the ceph distributed storage system

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scale 10x – january 22, 2012

hello

- why you should care
- what is it, what it does
- how it works, how you can use it
  - architecture
  - objects
  - recovery
  - block devices
  - file system
- who we are, why we do this

why should you care about another storage system?

requirements, time, money

requirements

- diverse storage needs
  - object storage (RESTful or low-level)
  - block devices (for VMs) with snapshots, cloning
  - shared file system with POSIX, coherent caches
- scale
  - terabytes, petabytes. exabytes?
  - heterogeneous hardware
  - reliability and fault tolerance

time

- ease of administration
- no manual data migration, load balancing
- painless scaling
  - expansion **and** contraction
  - seamless migration

money

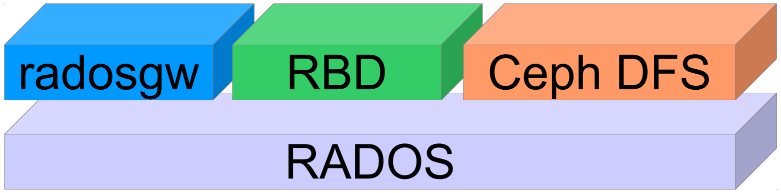
- low cost per gigabyte
- no vendor lock-in

- software solution
  - run on commodity hardware
- open source

what is ceph?

unified storage system

- objects
  - small or large
  - multi-protocol
- block devices
  - snapshots, cloning
- files
  - cache coherent
  - snapshots
  - usage accounting



open source

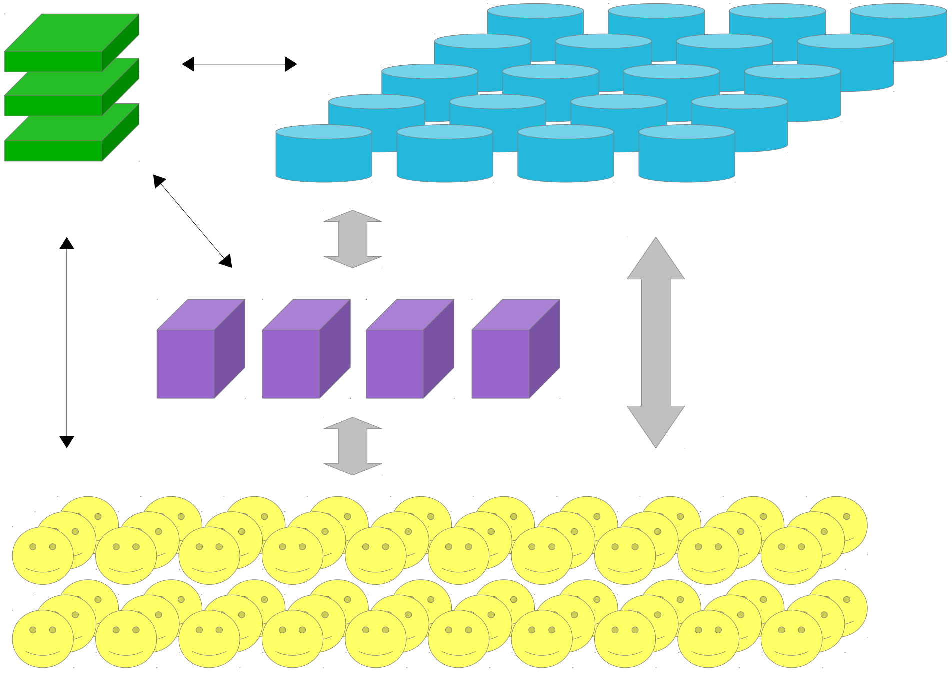
- LGPLv2
  - copyleft
  - free to link to proprietary code
- no copyright assignment
  - no dual licensing
  - no “enterprise-only” feature set
- active community
- commercial support

distributed storage system

- data center (not geo) scale
  - 10s to 10,000s of machines
  - terabytes to exabytes
- fault tolerant
  - no SPoF
  - commodify hardware
    - ethernet, SATA/SAS, HDD/SSD
    - RAID, SAN probably a waste of time, power, and money

architecture

- monitors (ceph-mon)
  - 1s-10s, paxos
  - lightweight process
  - authentication, cluster membership, critical cluster state
- object storage daemons (ceph-osd)
  - 1s-10,000s
  - smart, coordinate with peers
- clients (librados, librbd)
  - zillions
  - authenticate with monitors, talk directly to ceph-osds
- metadata servers (ceph-mds)
  - 1s-10s
  - build POSIX file system on top of objects



rados object storage model

- pools
  - 1s to 100s
  - independent namespaces or object collections
  - replication level, placement policy
- objects
  - trillions
  - blob of data (bytes to gigabytes)
  - attributes (e.g., “version=12”; bytes to kilobytes)
  - key/value bundle (bytes to gigabytes)

rados object API

- librados.so
  - C, C++, Python, Java. shell.
- read/write (extent), truncate, remove; get/set/remove xattr or key
  - like a file or .db file
- efficient copy-on-write clone
- atomic compound operations/transactions
  - read + getxattr, write + setxattr
  - compare xattr value, if match write + setxattr
- classes
  - load new code into cluster to implement new methods
  - calc sha1, grep/filter, generate thumbnail
  - encrypt, increment, rotate image
- watch/notify
  - use object as communication channel between clients (locking primitive)

object storage

- client/server, host/device paradigm doesn't scale
  - idle servers are wasted servers
  - if servers don't coordinate, clients must
- ceph-osds are intelligent storage daemons
  - coordinate with peers over TCP/IP
  - intelligent protocols; no 'IP fail over' or similar hacks
- flexible deployment
  - one per disk
  - one per host
  - one per RAID volume
- sit on local file system
  - btrfs, xfs, ext4, etc.

why we like btrfs

- pervasive checksumming
- snapshots, copy-on-write
- efficient metadata (xattrs)
- inline data for small files
- transparent compression
- integrated volume management
  - software RAID, mirroring, error recovery
  - SSD-aware
- online fsck
- active development community

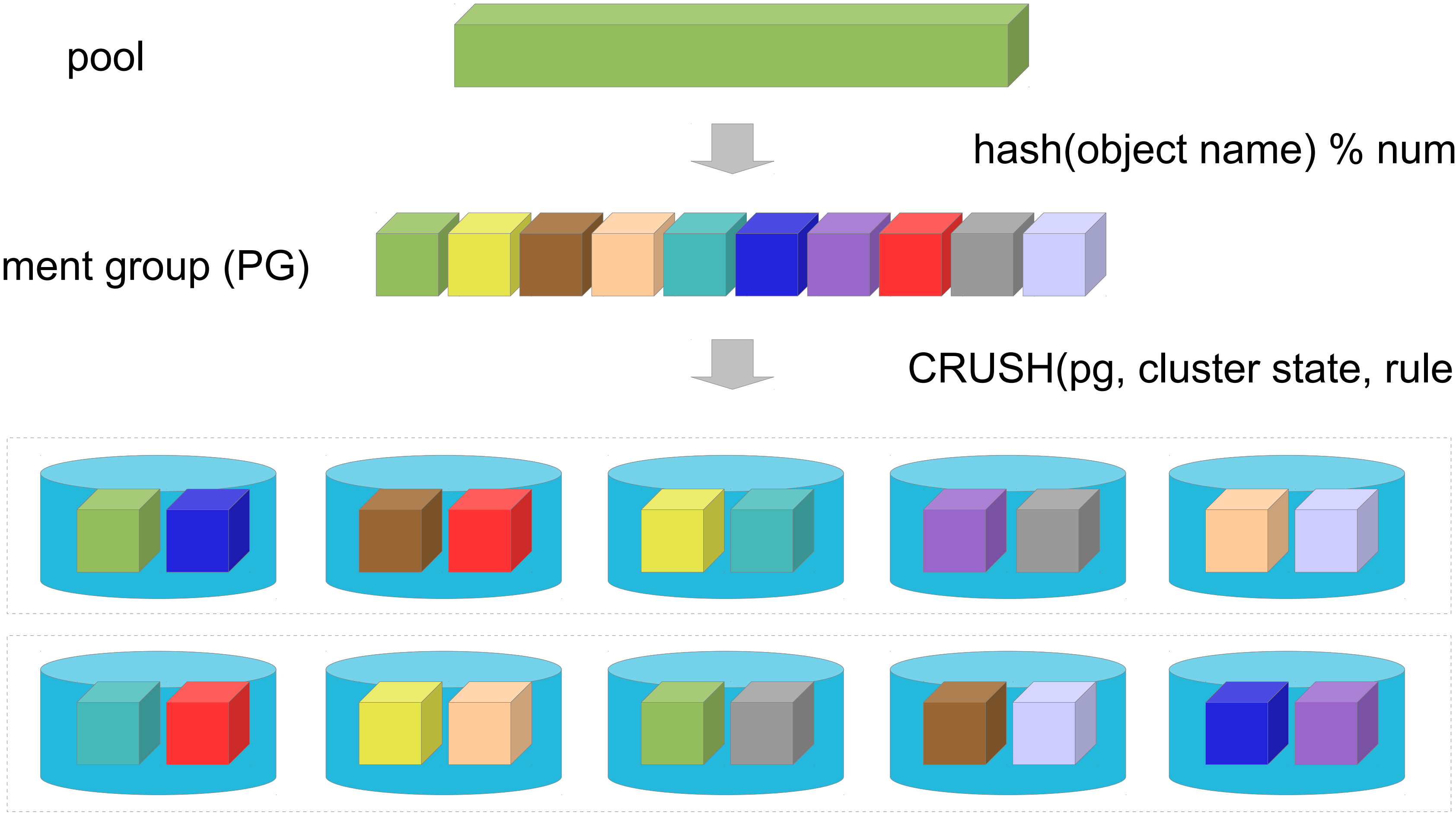
data distribution

- all objects are replicated N times
- objects are automatically placed, balanced, migrated in a dynamic cluster
- must consider physical infrastructure
  - ceph-osds on hosts in racks in rows in data centers
- three approaches
  - pick a spot; remember where you put it
  - pick a spot; write down where you put it
  - calculate where to put it, where to find it

CRUSH

- pseudo-random placement algorithm
  - uniform, weighted distribution
  - fast calculation, no lookup
- placement rules
  - in terms of physical infrastructure
    - “3 replicas, same row, different racks”
- predictable, bounded migration on changes
  - N → N + 1 ceph-osds means a bit over 1/Nth of data moves

object placement



pool

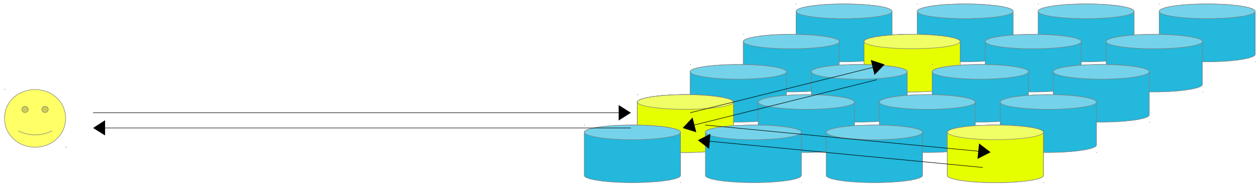
hash(object name) % num_pg = pg

placement group (PG)

CRUSH(pg, cluster state, rule) = [A, B]

replication

- all data replicated N times
- ceph-osd cluster handles replication
  - client writes to first replica



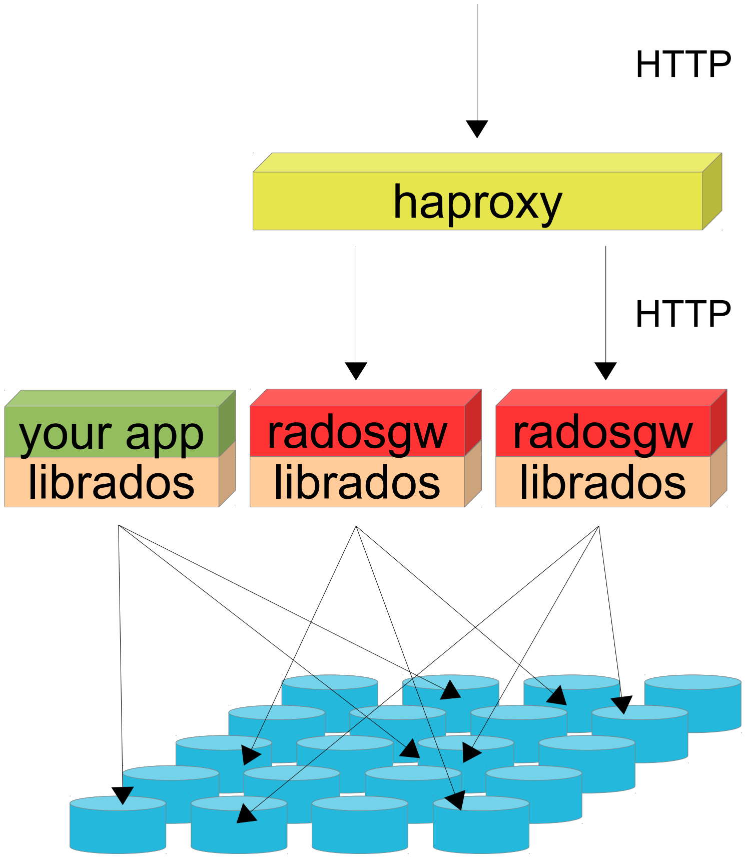
  - reduce client bandwidth
  - “only once” semantics
  - dual in-memory vs on-disk acks on request

recovery

- dynamic cluster
  - nodes are added, removed
  - nodes reboot, fail, recover
- “recovery” is the norm
  - “map” records cluster state at point in time
    - ceph-osd node status (up/down, weight, IP)
    - CRUSH function specifying desired data distribution
  - ceph-osds cooperatively migrate data to achieve that
- 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.

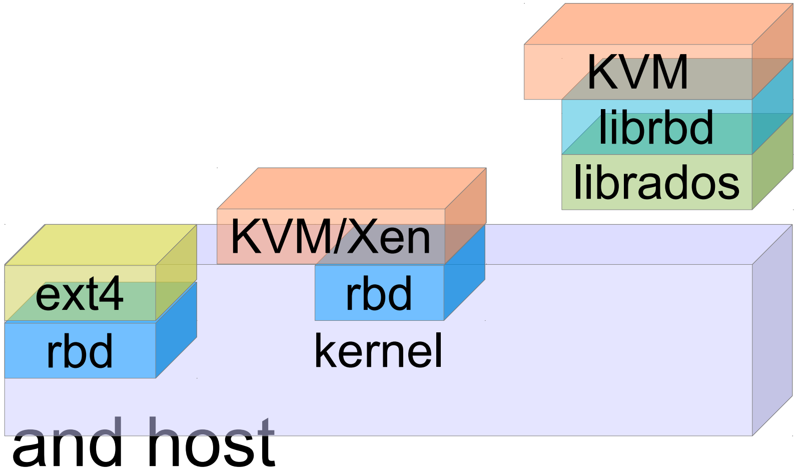
librados, radosgw

- librados
  - direct parallel access to cluster
  - rich API
- radosgw
  - RESTful object storage
    - S3, Swift APIs
  - proxy HTTP to rados
  - ACL-based security for the big bad internet



rbd – rados block device

- replicated, reliable, high-performance virtual disk
  - striped over objects across entire cluster
  - thinly provisioned, snapshots
  - image cloning (real soon now)
- well integrated
  - Linux kernel driver (/dev/rbd0)
  - qemu/KVM + librbd
  - libvirt, OpenStack
- sever link between virtual machine and host
  - fail-over, live migration

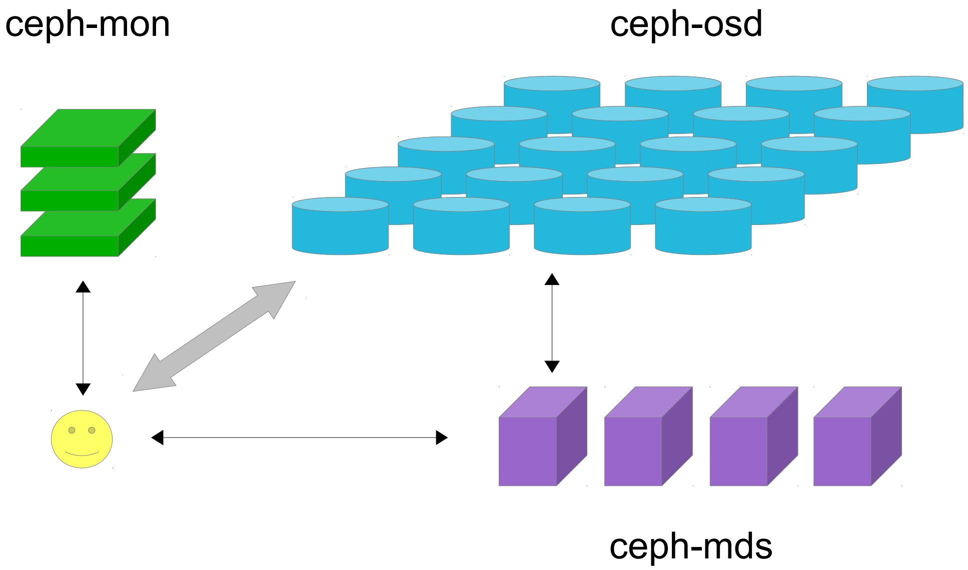


ceph distributed file system

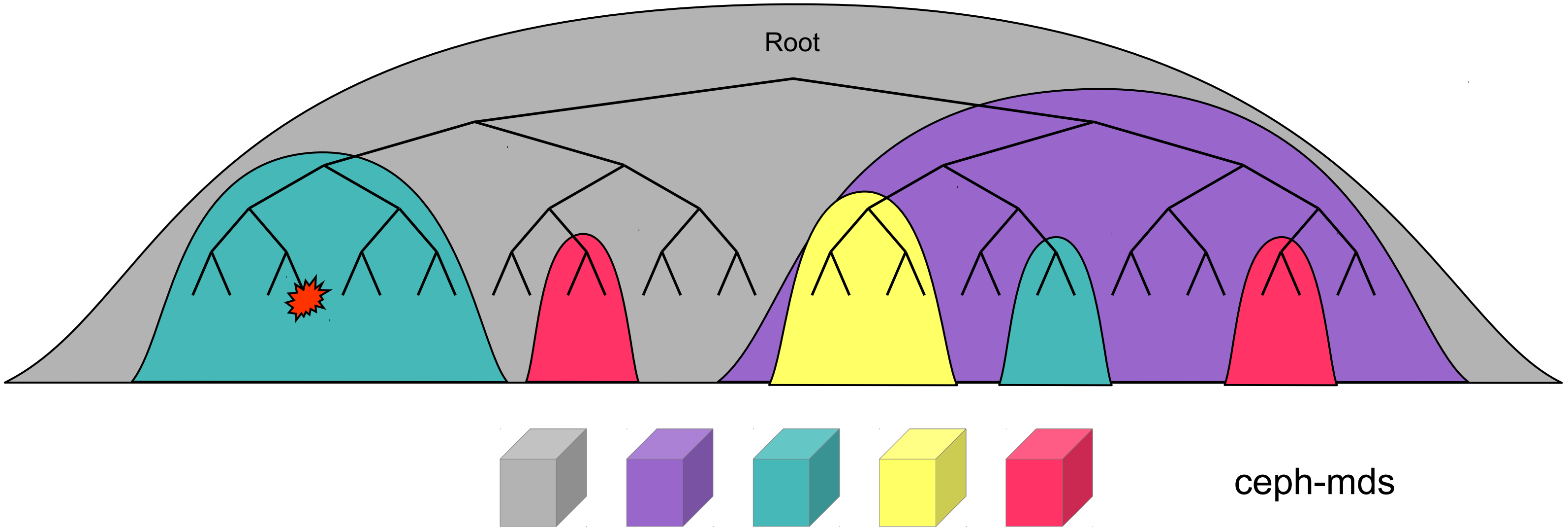
- shared cluster-coherent file system
- separate metadata and data paths
  - avoid “server” bottleneck inherent in NFS etc
- ceph-mds cluster
  - manages file system hierarchy
  - redistributes load based on workload
  - ultimately stores everything in objects
- highly stateful client sessions
  - lots of caching, prefetching, locks and leases

an example

- `mount -t ceph 1.2.3.4:/ /mnt`
  - 3 ceph-mon RT
  - 2 ceph-mds RT (1 ceph-mds to -osd RT)
- `cd /mnt/foo/bar`
  - 2 ceph-mds RT (2 ceph-mds to -osd RT)
- `ls -al`
  - open
  - readdir
    - 1 ceph-mds RT (1 ceph-mds to -osd RT)
  - stat each file
  - close
- `cp * /tmp`
  - N ceph-osd RT



dynamic subtree partitioning



- efficient
  - hierarchical partition preserve locality
- dynamic
  - daemons can join/leave
  - take over for failed nodes

- scalable
  - arbitrarily partition metadata
- adaptive
  - move work from busy to idle servers
  - replicate hot metadata

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
```

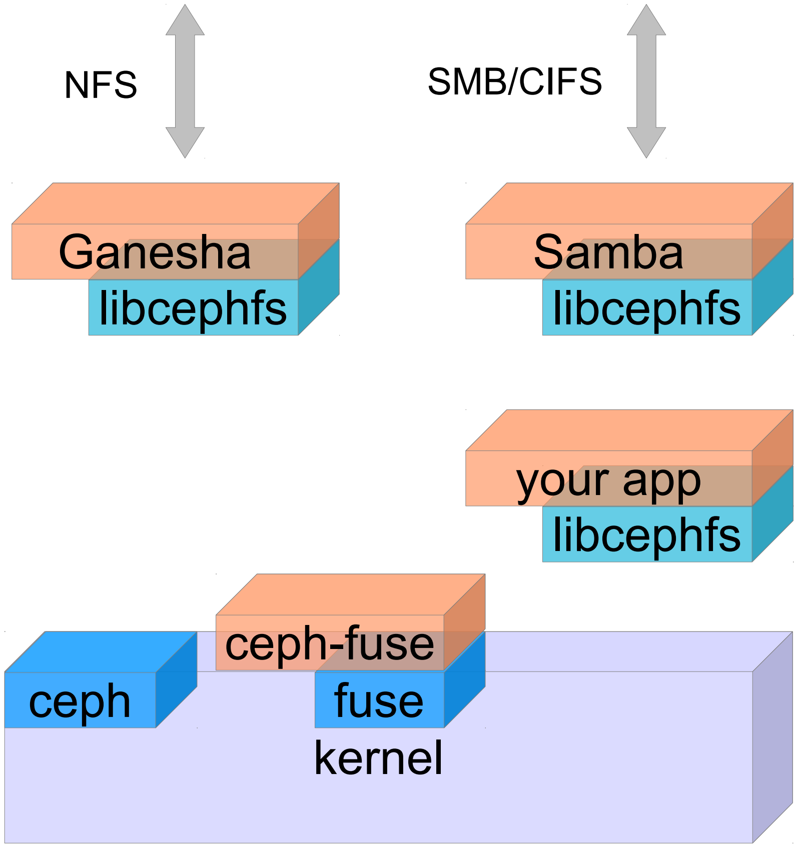
snapshots

- volume or subvolume unusable at petabyte scale
  - snapshot arbitrary subdirectories
- simple interface
  - hidden '.snap' directory
  - no special tools

```
$ mkdir foo/.snap/one    # create snapshot
$ ls foo/.snap
one
$ ls foo/bar/.snap
_one_1099511627776       # parent's snap name is mangled
$ rm foo/myfile
$ ls -F foo
bar/
$ ls -F foo/.snap/one
myfile  bar/
$ rmdir foo/.snap/one    # remove snapshot
```

multiple protocols, implementations

- Linux kernel client
  - mount -t ceph 1.2.3.4:/ /mnt
  - export (NFS), Samba (CIFS)
- ceph-fuse
- libcephfs.so
  - your app
  - Samba (CIFS)
  - Ganesha (NFS)
  - Hadoop (map/reduce)



can I deploy it already?

- rados object store is stable
  - librados
  - radosgw (RESTful APIs)
  - rbd rados block device
  - commercial support in 1-3 months
- file system is not ready
  - feature complete
  - suitable for testing, PoC, benchmarking
  - needs testing, deliberate qa effort for production

why we do this

- limited options for scalable open source storage
  - nexenta
  - orangefs, lustre
  - glusterfs
- proprietary solutions
  - marry hardware and software
  - expensive
  - don't scale (well or out)
- we can change the industry

who we are

- created at UC Santa Cruz (2007)
- supported by DreamHost (2008-2011)
- spun off as new company (2012)
  - downtown Los Angeles, downtown San Francisco
- growing user and developer community
  - Silicon Valley, Asia, Europe
  - Debian, SuSE, Canonical, RedHat
  - cloud computing stacks
- we are hiring
  - C/C++/Python developers
  - sysadmins, testing engineers

http://ceph.newdream.net/