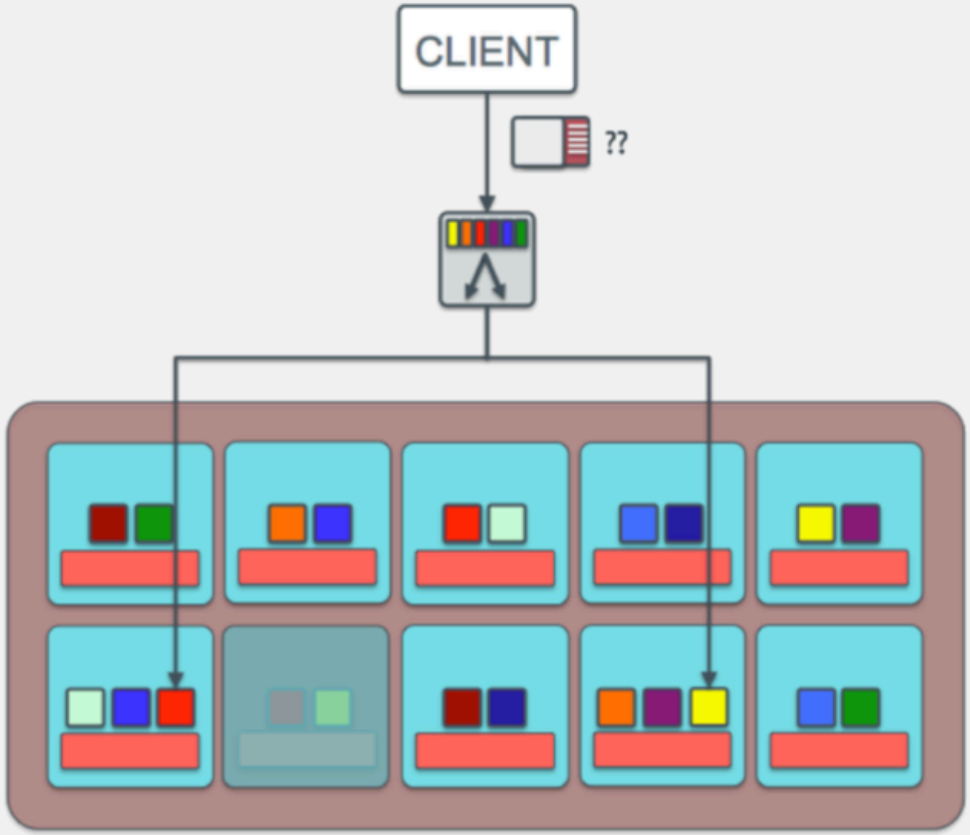
- What happens, though, when a node goes down?
  - The OSDs are always talking to each other (and the monitors)
  - They know when something is wrong
    - The 3^{rd} & 5^{th} nodes noticed that 2^{nd} node on the bottom row is gone
    - They are also aware that they have replicas of the missing data

CRUSH



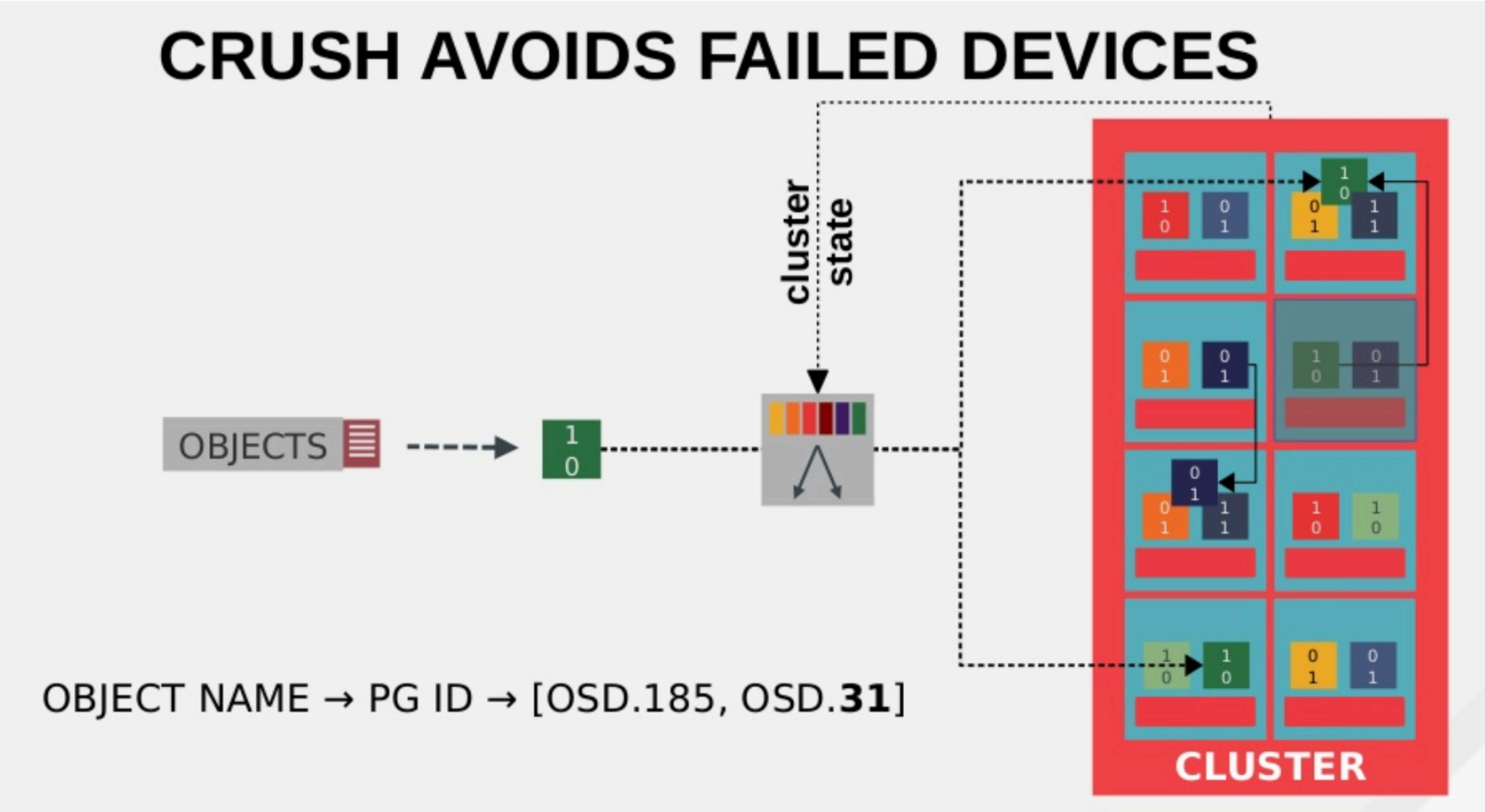
- The OSDs collectively
  - Use the CRUSH algorithm to determine how the cluster should look based on its new state
  - and move the data to where clients running CRUSH expect it to be

CRUSH



- Placement is calculated rather than centrally controlled
- Node failures are transparent to clients

OSD Fail


CRUSH AVOIDS FAILED DEVICES
cluster state
OBJECTS
1
0
OBJECT NAME → PG ID → [OSD.185, OSD.31]
CLUSTER

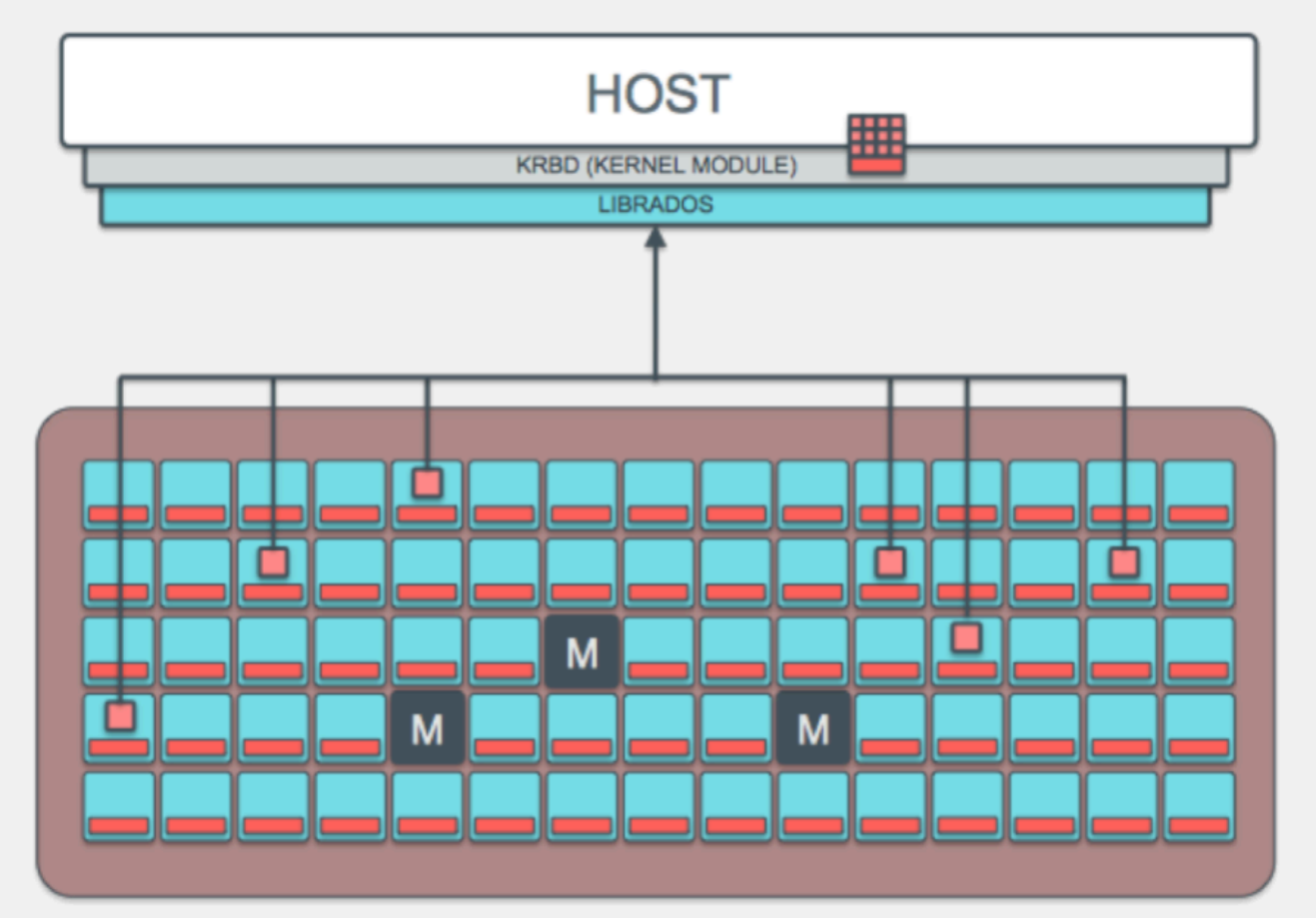
Python S3 Example

```python
# creating a connection
conn = boto.connect_s3(aws_access_key_id = access_key,
    aws_secret_access_key = secret_key,
    host = 'objects.dreamhost.com',
    calling_format = boto.s3.connection.OrdinaryCallingFormat())

# listing owned buckets
for bucket in conn.get_all_buckets():
    print "{name}\t{created}".format(name = bucket.name, created = bucket.creation_date)
# mahbuckat1    2011-04-21T18:05:39.000Z
# mahbuckat2    2011-04-21T18:05:48.000Z

# listing a bucket's content
for key in bucket.list():
    print "{name}\t{size}\t{modified}".format(name = key.name, size = key.size, modified = key.
      last_modified)
# myphoto1.jpg 251262  2011-08-08T21:35:48.000Z
# myphoto2.jpg 262518  2011-08-08T21:38:01.000Z

# creating an object
key = bucket.new_key('hello.txt')
key.set_contents_from_string('Hello World!')

# download an object to a file
key = bucket.get_key('perl_poetry.pdf')
key.get_contents_to_filename('/home/larry/documents/perl_poetry.pdf')
```

Create and Mount RBD

```
1  # create a block device pool
2  $ ceph osd pool create rbd 128
3  $ rbd pool init
4
5  # create a block device image(1024MB)
6  $ rbd create --size 1024 foo
7  $ rbd list
8  foo
9
10 # map a block device
11 $ sudo rbd device map rbd/foo --id admin
12 /dev/rbd0
13 $ rbd device list
14 id pool image snap device
15 0  rbd  foo   -    /dev/rbd0
16
17 # format the block device and create a file system
18 $ sudo mkfs.ext4 -m0 /dev/rbd0
19 $ sudo mkdir /mnt/rbd
20 $ sudo mount /dev/rbd/rbd/foo /mnt/rbd
21
22 # 查看挂载情况
23 $ df -h
24 ...
25 /dev/rbd0            976M  2.6M  958M    1% /mnt/rbd
```

RBD: Native

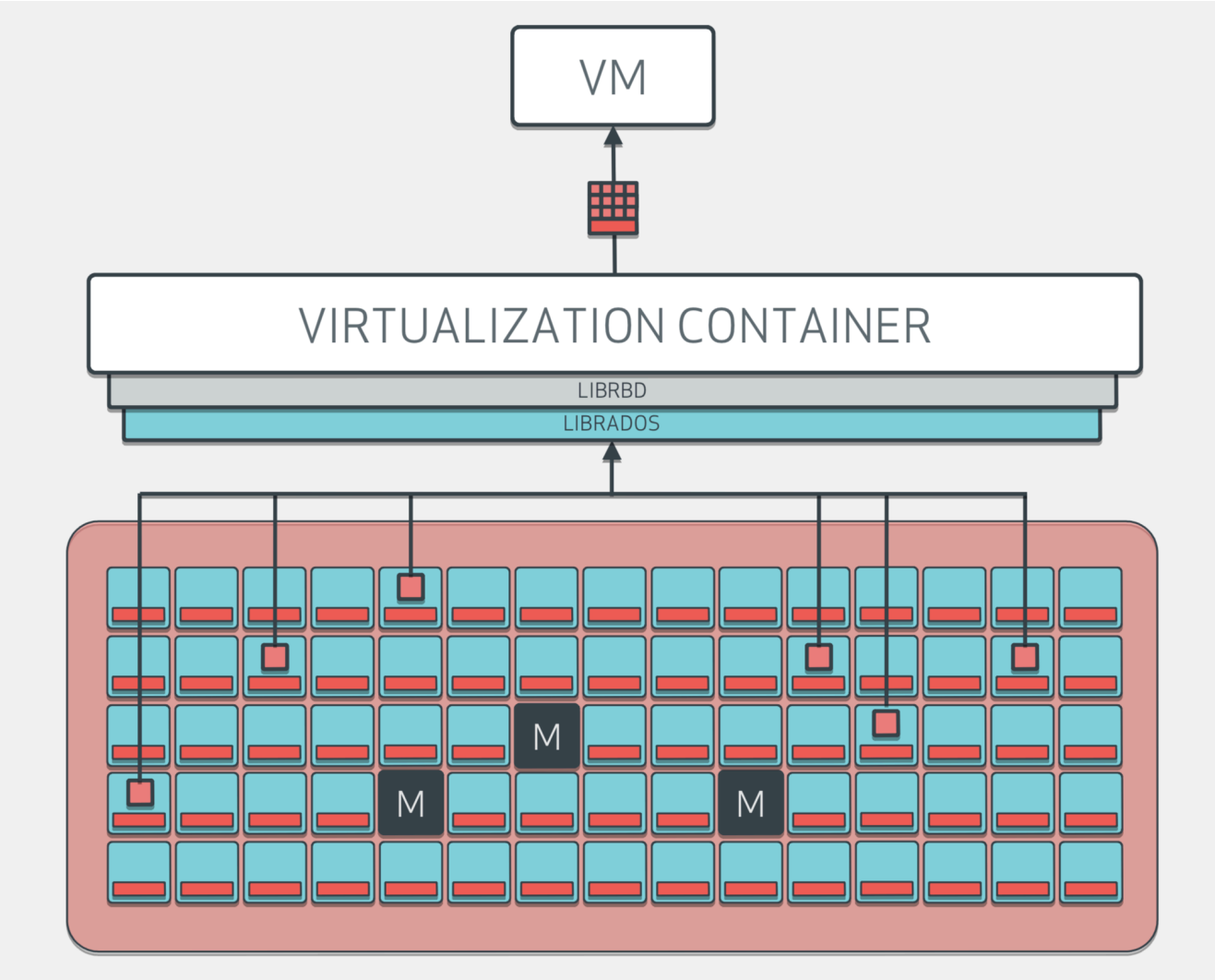


Machines can mount an RBD image using native linux kernel drivers

RBD: Virtual Machines

- **The *librbd* library**
  - Maps data blocks into objects for storage in the Ceph Object Store
  - Inherit *librados* capabilities such as snapshots and clones
- **Virtualization containers**
  - KVM or QEMU can use VM images that are stored in RADOS
  - Virtualization containers can also use RBD block storage in OpenStack and CloudStack platforms
- **Ceph based VM Images**
  - Are striped across the entire cluster
  - Allow simultaneous read access from different cluster nodes

RBD: Virtual Machines



Access RBD using librbd

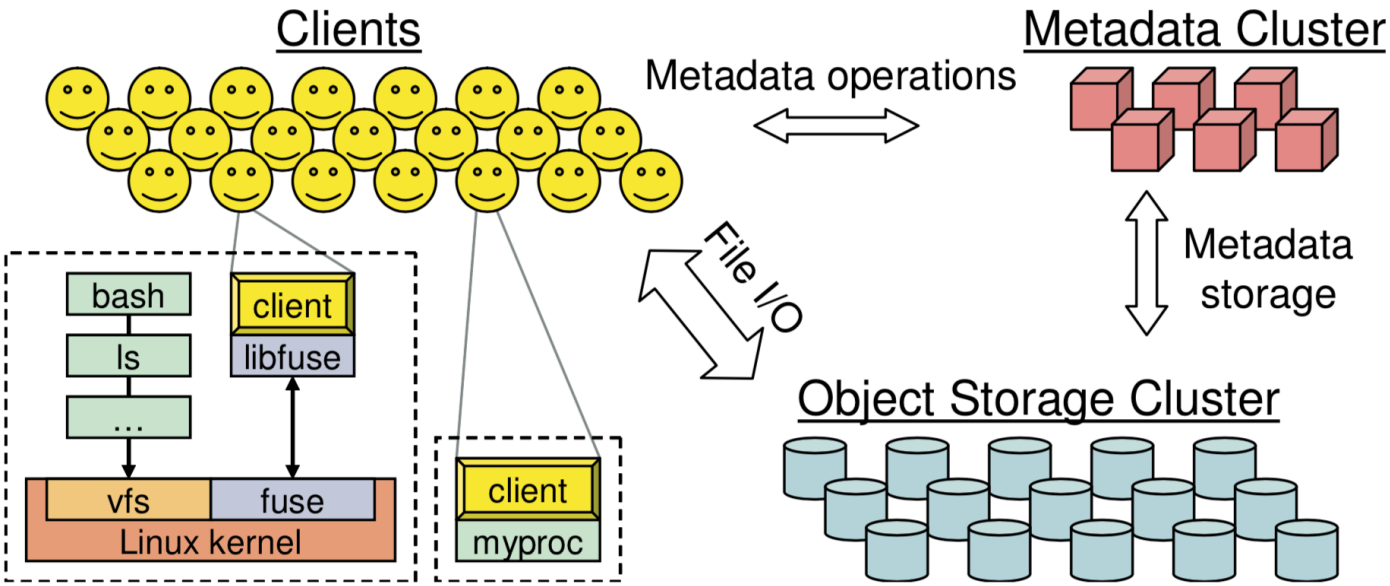
```
with rados.Rados(conffile='my_ceph.conf') as cluster:
    with cluster.open_ioctx('mypool') as ioctx:
        rbd_inst = rbd.RBD()
        size = 4 * 1024**3  # 4 GiB
        rbd_inst.create(ioctx, 'myimage', size)
        with rbd.Image(ioctx, 'myimage') as image:
            data = 'foo' * 200
            image.write(data, 0)
```

```yaml
apiVersion: v1
kind: PersistentVolume
metadata:
  name: ceph-rbd-pv
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  rbd:
    monitors:
    - '172.31.56.105:6789'
    - '172.31.57.232:6789'
    - '172.31.58.195:6789'
    pool: rbd
    image: foo
    user: admin
    secretRef:
      name: ceph-secret
    fsType: ext4
    readOnly: false
```

```yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: ceph-rbd-pv-claim
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
```

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: ceph-rbd-pv-pod1
spec:
  containers:
  - name: rbd-rw
    image: kubernetes/pause
    volumeMounts:
    - name: ceph-rbd-vol1
      mountPath: /mnt/rbd
      readOnly: false
  volumes:
  - name: ceph-rbd-vol1
    persistentVolumeClaim:
      claimName: ceph-rbd-pv-claim
```

System Architecture



System Architecture

- **Clients**
  - Export a near-POSIX file system interface
- **Cluster of OSDs**
  - Store all data and metadata
  - Communicate directly with clients
- **Metadata Server Cluster**
  - Manages the namespace (files + directories)
  - Security, consistency and coherence

Key Ideas

- **Seperate data and metadata management tasks**
- **Dynamic partitioning of metadata data tasks inside metadata cluster**
  - Avoid hot spots
- **Let OSDs handle file migration and replication tasks**

Create and Mount CephFS

```
## creating pools
$ ceph osd pool create cephfs_data 128
$ ceph osd pool create cephfs_metadata 128
## creating a file system
$ ceph fs new cephfs cephfs_metadata cephfs_data
$ ceph fs ls
name: cephfs, metadata pool: cephfs_metadata, data pools: [cephfs_data ]
```

```
## there are 2 ways to mount a file system
## ceph-fuse is most of the time slower than the cephfs kernel module

## mount cephfs with the kernel driver
$ sudo mkdir /mnt/mycephfs
$ sudo mount -t ceph 192.168.0.1:6789:/ /mnt/mycephfs

## mount cephfs using fuse
$ sudo mkdir /home/username/cephfs
$ sudo ceph-fuse -m 192.168.0.1:6789 /home/username/cephfs
```

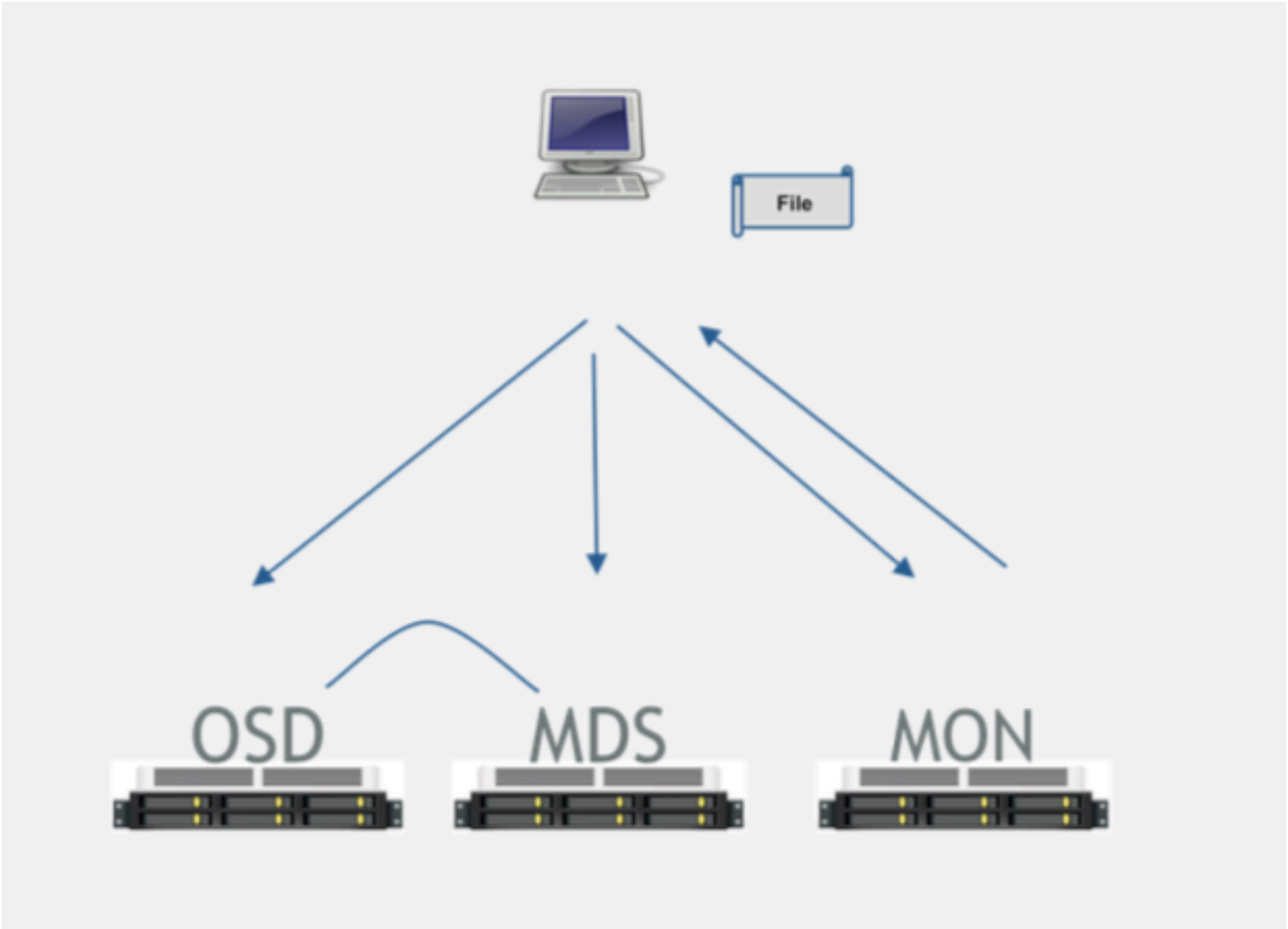
MDS High Availabilty

- MDSs can be running in two modes
  - active
  - standby
- A standby MDS can become active
  - If the previously active daemon goes away
- Multiple active MDSs for load balancing
  - Are a possibility
  - This configuration is currently not supported/recommended

MDS Functionality

- The client learns about MDSs and OSDs from MON
  - via MON Map, OSD Map and MDS Map
- Clients talk to MDS for access to Metadata
  - Permission bits, ACLs, file ownership, etc.
- Clients talk to OSD for access to data
- MDSs themselves store all their data in OSDs
  - In a separate pool called metadata

MDS Functionality



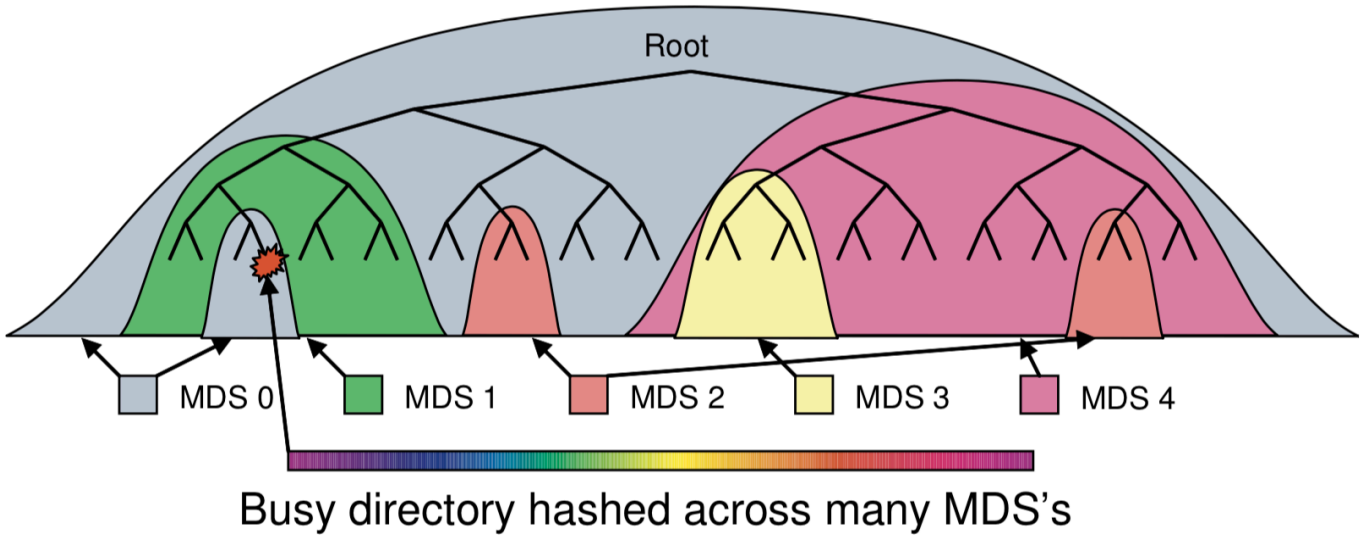
Client Access Example

- Client sends open request to MDS
- MDS returns capability, file inode, file size and stripe information
  - capability specifies authorized operations on file
- Client read/write directly from/to OSDs
- MDS manages the capability
- Client sends close request, relinquishes capability, provides details to MDS

Metadata management

- Metadata operations often make up as much as half of file system workloads...
- **Dynamic Subtree Partitioning**
  - Lets Ceph dynamically share metadata workload among tens or hundreds of metadata servers(MDSs)
  - Sharing is dynamic and based on current access patterns
- Results in near-linear performance scaling in the number of MDSs

Mapping Subdirectories to MDSs



```yaml
apiVersion: v1
kind: PersistentVolume
metadata:
  name: cephfs-pv
spec:
  capacity:
    storage: 10Gi
  accessModes:
    - ReadWriteMany
  cephfs:
    monitors:
    - '172.31.56.105:6789'
    - '172.31.57.232:6789'
    - '172.31.58.195:6789'
    user: admin
    secretRef:
      name: ceph-secret
    readOnly: false
```

```yaml
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: cephfs-pv-claim
spec:
  accessModes:
    - ReadWriteMany
  resources:
    requests:
      storage: 10Gi
```

```yaml
apiVersion: v1
kind: Pod
metadata:
  labels:
    test: cephfs-pvc-pod
  name: cephfs-pv-pod1
spec:
  containers:
  - name: cephfs-pv-busybox1
    image: busybox
    command: ["sleep", "60000"]
    volumeMounts:
    - mountPath: "/mnt/cephfs"
      name: cephfs-vol1
      readOnly: false
  volumes:
  - name: cephfs-vol1
    persistentVolumeClaim:
      claimName: cephfs-pv-claim
```

Conclusion

- Scalability, Reliablity, Performance
- Seperation of data and metadata
- Object based storage
- Pseudo-Random data distribution function(CRUSH)