

# CRUSH MAPS

The CRUSH algorithm determines how to store and retrieve data by computing data storage locations. CRUSH empowers Ceph clients to communicate with OSDs directly rather than through a centralized server or broker. With an algorithmically determined method of storing and retrieving data, Ceph avoids a single point of failure, a performance bottleneck, and a physical limit to its scalability.

CRUSH requires a map of your cluster, and uses the CRUSH map to pseudo-randomly store and retrieve data in OSDs with a uniform distribution of data across the cluster. For a detailed discussion of CRUSH, see [CRUSH - Controlled, Scalable, Decentralized Placement of Replicated Data](#)

CRUSH maps contain a list of OSDs, a list of ‘buckets’ for aggregating the devices into physical locations, and a list of rules that tell CRUSH how it should replicate data in a Ceph cluster’s pools. By reflecting the underlying physical organization of the installation, CRUSH can model—and thereby address—potential sources of correlated device failures. Typical sources include physical proximity, a shared power source, and a shared network. By encoding this information into the cluster map, CRUSH placement policies can separate object replicas across different failure domains while still maintaining the desired distribution. For example, to address the possibility of concurrent failures, it may be desirable to ensure that data replicas are on devices using different shelves, racks, power supplies, controllers, and/or physical locations.

When you create a configuration file and deploy Ceph with `mkcephfs`, Ceph generates a default CRUSH map for your configuration. The default CRUSH map is fine for your Ceph sandbox environment. However, when you deploy a large-scale data cluster, you should give significant consideration to developing a custom CRUSH map, because it will help you manage your Ceph cluster, improve performance and ensure data safety.

For example, if an OSD goes down, a CRUSH map can help you can locate the physical data center, room, row and rack of the host with the failed OSD in the event you need to use onsite support or replace hardware.

Similarly, CRUSH may help you identify faults more quickly. For example, if all OSDs in a particular rack go down simultaneously, the fault may lie with a network switch or power to the rack or the network switch rather than the OSDs themselves.

A custom CRUSH map can also help you identify the physical locations where Ceph stores redundant copies of data when the placement group(s) associated with a failed host are in a degraded state.

[Inktank](#) provides excellent premium support for developing CRUSH maps.

**Note:** Lines of code in example boxes may extend past the edge of the box. Please scroll when reading or copying longer examples.

## EDITING A CRUSH MAP

To edit an existing CRUSH map:

1. [Get the CRUSH map](#).
2. [Decompile](#) the CRUSH map.
3. Edit at least one of [Devices](#), [Buckets](#) and [Rules](#).
4. [Recompile](#) the CRUSH map.
5. [Set the CRUSH map](#).

To activate CRUSH Map rules for a specific pool, identify the common ruleset number for those rules and specify that ruleset number for the pool. See [Set Pool Values](#) for details.

## GET A CRUSH MAP

To get the CRUSH map for your cluster, execute the following:

```
ceph osd getcrushmap -o {compiled-crushmap-filename}
```

Ceph will output (-o) a compiled CRUSH map to the filename you specified. Since the CRUSH map is in a compiled form, you must decompile it first before you can edit it.

## DECOMPILE A CRUSH MAP

To decompile a CRUSH map, execute the following:

```
crushtool -d {compiled-crushmap-filename} -o {decompiled-crushmap-filename}
```

Ceph will decompile (-d) the compiled CRUSH map and output (-o) it to the filename you specified.

## COMPILE A CRUSH MAP

To compile a CRUSH map, execute the following:

```
crushtool -c {decompiled-crush-map-filename} -o {compiled-crush-map-filename}
```

Ceph will store a compiled CRUSH map to the filename you specified.

## SET A CRUSH MAP

To set the CRUSH map for your cluster, execute the following:

```
ceph osd setcrushmap -i {compiled-crushmap-filename}
```

Ceph will input the compiled CRUSH map of the filename you specified as the CRUSH map for the cluster.

## CRUSH MAP PARAMETERS

There are four main sections to a CRUSH Map.

1. **Devices:** Devices consist of any object storage device—i.e., the storage drive corresponding to a ceph-osd daemon. You should have a device for each OSD daemon in your Ceph configuration file.
2. **Bucket Types:** Bucket types define the types of buckets used in your CRUSH hierarchy. Buckets consist of a hierarchical aggregation of storage locations (e.g., rows, racks, hosts, etc.) and their assigned weights.
3. **Bucket Instances:** Once you define bucket types, you must declare bucket instances for your hosts, and any other failure domain partitioning you choose.
4. **Rules:** Rules consist of the manner of selecting buckets.

If you launched Ceph using one of our Quick Start guides, you'll notice that you didn't need to create a CRUSH map. Ceph's deployment tools generate a default CRUSH map that lists devices from the OSDs you defined in your Ceph configuration file, and it declares a bucket for each host you specified in the [osd] sections of your Ceph configuration file. You should create your own CRUSH maps with buckets that reflect your cluster's failure domains to better ensure data safety and availability.

**Note:** The generated CRUSH map doesn't take your larger grained failure domains into account. So you should modify your CRUSH map to account for larger grained failure domains such as racks, rows, data centers, etc.

## CRUSH MAP DEVICES

To map placement groups to OSDs, a CRUSH map requires a list of OSD devices (i.e., the names of the OSD daemons from the Ceph configuration file). The list of devices appears first in the CRUSH map. To declare a device in the CRUSH map, create a new line under your list of devices, enter device followed by a unique numeric ID, followed by the corresponding ceph-osd daemon instance.

```
#devices  
device {num} {osd.name}
```

For example:

```
#devices
```

```
device 0 osd.0
device 1 osd.1
device 2 osd.2
device 3 osd.3
```

As a general rule, an OSD daemon maps to a single storage drive or to a RAID.

## CRUSH MAP BUCKET TYPES

The second list in the CRUSH map defines ‘bucket’ types. Buckets facilitate a hierarchy of nodes and leaves. Node (or non-leaf) buckets typically represent physical locations in a hierarchy. Nodes aggregate other nodes or leaves. Leaf buckets represent ceph-osd daemons and their corresponding storage media.

**Tip:** The term “bucket” used in the context of CRUSH means a node in the hierarchy, i.e. a location or a piece of physical hardware. It is a different concept from the term “bucket” when used in the context of RADOS Gateway APIs.

To add a bucket type to the CRUSH map, create a new line under your list of bucket types. Enter type followed by a unique numeric ID and a bucket name. By convention, there is one leaf bucket and it is type 0; however, you may give it any name you like (e.g., osd, disk, drive, storage, etc.):

```
#types
type {num} {bucket-name}
```

For example:

```
# types
type 0 osd
type 1 host
type 2 rack
```

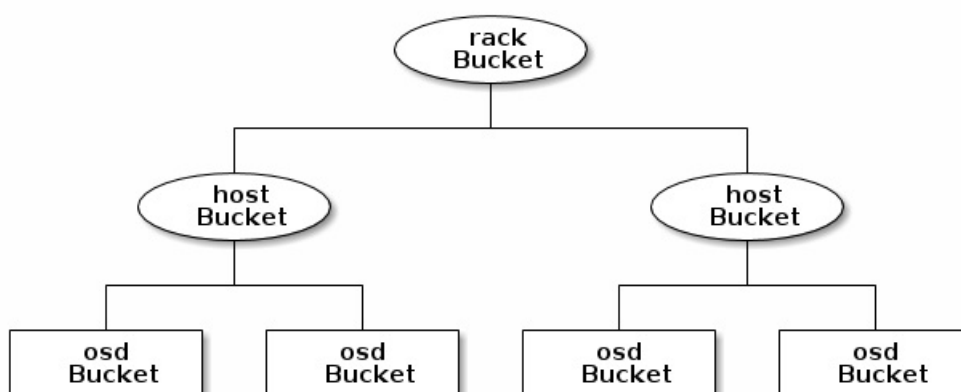
## CRUSH MAP BUCKET HIERARCHY

The CRUSH algorithm distributes data objects among storage devices according to a per-device weight value, approximating a uniform probability distribution. CRUSH distributes objects and their replicas according to the hierarchical cluster map you define. Your CRUSH map represents the available storage devices and the logical elements that contain them.

To map placement groups to OSDs across failure domains, a CRUSH map defines a hierarchical list of bucket types (i.e., under #types in the generated CRUSH map). The purpose of creating a bucket hierarchy is to segregate the leaf nodes by their failure domains, such as hosts, racks, rows, rooms, and data centers. With the exception of the leaf nodes representing OSDs, the rest of the hierarchy is arbitrary, and you may define it according to your own needs.

We recommend adapting your CRUSH map to your firm’s hardware naming conventions and using instances names that reflect the physical hardware. Your naming practice can make it easier to administer the cluster and troubleshoot problems when an OSD and/or other hardware malfunctions and the administrator need access to physical hardware.

In the following example, the bucket hierarchy has a leaf bucket named osd, and two node buckets named host and rack respectively.



**Note:** The higher numbered rack bucket type aggregates the lower numbered host bucket type.

Since leaf nodes reflect storage devices declared under the `#devices` list at the beginning of the CRUSH map, you do not need to declare them as bucket instances. The second lowest bucket type in your hierarchy usually aggregates the devices (i.e., it's usually the computer containing the storage media, and uses whatever term you prefer to describe it, such as "node", "computer", "server," "host", "machine", etc.).

When declaring a bucket instance, you must specify its type, give it a unique name (string), assign it a unique ID expressed as a negative integer (optional), specify a weight relative to the total capacity/capability of its item(s), specify the bucket algorithm (usually straw), and the hash (usually 0, reflecting hash algorithm rjenkins1). A bucket may have one or more items. The items may consist of node buckets or leaves. Items may have a weight that reflects the relative weight of the item.

You may declare a node bucket with the following syntax:

```
[bucket-type] [bucket-name] {
    id [a unique negative numeric ID]
    weight [the relative capacity/capability of the item(s)]
    alg [the bucket type: uniform | list | tree | straw ]
    hash [the hash type: 0 by default]
    item [item-name] weight [weight]
}
```

For example, using the diagram above, we would define two host buckets and one rack bucket. The OSDs are declared as items within the host buckets:

```
host node1 {
    id -1
    alg straw
    hash 0
    item osd.0 weight 1.00
    item osd.1 weight 1.00
}

host node2 {
    id -2
    alg straw
    hash 0
    item osd.2 weight 1.00
    item osd.3 weight 1.00
}

rack rack1 {
    id -3
    alg straw
    hash 0
    item node1 weight 2.00
    item node2 weight 2.00
}
```

**Note:** In the foregoing example, note that the rack bucket does not contain any OSDs. Rather it contains lower level host buckets, and includes the sum total of their weight in the item entry.

## Bucket Types

Ceph supports four bucket types, each representing a tradeoff between performance and reorganization efficiency. If you are unsure of which bucket type to use, we recommend using a straw bucket. For a detailed discussion of bucket types, refer to [CRUSH - Controlled, Scalable, Decentralized Placement of Replicated Data](#), and more specifically to **Section 3.4**. The bucket types are:

1. **Uniform:** Uniform buckets aggregate devices with **exactly** the same weight. For example, when firms commission or decommission hardware, they typically do so with many machines that have exactly the same physical configuration (e.g., bulk purchases). When storage devices have exactly the same weight, you may use the uniform bucket type, which allows CRUSH to map replicas into uniform buckets in constant time. With non-uniform weights, you should use another bucket algorithm.
2. **List:** List buckets aggregate their content as linked lists. Based on the [RUSH](#) algorithm, a list is a natural and intuitive choice for an **expanding cluster**: either an object is relocated to the newest device with some appropriate probability, or it remains on the older devices as before. The result is optimal data

migration when items are added to the bucket. Items removed from the middle or tail of the list, however, can result in a significant amount of unnecessary movement, making list buckets most suitable for circumstances in which they **never (or very rarely) shrink**.

3. **Tree:** Tree buckets use a binary search tree. They are more efficient than list buckets when a bucket contains a larger set of items. Based on the [RUSH<sub>R</sub>](#) algorithm, tree buckets reduce the placement time to  $O(\log n)$ , making them suitable for managing much larger sets of devices or nested buckets.
4. **Straw:** List and Tree buckets use a divide and conquer strategy in a way that either gives certain items precedence (e.g., those at the beginning of a list) or obviates the need to consider entire subtrees of items at all. That improves the performance of the replica placement process, but can also introduce suboptimal reorganization behavior when the contents of a bucket change due an addition, removal, or re-weighting of an item. The straw bucket type allows all items to fairly “compete” against each other for replica placement through a process analogous to a draw of straws.

## Hash

Each bucket uses a hash algorithm. Currently, Ceph supports `rjenkins1`. Enter `0` as your hash setting to select `rjenkins1`.

## Weighting Bucket Items

Ceph expresses bucket weights as double integers, which allows for fine weighting. A weight is the relative difference between device capacities. We recommend using `1.00` as the relative weight for a 1TB storage device. In such a scenario, a weight of `0.5` would represent approximately 500GB, and a weight of `3.00` would represent approximately 3TB. Higher level buckets have a weight that is the sum total of the leaf items aggregated by the bucket.

A bucket item weight is one dimensional, but you may also calculate your item weights to reflect the performance of the storage drive. For example, if you have many 1TB drives where some have relatively low data transfer rate and the others have a relatively high data transfer rate, you may weight them differently, even though they have the same capacity (e.g., a weight of `0.80` for the first set of drives with lower total throughput, and `1.20` for the second set of drives with higher total throughput).

## CRUSH MAP RULES

CRUSH maps support the notion of ‘CRUSH rules’, which are the rules that determine data placement for a pool. For large clusters, you will likely create many pools where each pool may have its own CRUSH ruleset and rules. The default CRUSH map has a rule for each pool, and one ruleset assigned to each of the default pools, which include:

- data
- metadata
- rbd

**Note:** In most cases, you will not need to modify the default rules. When you create a new pool, its default ruleset is `0`.

CRUSH rules defines placement and replication strategies or distribution policies that allow you to specify exactly how CRUSH places object replicas. For example, you might create a rule selecting a pair of targets for 2-way mirroring, another rule for selecting three targets in two different data centers for 3-way mirroring, and yet another rule for RAID-4 over six storage devices. For a detailed discussion of CRUSH rules, refer to [CRUSH - Controlled, Scalable, Decentralized Placement of Replicated Data](#), and more specifically to **Section 3.2**.

A rule takes the following form:

```
rule <rulename> {  
    ruleset <ruleset>  
    type [ replicated | raid4 ]  
    min_size <min-size>  
    max_size <max-size>  
    step take <bucket-type>  
    step [choose|chooseleaf] [firstn|indep] <N> <bucket-type>  
    step emit  
}
```

ruleset

**Description:** A means of classifying a rule as belonging to a set of rules. Activated by [setting the ruleset in a pool](#).  
**Purpose:** A component of the rule mask.  
**Type:** Integer  
**Required:** Yes  
**Default:** 0

type

**Description:** Describes a rule for either a storage drive (replicated) or a RAID.  
**Purpose:** A component of the rule mask.  
**Type:** String  
**Required:** Yes  
**Default:** replicated  
**Valid Values:** Currently only replicated

min\_size

**Description:** If a pool makes fewer replicas than this number, CRUSH will NOT select this rule.  
**Type:** Integer  
**Purpose:** A component of the rule mask.  
**Required:** Yes  
**Default:** 1

max\_size

**Description:** If a pool makes more replicas than this number, CRUSH will NOT select this rule.  
**Type:** Integer  
**Purpose:** A component of the rule mask.  
**Required:** Yes  
**Default:** 10

step take <bucket-name>

**Description:** Takes a bucket name, and begins iterating down the tree.  
**Purpose:** A component of the rule.  
**Required:** Yes  
**Example:** step take data

step choose firstn {num} type {bucket-type}

**Description:** Selects the number of buckets of the given type. The number is usually the number of replicas in the pool (i.e., pool size).

- If {num} == 0, choose pool-num-replicas buckets (all available).
- If {num} > 0 && < pool-num-replicas, choose that many buckets.
- If {num} < 0, it means pool-num-replicas - {num}.

**Purpose:** A component of the rule.  
**Prerequisite:** Follows step take or step choose.  
**Example:** step choose firstn 1 type row

step chooseleaf firstn {num} type {bucket-type}

**Description:** Selects a set of buckets of {bucket-type} and chooses a leaf node from the subtree of each bucket in the set of buckets. The number of buckets in the set is usually the number of replicas in the pool (i.e., pool size).

- If {num} == 0, choose pool-num-replicas buckets (all available).
- If {num} > 0 && < pool-num-replicas, choose that many buckets.
- If {num} < 0, it means pool-num-replicas - {num}.

**Purpose:** A component of the rule. Usage removes the need to select a device using two steps.  
**Prerequisite:** Follows step take or step choose.  
**Example:** step chooseleaf firstn 0 type row

step emit

**Description:** Outputs the current value and empties the stack. Typically used at the end of a rule, but may also be

used to pick from different trees in the same rule.

**Purpose:** A component of the rule.

**Prerequisite:** Follows step choose.

**Example:** step emit

**Important:** To activate one or more rules with a common ruleset number to a pool, set the ruleset number of the pool.

## PLACING DIFFERENT POOLS ON DIFFERENT OSDS:

Suppose you want to have most pools default to OSDs backed by large hard drives, but have some pools mapped to OSDs backed by fast solid-state drives (SSDs). It's possible to have multiple independent CRUSH heirarchies within the same CRUSH map. Define two hierachies with two different root nodes-one for hard disks (e.g., "root platter") and one for SSDs (e.g., "root ssd") as shown below:

```
device 0 osd.0
device 1 osd.1
device 2 osd.2
device 3 osd.3
device 4 osd.4
device 5 osd.5
device 6 osd.6
device 7 osd.7

host ceph-osd-ssd-server-1 {
    id -1
    alg straw
    hash 0
    item osd.0 weight 1.00
    item osd.1 weight 1.00
}

host ceph-osd-ssd-server-2 {
    id -2
    alg straw
    hash 0
    item osd.2 weight 1.00
    item osd.3 weight 1.00
}

host ceph-osd-platter-server-1 {
    id -3
    alg straw
    hash 0
    item osd.4 weight 1.00
    item osd.5 weight 1.00
}

host ceph-osd-platter-server-2 {
    id -4
    alg straw
    hash 0
    item osd.6 weight 1.00
    item osd.7 weight 1.00
}

root platter {
    id -5
    alg straw
    hash 0
    item ceph-osd-platter-server-1 weight 2.00
    item ceph-osd-platter-server-2 weight 2.00
}

root ssd {
    id -6
    alg straw
    hash 0
    item ceph-osd-ssd-server-1 weight 2.00
    item ceph-osd-ssd-server-2 weight 2.00
}
```

```

rule data {
    ruleset 0
    type replicated
    min_size 2
    max_size 2
    step take platter
    step chooseleaf firstn 0 type host
    step emit
}

rule metadata {
    ruleset 1
    type replicated
    min_size 0
    max_size 10
    step take platter
    step chooseleaf firstn 0 type host
    step emit
}

rule rbd {
    ruleset 2
    type replicated
    min_size 0
    max_size 10
    step take platter
    step chooseleaf firstn 0 type host
    step emit
}

rule platter {
    ruleset 3
    type replicated
    min_size 0
    max_size 10
    step take platter
    step chooseleaf firstn 0 type host
    step emit
}

rule ssd {
    ruleset 4
    type replicated
    min_size 0
    max_size 10
    step take ssd
    step chooseleaf firstn 0 type host
    step emit
}

rule ssd-primary {
    ruleset 4
    type replicated
    min_size 0
    max_size 10
    step take ssd
    step chooseleaf firstn 1 type host
    step emit
    step take platter
    step chooseleaf firstn -1 type host
    step emit
}

```

You can then set a pool to use the SSD rule by:

```
ceph osd pool set <poolname> crush_ruleset 4
```

Similarly, using the ssd-primary rule will cause each placement group in the pool to be placed with an SSD as the primary and platters as the replicas.



## ADD/MOVE AN OSD

To add or move an OSD in the CRUSH map of a running cluster, execute the `ceph osd crush set`. For Argonaut (v 0.48), execute the following:

```
ceph osd crush set {id} {name} {weight} pool={pool-name} [{bucket-type}={bucket-name} ...]
```

For Bobtail (v 0.56), execute the following:

```
ceph osd crush set {id-or-name} {weight} root={pool-name} [{bucket-type}={bucket-name} ...]
```

Where:

`id`

**Description:** The numeric ID of the OSD.  
**Type:** Integer  
**Required:** Yes  
**Example:** 0

`name`

**Description:** The full name of the OSD.  
**Type:** String  
**Required:** Yes  
**Example:** osd.0

`weight`

**Description:** The CRUSH weight for the OSD.  
**Type:** Double  
**Required:** Yes  
**Example:** 2.0

`root`

**Description:** The root of the tree in which the OSD resides.  
**Type:** Key/value pair.  
**Required:** Yes  
**Example:** root=default

`bucket-type`

**Description:** You may specify the OSD's location in the CRUSH hierarchy.  
**Type:** Key/value pairs.  
**Required:** No  
**Example:** datacenter=dc1 room=room1 row=foo rack=bar host=foo-bar-1

The following example adds `osd.0` to the hierarchy, or moves the OSD from a previous location.

```
ceph osd crush set osd.0 1.0 root=default datacenter=dc1 room=room1 row=foo rack=bar host=foo
```

## ADJUST AN OSD'S CRUSH WEIGHT

To adjust an OSD's crush weight in the CRUSH map of a running cluster, execute the following:

```
ceph osd crush reweight {name} {weight}
```

Where:

name

**Description:** The full name of the OSD.  
**Type:** String  
**Required:** Yes  
**Example:** `osd.0`

weight

**Description:** The CRUSH weight for the OSD.  
**Type:** Double  
**Required:** Yes  
**Example:** `2.0`

## REMOVE AN OSD

To remove an OSD from the CRUSH map of a running cluster, execute the following:

```
ceph osd crush remove {name}
```

Where:

name

**Description:** The full name of the OSD.  
**Type:** String  
**Required:** Yes  
**Example:** `osd.0`

## MOVE A BUCKET

To move a bucket to a different location or position in the CRUSH map hierarchy, execute the following:

```
ceph osd crush move {bucket-name} {bucket-type}={bucket-name}, [...]
```

Where:

bucket-name

**Description:** The name of the bucket to move/reposition.  
**Type:** String  
**Required:** Yes  
**Example:** `foo-bar-1`

bucket-type

**Description:** You may specify the bucket's location in the CRUSH hierarchy.  
**Type:** Key/value pairs.  
**Required:** No  
**Example:** `datacenter=dc1 room=room1 row=foo rack=bar host=foo-bar-1`

## TUNABLES

*New in version 0.48.*

There are several magic numbers that were used in the original CRUSH implementation that have proven to be poor choices. To support the transition away from them, newer versions of CRUSH (starting with the v0.48 argonaut series) allow the values to be adjusted or tuned.

Clusters running recent Ceph releases support using the tunable values in the CRUSH maps. However, older clients and daemons will not correctly interact with clusters using the “tuned” CRUSH maps. To detect this situation, there are now features bits CRUSH\_TUNABLES (value 0x40000) and CRUSH\_TUNABLES2 to reflect support for tunables.

If the OSDMap currently used by the ceph-mon or ceph-osd daemon has non-legacy values, it will require the CRUSH\_TUNABLES or CRUSH\_TUNABLES2 feature bits from clients and daemons who connect to it. This means that old clients will not be able to connect.

At some future point in time, newly created clusters will have improved default values for the tunables. This is a matter of waiting until the support has been present in the Linux kernel clients long enough to make this a painless transition for most users.

## IMPACT OF LEGACY VALUES

The legacy values result in several misbehaviors:

- For hierarchies with a small number of devices in the leaf buckets, some PGs map to fewer than the desired number of replicas. This commonly happens for hierarchies with “host” nodes with a small number (1-3) of OSDs nested beneath each one.
- For large clusters, some small percentages of PGs map to less than the desired number of OSDs. This is more prevalent when there are several layers of the hierarchy (e.g., row, rack, host, osd).
- When some OSDs are marked out, the data tends to get redistributed to nearby OSDs instead of across the entire hierarchy.

## CRUSH\_TUNABLES

- `choose_local_tries`: Number of local retries. Legacy value is 2, optimal value is 0.
- `choose_local_fallback_tries`: Legacy value is 5, optimal value is 0.
- `choose_total_tries`: Total number of attempts to choose an item. Legacy value was 19, subsequent testing indicates that a value of 50 is more appropriate for typical clusters. For extremely large clusters, a larger value might be necessary.

## CRUSH\_TUNABLES2

- `chooseleaf_descend_once`: Whether a recursive chooseleaf attempt will retry, or only try once and allow the original placement to retry. Legacy default is 0, optimal value is 1.

## WHICH CLIENT VERSIONS SUPPORT CRUSH\_TUNABLES

- argonaut series, v0.48.1 or later
- v0.49 or later
- Linux kernel version v3.6 or later (for the file system and RBD kernel clients)

## WHICH CLIENT VERSIONS SUPPORT CRUSH\_TUNABLES2

- v0.55 or later, including bobtail series (v0.56.x)
- Linux kernel version v3.9 or later (for the file system and RBD kernel clients)

## A FEW IMPORTANT POINTS

- Adjusting these values will result in the shift of some PGs between storage nodes. If the Ceph cluster is already storing a lot of data, be prepared for some fraction of the data to move.
- The ceph-osd and ceph-mon daemons will start requiring the feature bits of new connections as soon as they get the updated map. However, already-connected clients are effectively grandfathered in, and will misbehave if they do not support the new feature.
- If the CRUSH tunables are set to non-legacy values and then later changed back to the default values, ceph-osd daemons will not be required to support the feature. However, the OSD peering process requires examining and understanding old maps. Therefore, you should not run old versions of the ceph-osd daemon if the cluster has previously used non-legacy CRUSH values, even if the latest version of the map has been switched back to using the legacy defaults.

## TUNING CRUSH

The simplest way to adjust the crush tunables is by changing to a known profile. Those are:

- `legacy`: the legacy behavior from argonaut and earlier.
- `argonaut`: the legacy values supported by the original argonaut release
- `bobtail`: the values supported by the bobtail release
- `optimal`: the current best values
- `default`: the current default values for a new cluster

Currently, `legacy`, `default`, and `argonaut` are the same, and `bobtail` and `optimal` include `CRUSH_TUNABLES` and `CRUSH_TUNABLES2`.

You can select a profile on a running cluster with the command:

```
ceph osd crush tunables {PROFILE}
```

Note that this may result in some data movement.

## TUNING CRUSH, THE HARD WAY

If you can ensure that all clients are running recent code, you can adjust the tunables by extracting the CRUSH map, modifying the values, and reinjecting it into the cluster.

- Extract the latest CRUSH map:

```
ceph osd getcrushmap -o /tmp/crush
```

- Adjust tunables. These values appear to offer the best behavior for both large and small clusters we tested with. You will need to additionally specify the `--enable-unsafe-tunables` argument to `crushtool` for this to work. Please use this option with extreme care.:

```
crushtool -i /tmp/crush --set-choose-local-tries 0 --set-choose-local-fallback-tries 0 --
```

- Reinject modified map:

```
ceph osd setcrushmap -i /tmp/crush.new
```

## LEGACY VALUES

For reference, the legacy values for the CRUSH tunables can be set with:

```
crushtool -i /tmp/crush --set-choose-local-tries 2 --set-choose-local-fallback-tries 5 --set-
```

Again, the special `--enable-unsafe-tunables` option is required. Further, as noted above, be careful running old versions of the `ceph-osd` daemon after reverting to legacy values as the feature bit is not perfectly enforced.