ceph

managing a distributed storage system at scale

sage weil – inktank
LISA – 12.12.12

outline

- the scale-out world
- what is it, what it's for, how it works
- how you can use it
  - librados
  - radosgw
  - RBD, the ceph block device
  - distributed file system
- how do you deploy and manage it
- roadmap
- why we do this, who we are

why should you care about another storage system?

the old reality

- direct-attached storage
  - raw disks
  - RAID controller
- network-attached storage
  - a few large arrays
  - NFS, CIFS, maybe iSCSI
- SAN
  - expensive enterprise array
- scalable capacity and performance, to a point
- poor management scalability

new user demands

- “cloud”
  - many disk volumes, with automated provisioning
  - larger data sets
    - RESTful object storage (e.g., S3, Swift)
    - NoSQL distributed key/value stores (Cassandra, Riak)
- “big data”
  - distributed processing
  - “unstructured data”
- ...and the more traditional workloads

requirements

- diverse use-cases
  - object storage
  - block devices (for VMs) with snapshots, cloning
  - shared file system with POSIX, coherent caches
  - structured data... files, block devices, or objects?
- scale
  - terabytes, petabytes, exabytes
  - heterogeneous hardware
  - reliability and fault tolerance

cost

- near-linear function of size or performance
- incremental expansion
  - no fork-lift upgrades
- no vendor lock-in
  - choice of hardware
  - choice of software
- open

time

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

- devops friendly

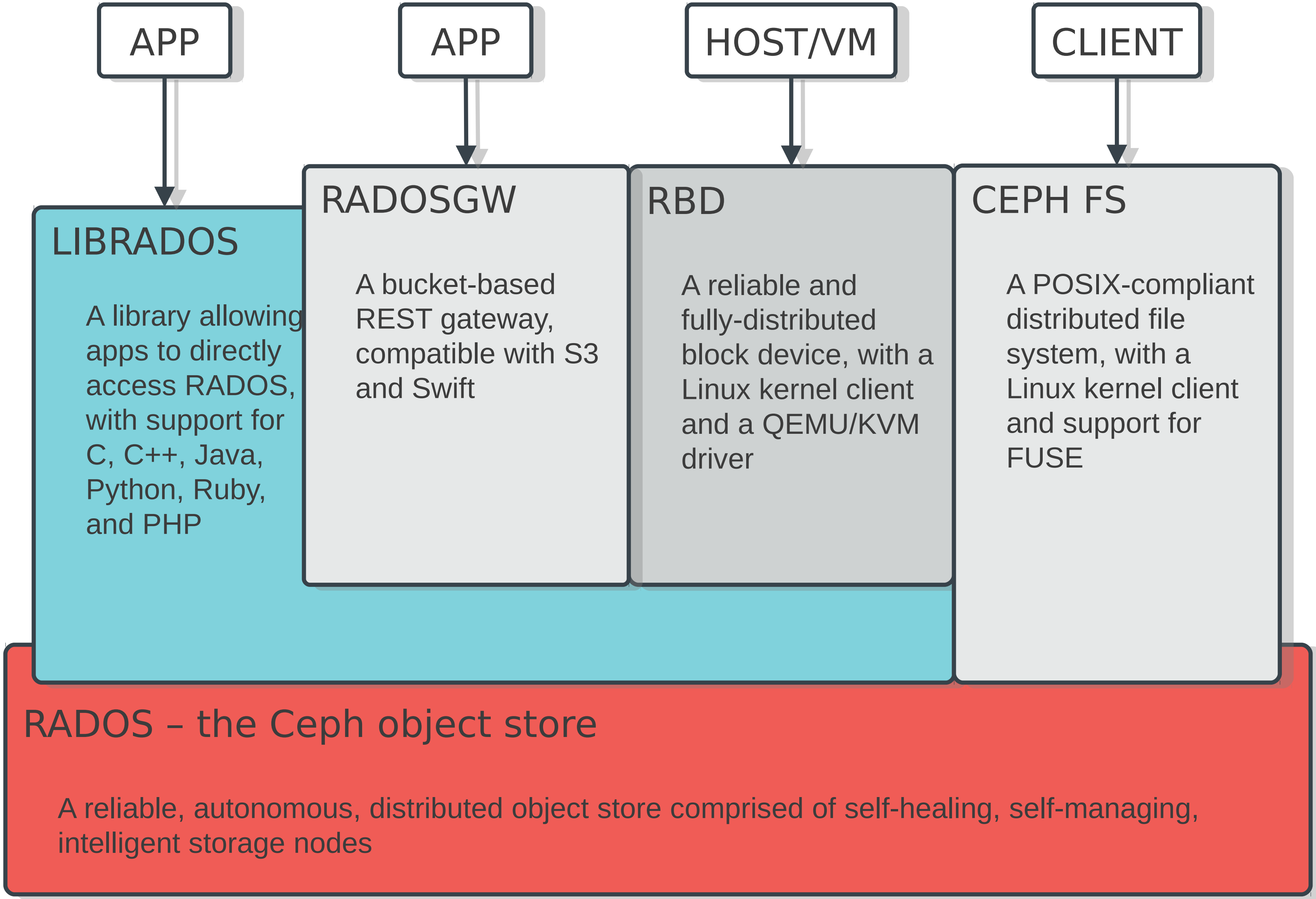
being a good devops citizen

- seamless integration with infrastructure tools
  - Chef, Juju, Puppet, Crowbar, or home-grown
  - collectd, statsd, graphite, nagios
  - OpenStack, CloudStack
- simple processes for
  - expanding or contracting the storage cluster
  - responding to failure scenarios: initial healing, or mop-up
- evolution of “Unix philosophy”
  - everything is just daemon
  - CLI, REST APIs, JSON
  - solve one problem, and solve it well

what is ceph?

unified storage system

- objects
  - native API
  - RESTful
- block
  - thin provisioning, snapshots, cloning
- file
  - strong consistency, snapshots


APP
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HOST/VM
CLIENT
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A reliable, autonomous, distributed object store comprised of self-healing, self-managing, intelligent storage nodes

distributed storage system

- data center scale
  - 10s to 10,000s of machines
  - terabytes to exabytes
- fault tolerant
  - no single point of failure
  - commodity hardware
- self-managing, self-healing

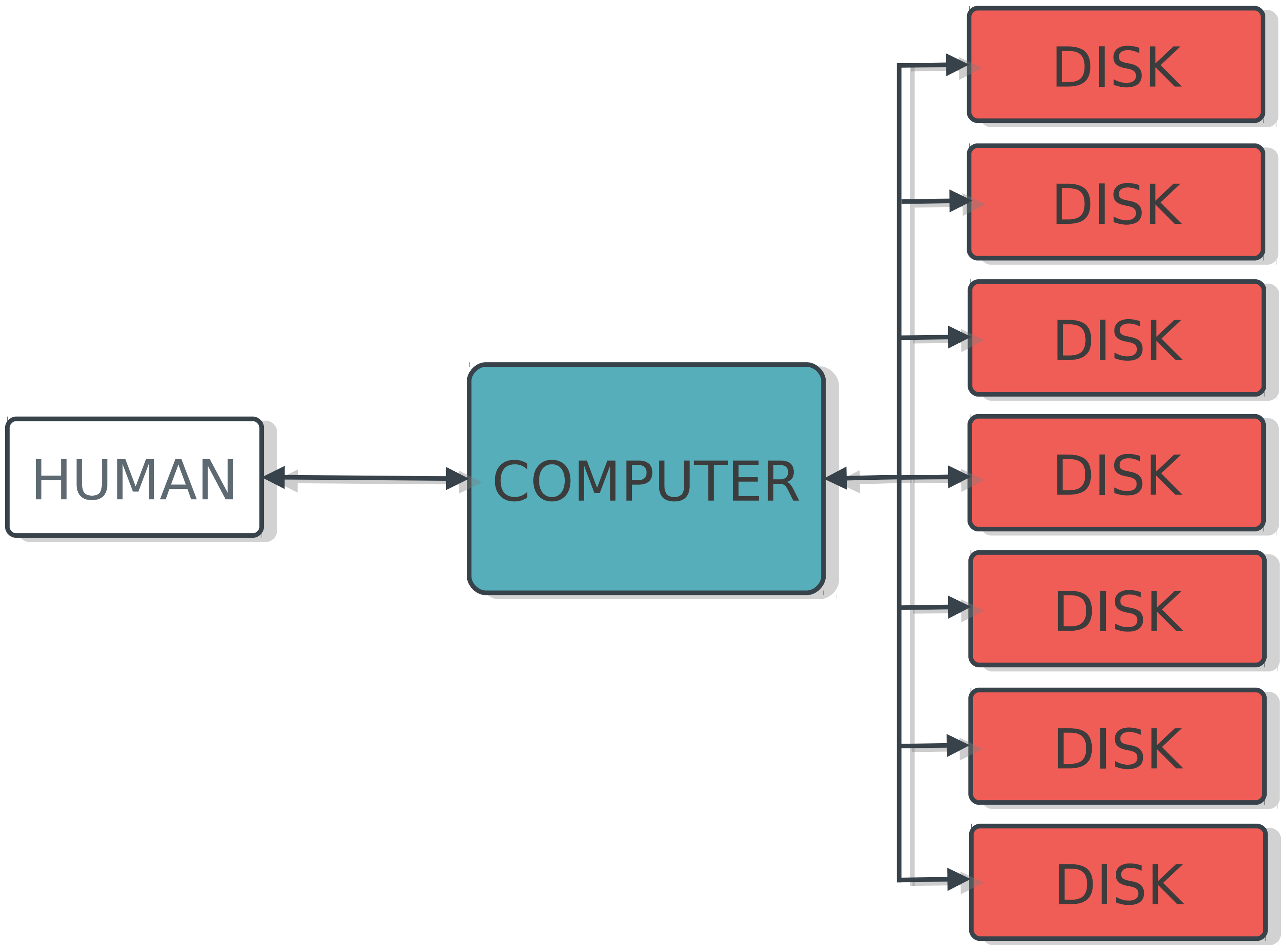
ceph object model

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

why start with objects?

- more useful than (disk) blocks
  - names in a simple 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

How do you design
a storage system that scales?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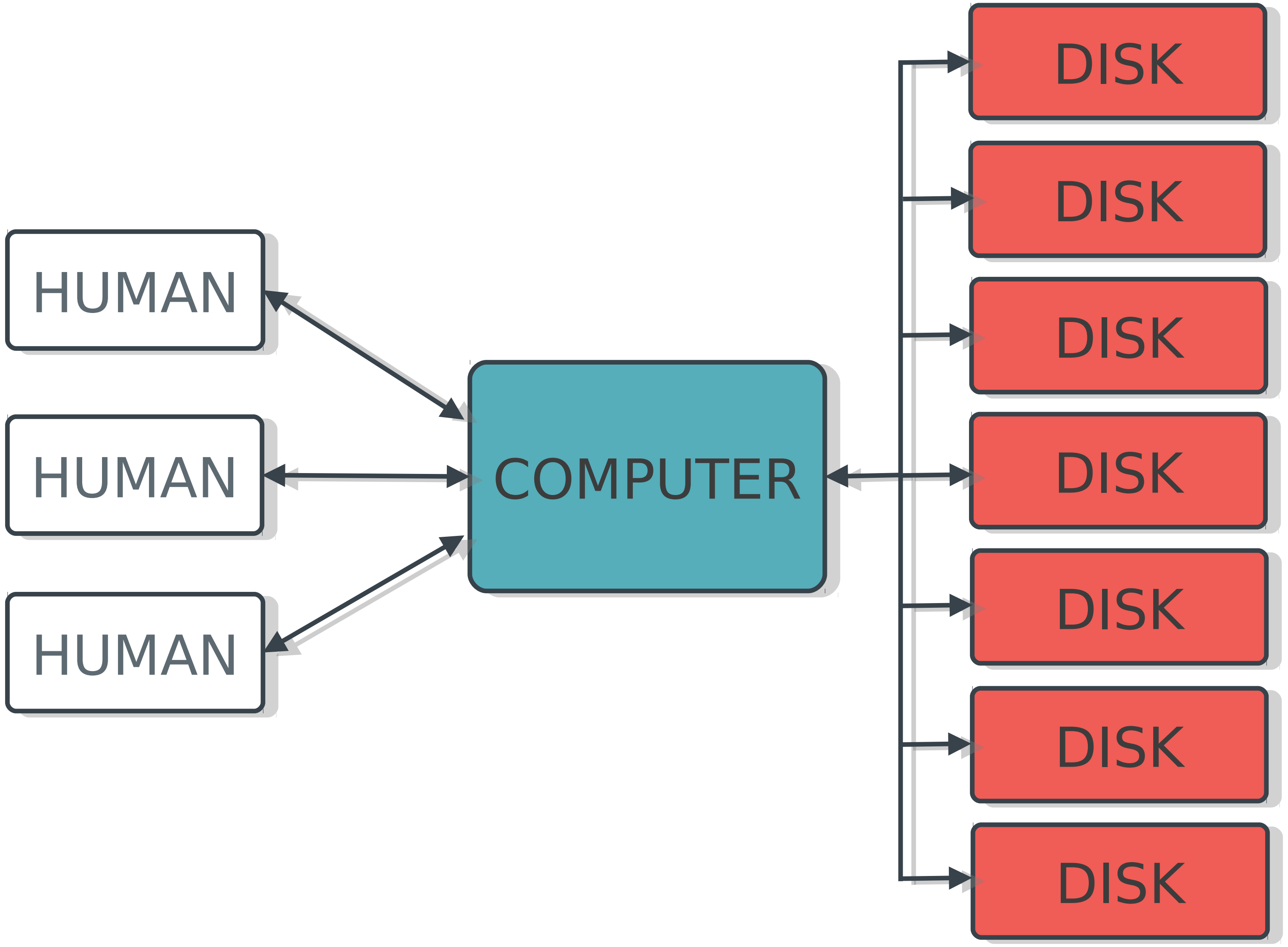
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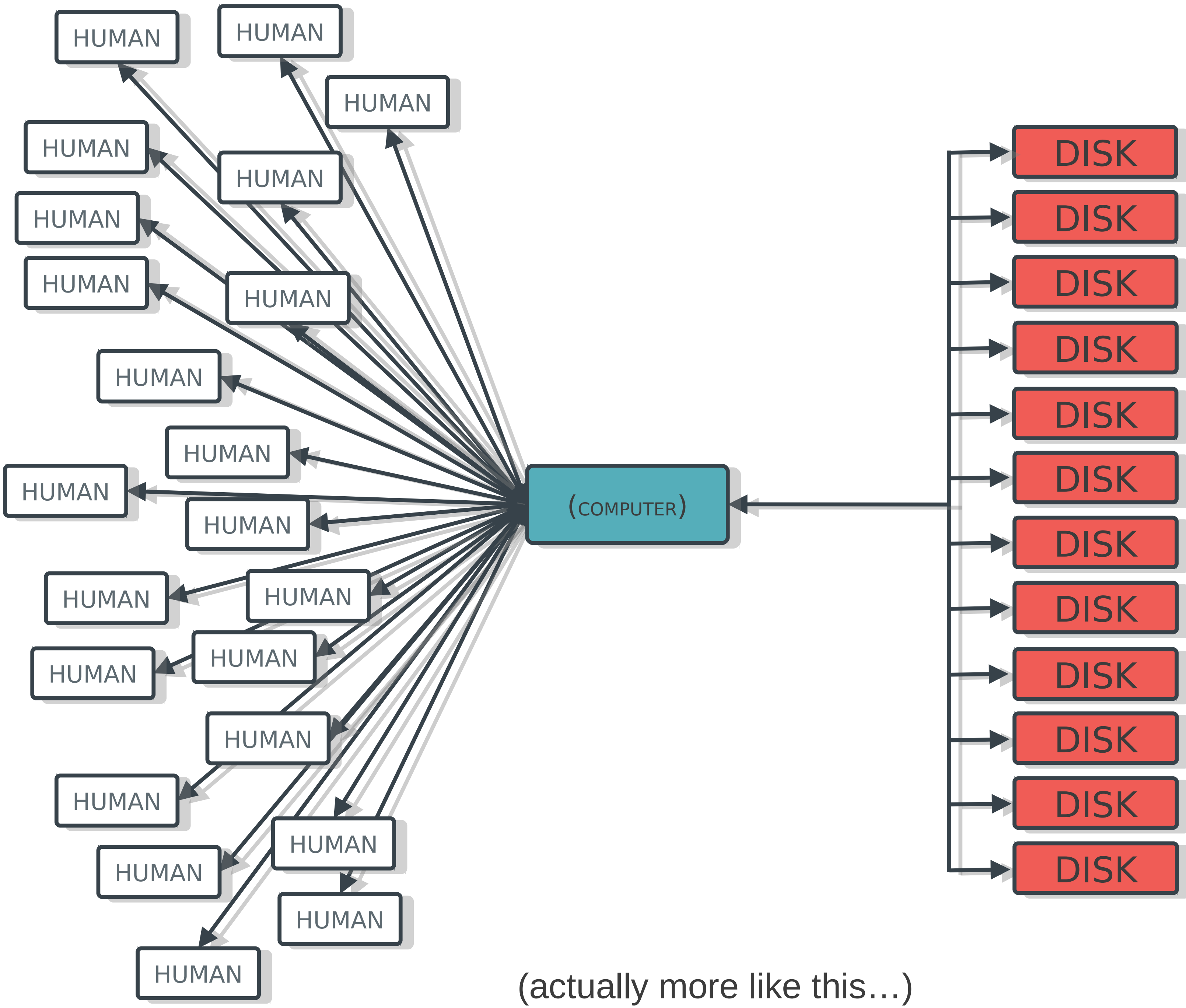
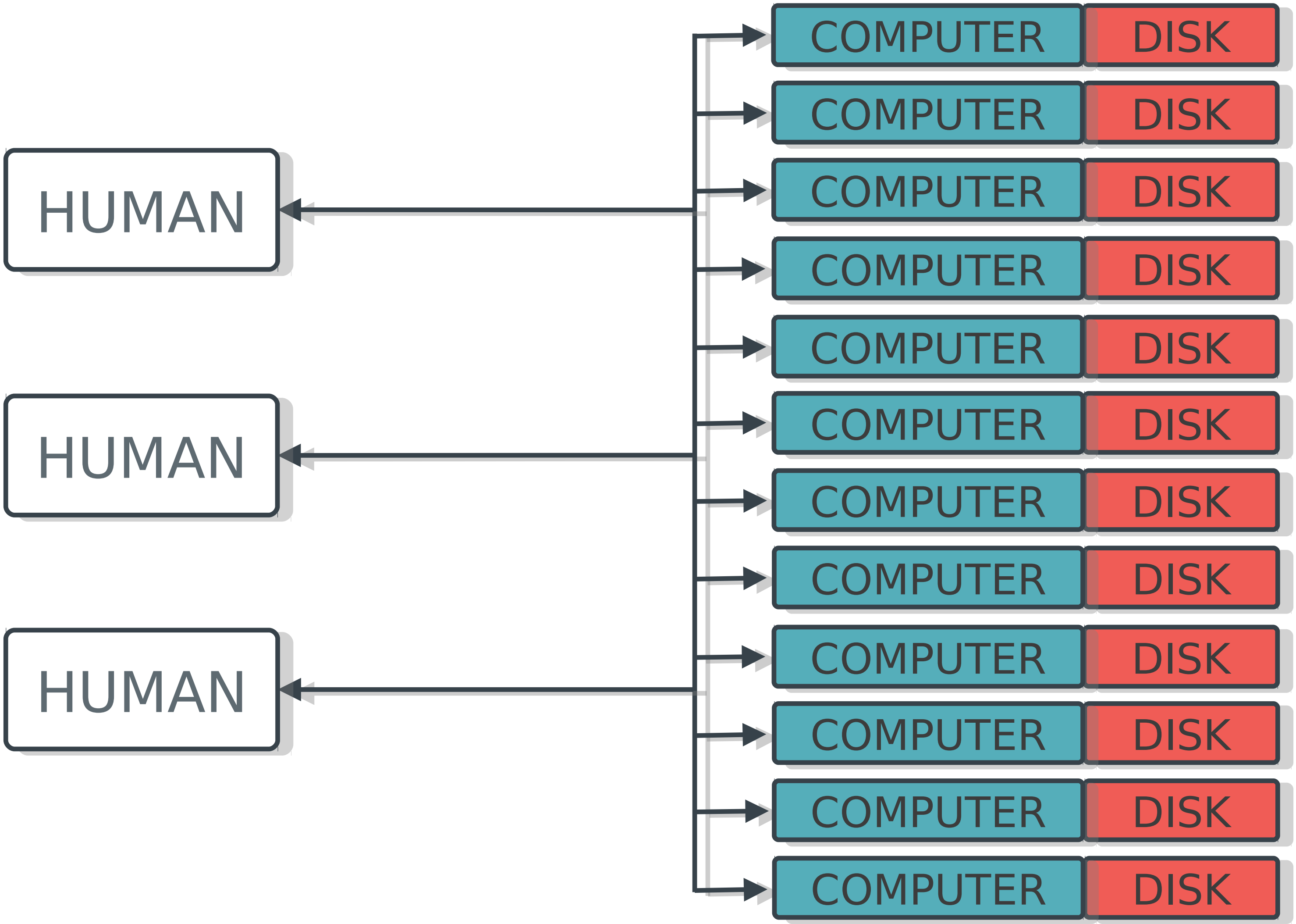


(actually more like this…)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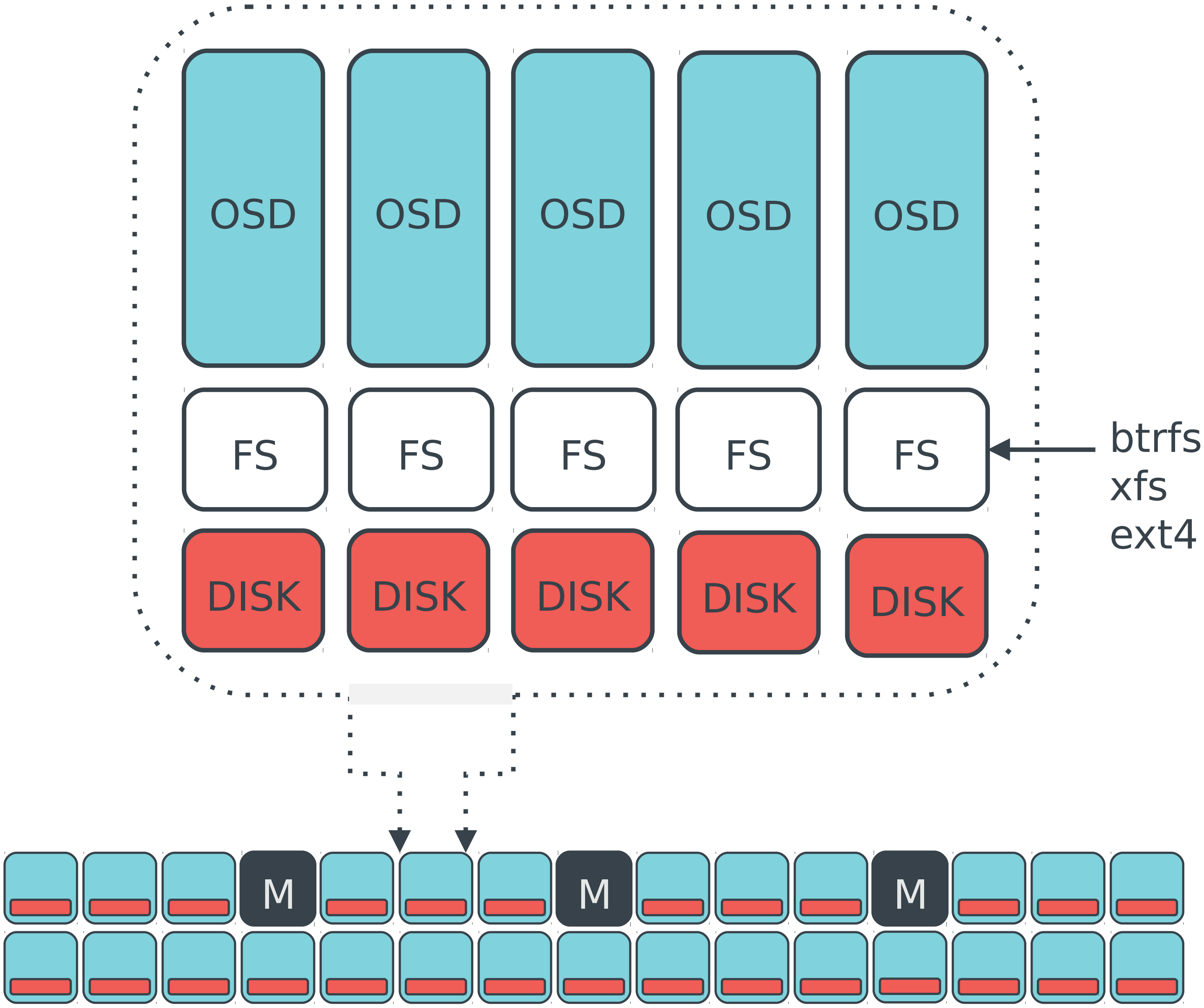
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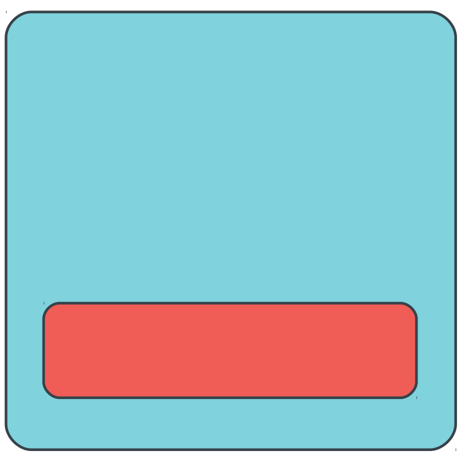
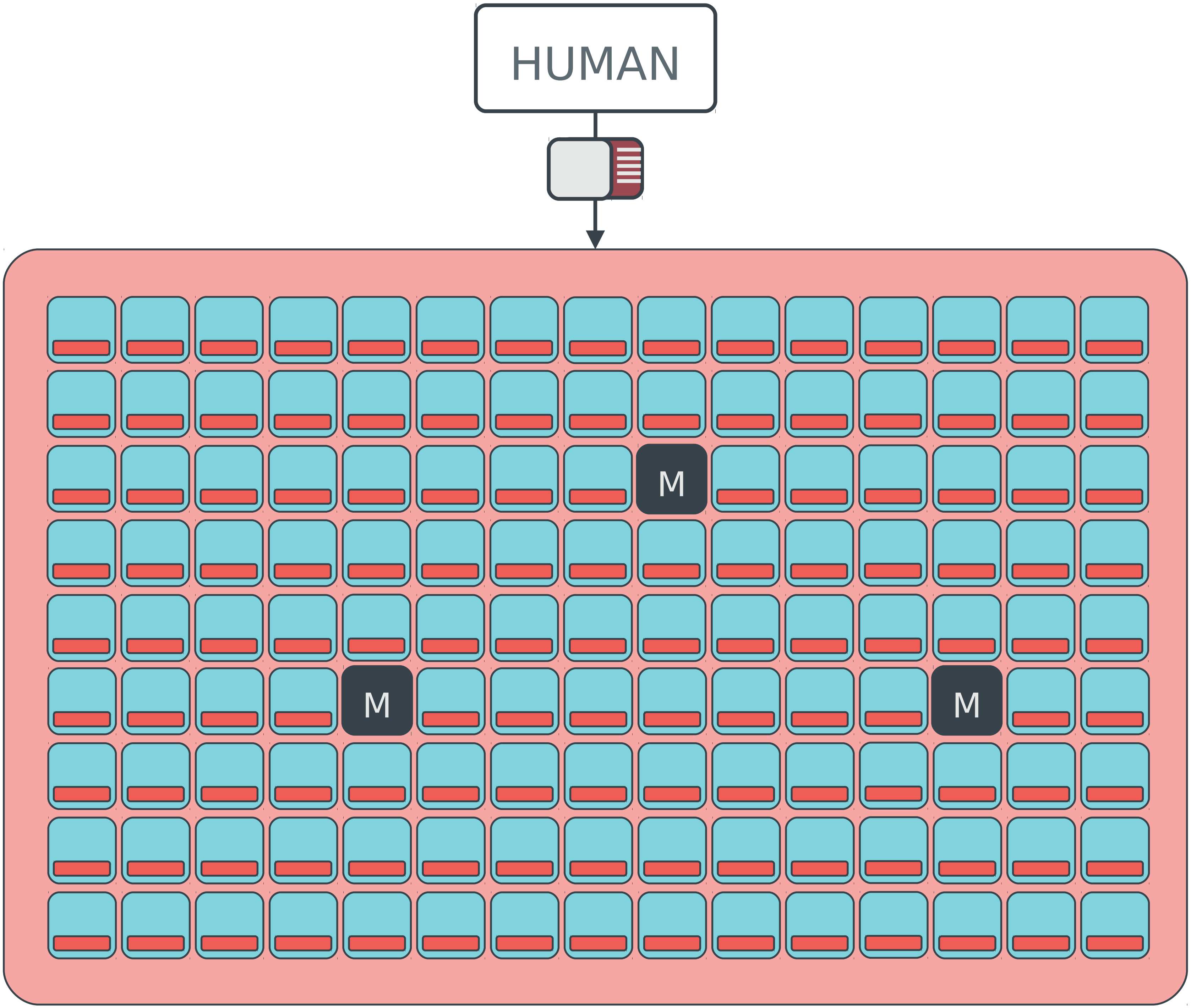
Monitors

- maintain cluster membership and state
- provide consensus for distributed decision-making
- small, odd number
- these do not served stored objects to clients



Object Storage Daemons (OSDs)

- 10s to 10000s in a cluster
- one per disk, SSD, or RAID group
  - hardware agnostic
- serve stored objects to clients
- intelligently peer to perform replication and recovery tasks



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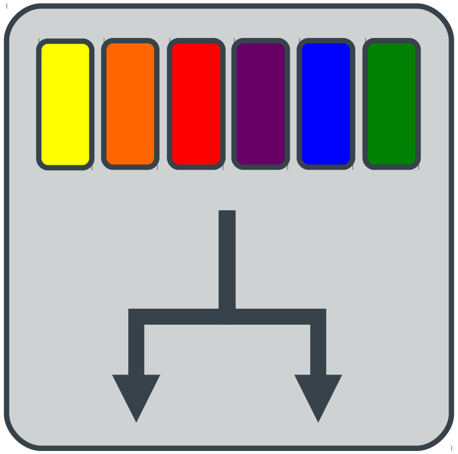
data distribution

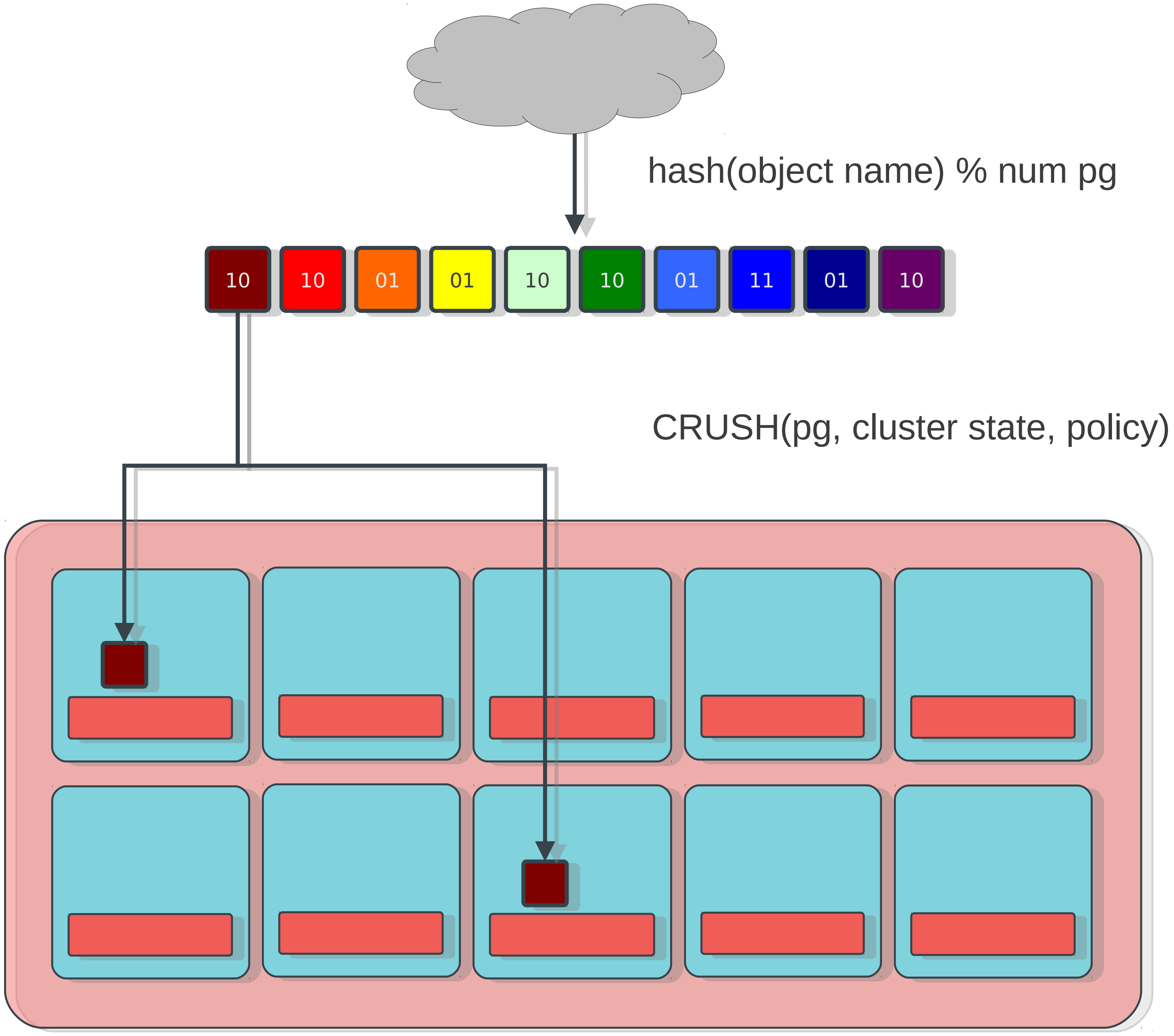
- all objects are replicated N times
- objects are automatically placed, balanced, migrated in a dynamic cluster
- must consider physical infrastructure
  - ceph-osds on hosts in racks in rows in data centers

- 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
  - fast calculation, **no lookup**
  - repeatable, deterministic
- statistically uniform distribution
- stable mapping
  - limited data migration on change
- rule-based configuration
  - infrastructure topology aware
  - adjustable replication
  - allows weighting


hash(object name) % num pg
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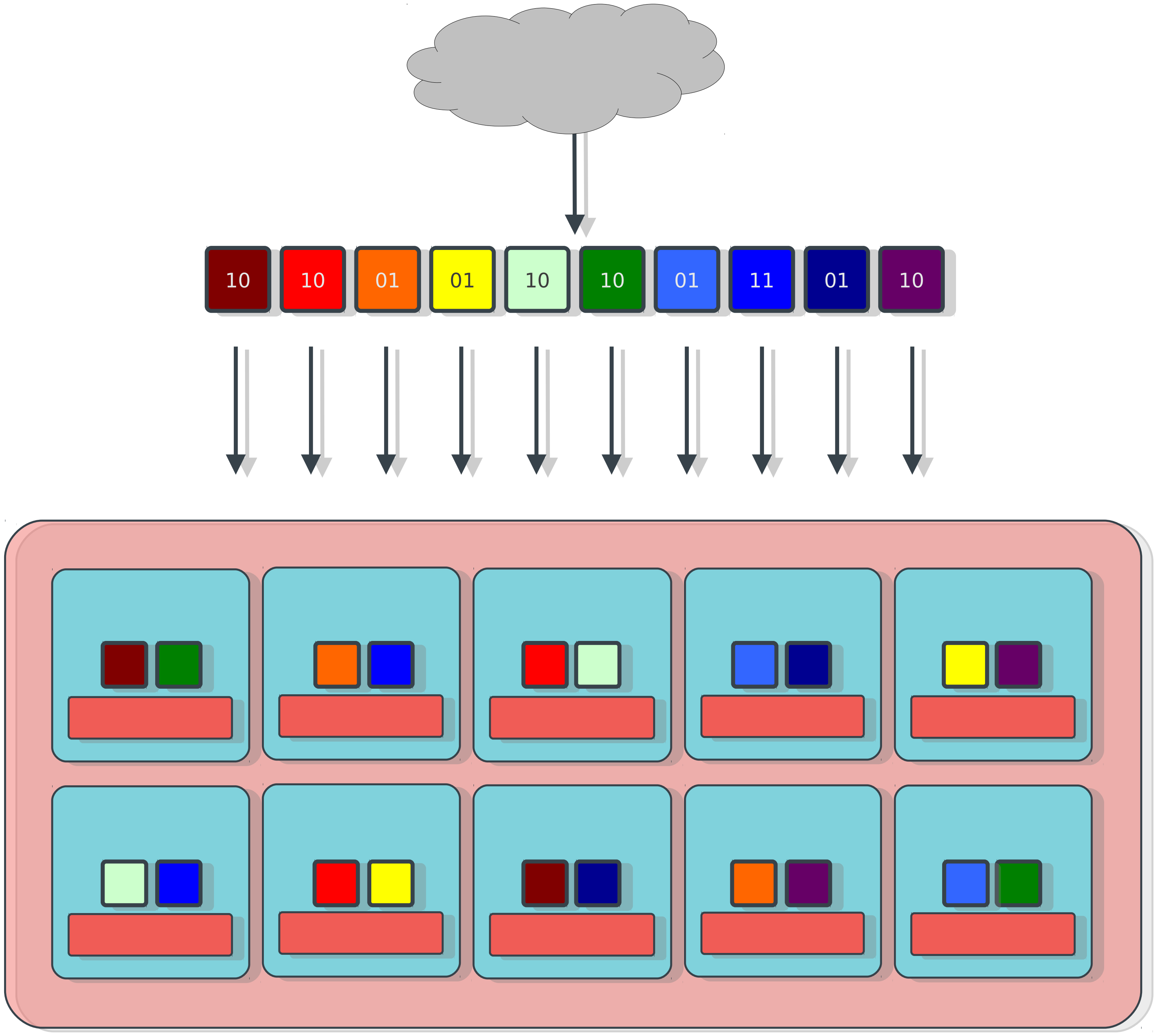
10
CRUSH(pg, cluster state, policy)


10
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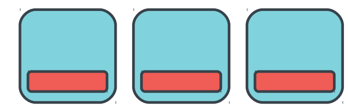
RADOS

- monitors publish **osd map** that describes cluster state

  - ceph-osd node status (up/down, weight, IP)
  - CRUSH function specifying desired data distribution
- object storage daemons (OSDs)



  - safely replicate and store object
  - migrate data as the cluster changes over time
  - coordinate based on shared view of reality
- decentralized, distributed approach allows
  - massive scales (10,000s of servers or more)
  - the illusion of a single copy with consistent behavior

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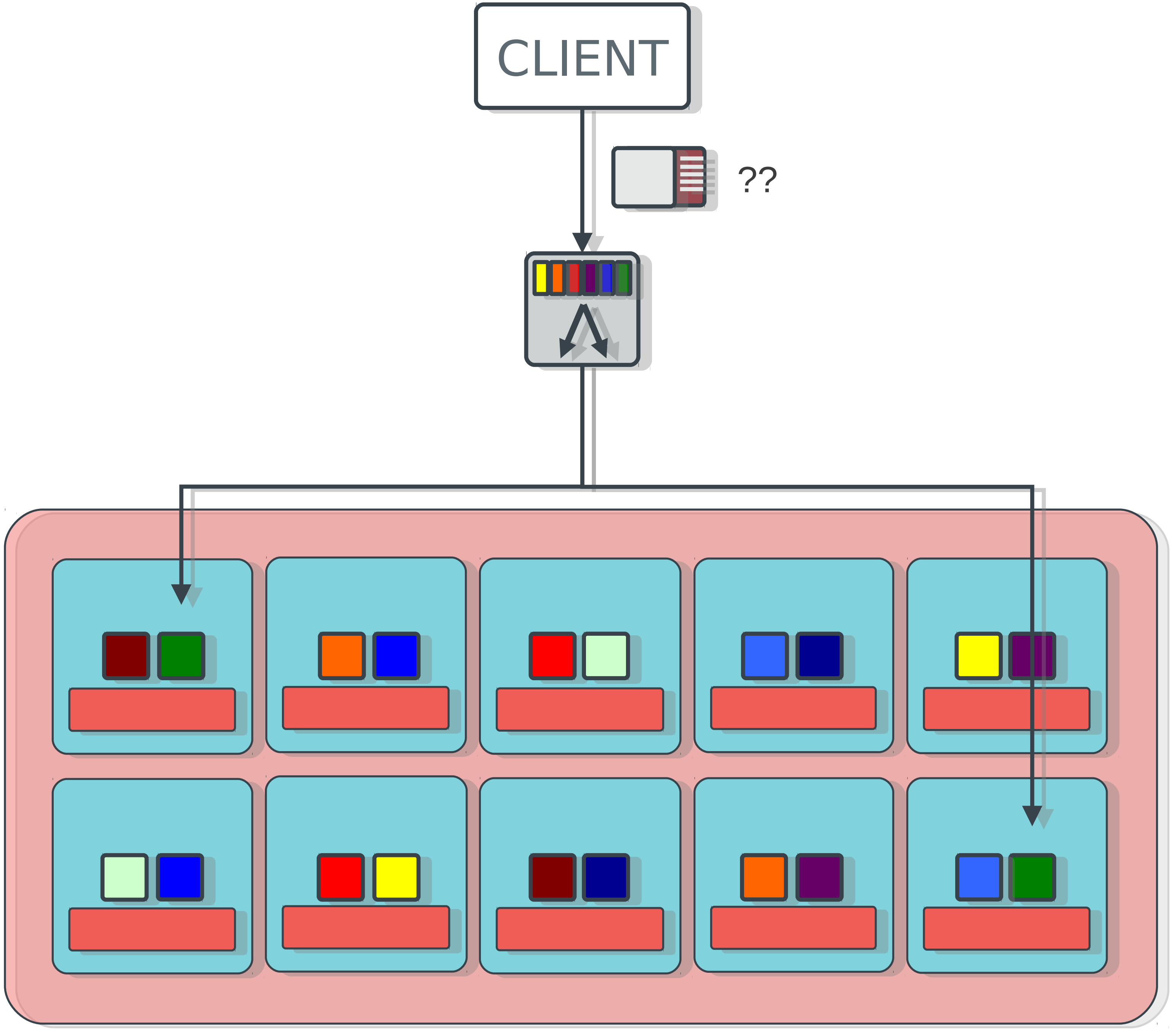
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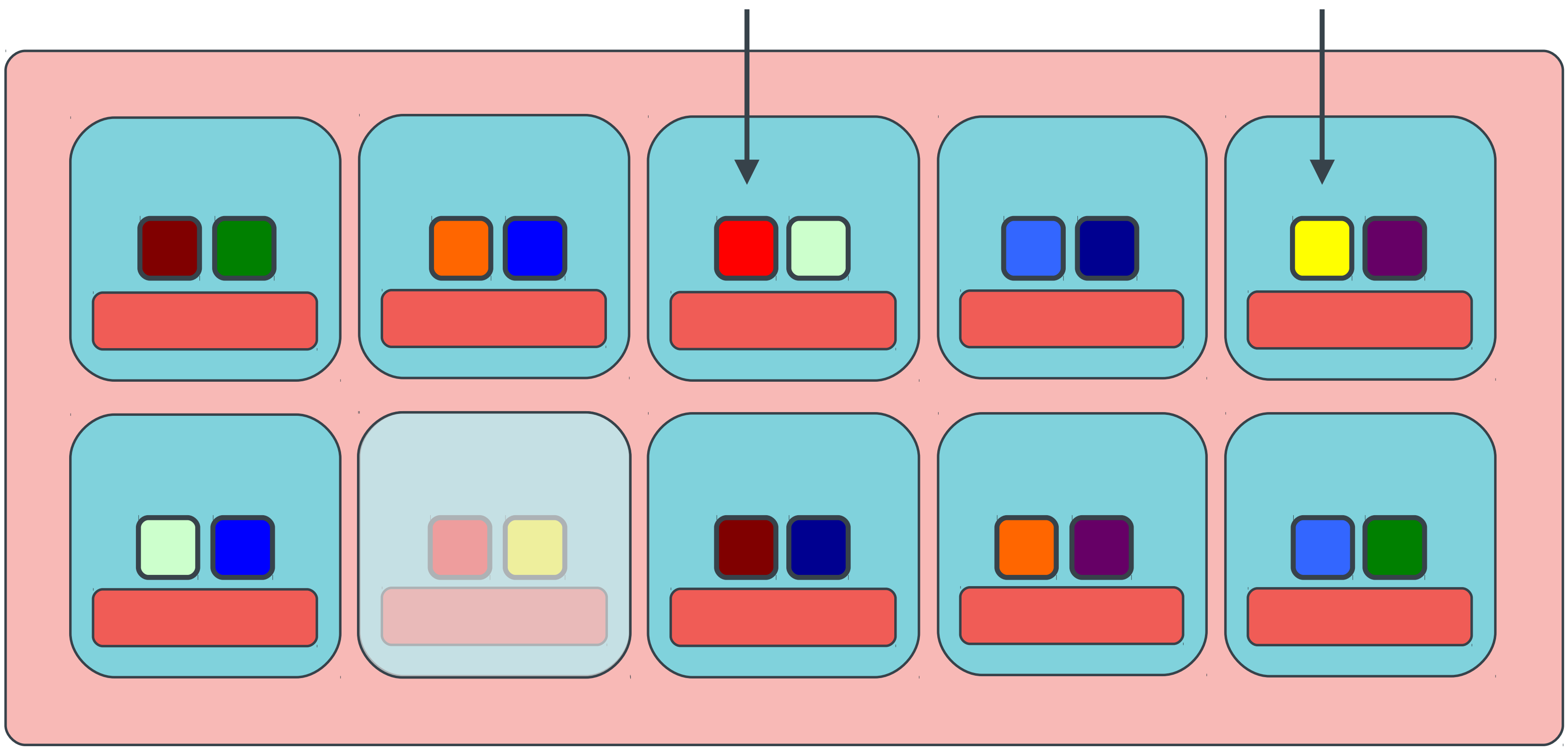

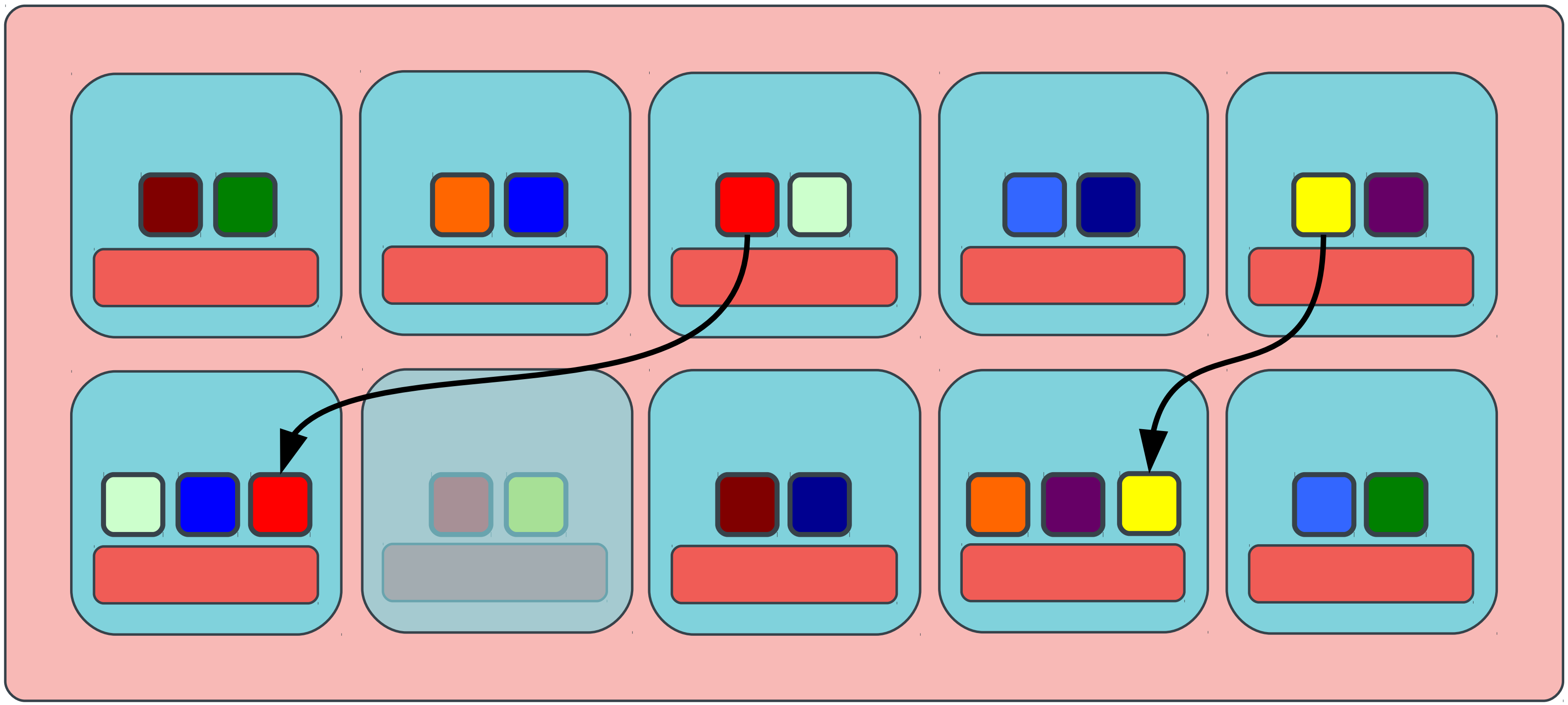

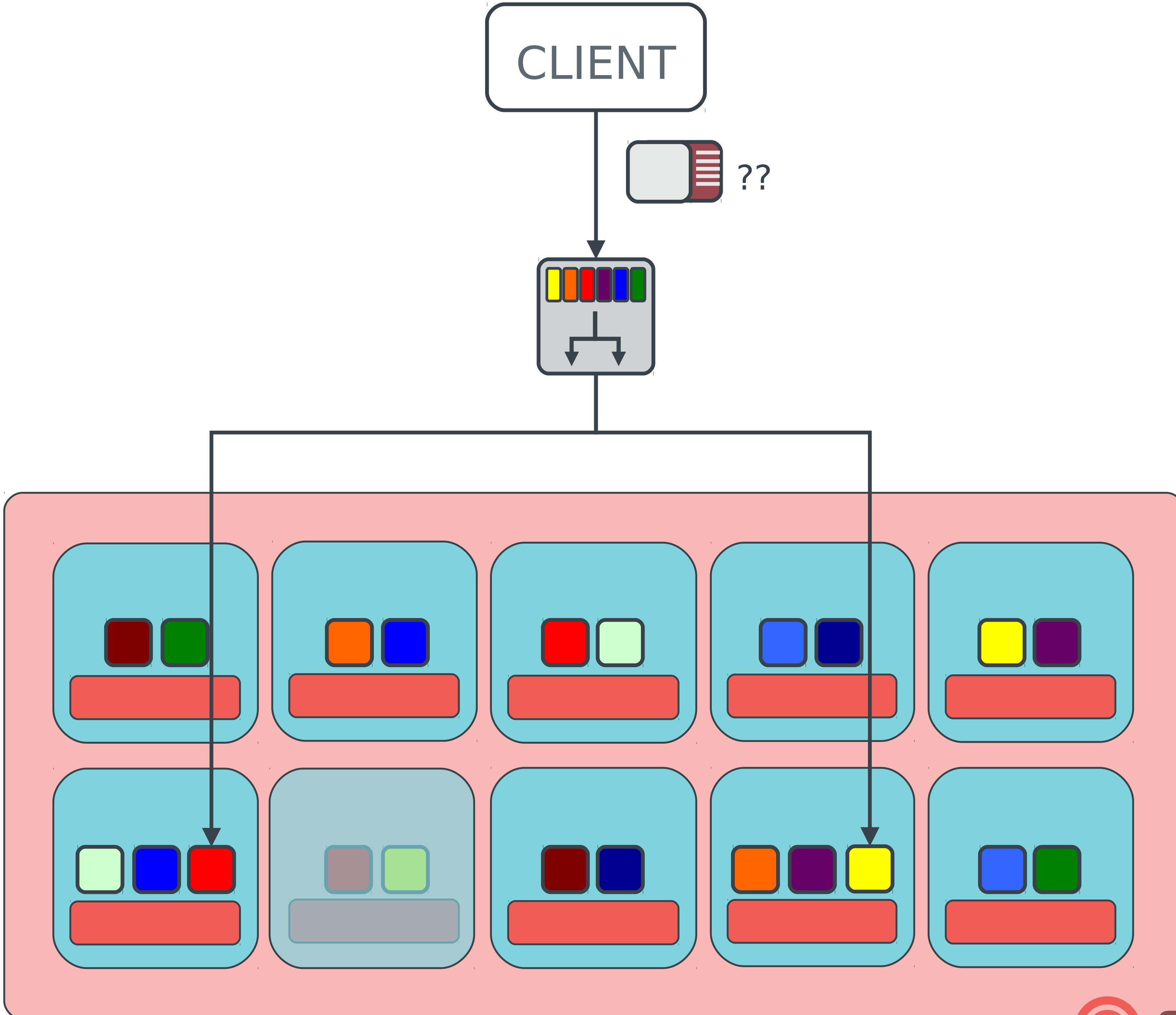
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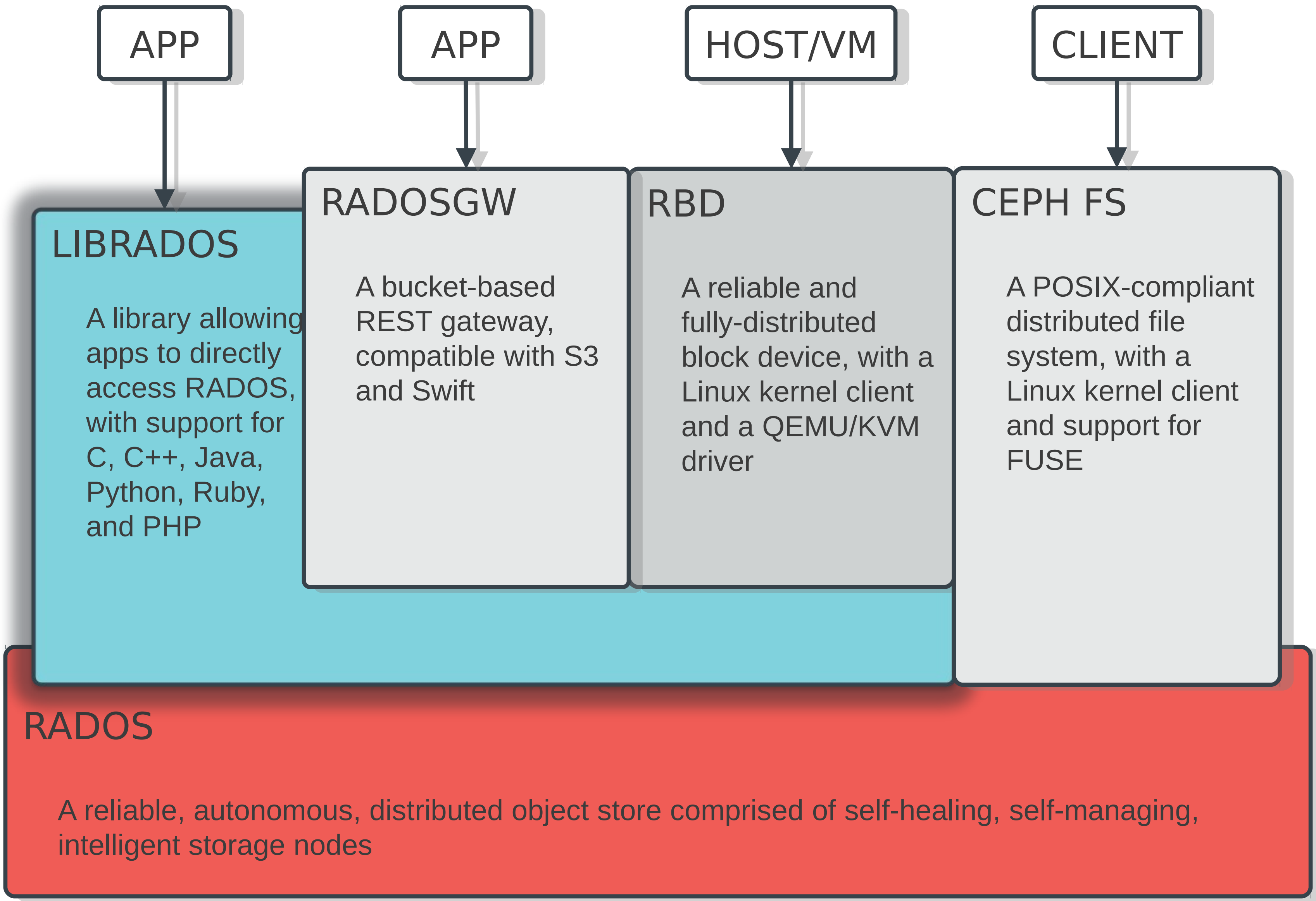
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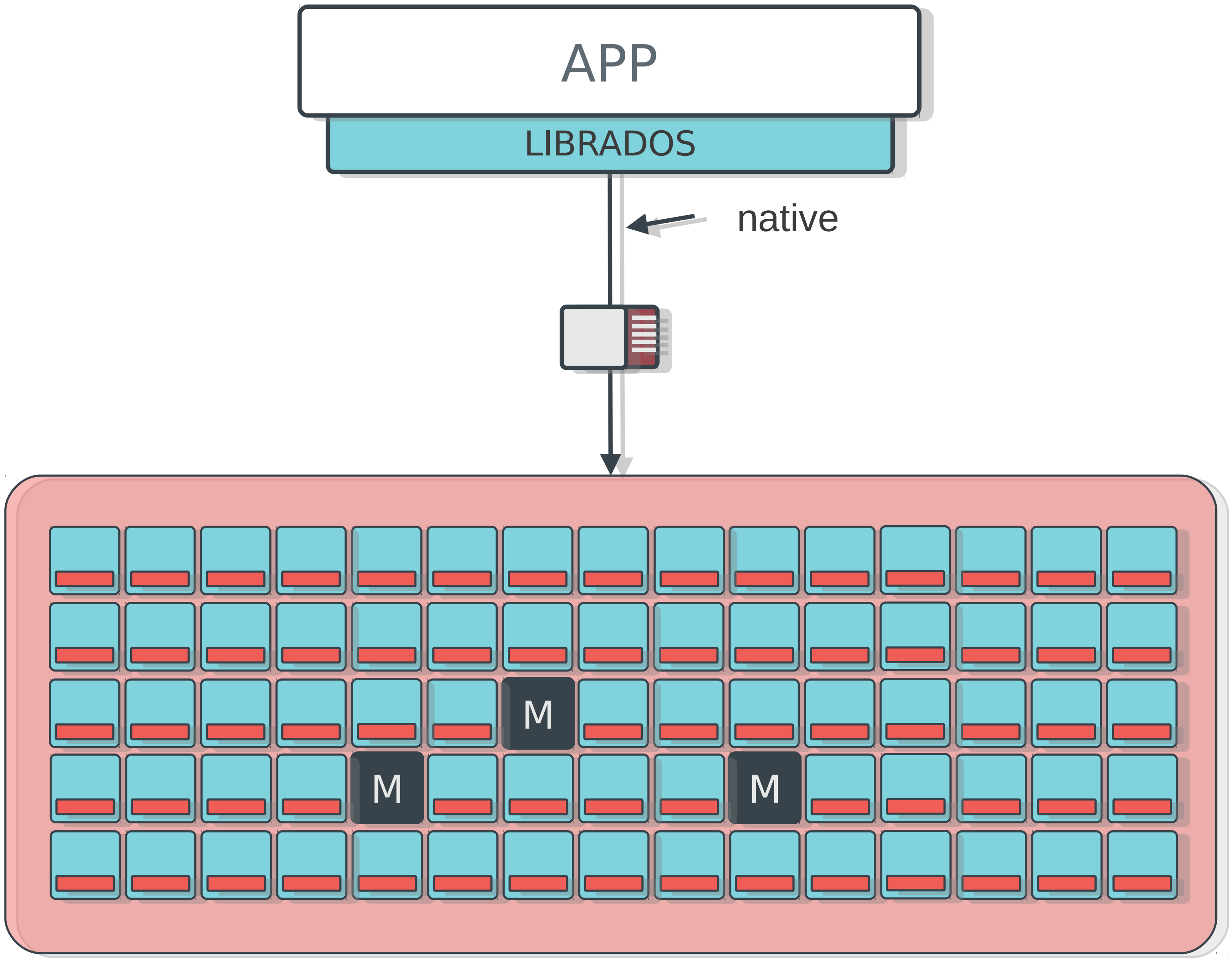
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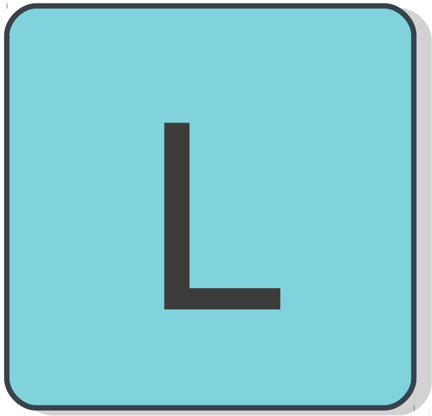
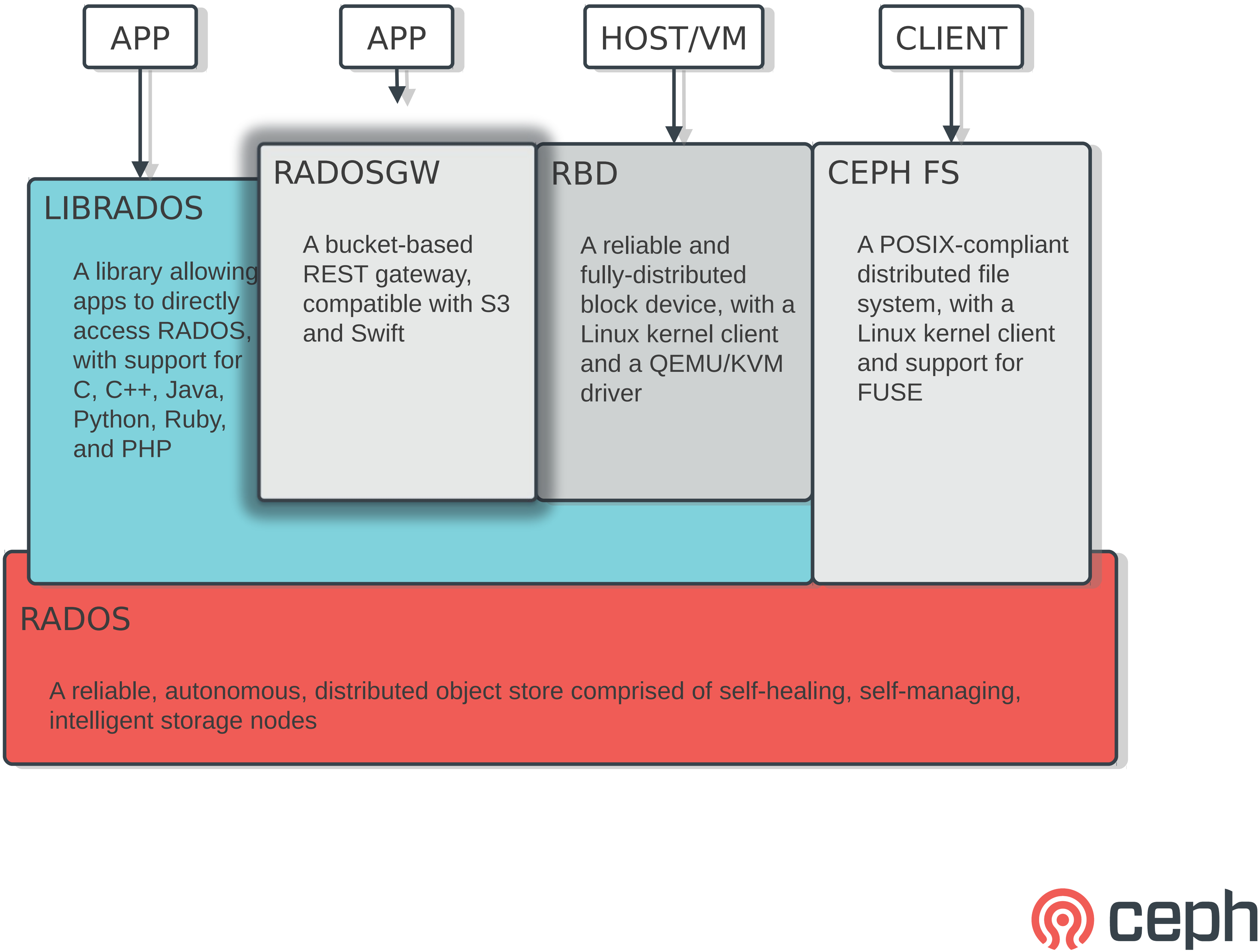


librados

- direct access to RADOS from applications
- C, C++, Python, PHP, Java, Erlang
- direct access to storage nodes
- no HTTP overhead

rich librados API

- atomic single-object transactions
  - update data, attr together
  - atomic compare-and-swap
- efficient key/value storage inside an object
- object-granularity snapshot infrastructure
- embed code in ceph-osd daemon via plugin API
- inter-client communication via object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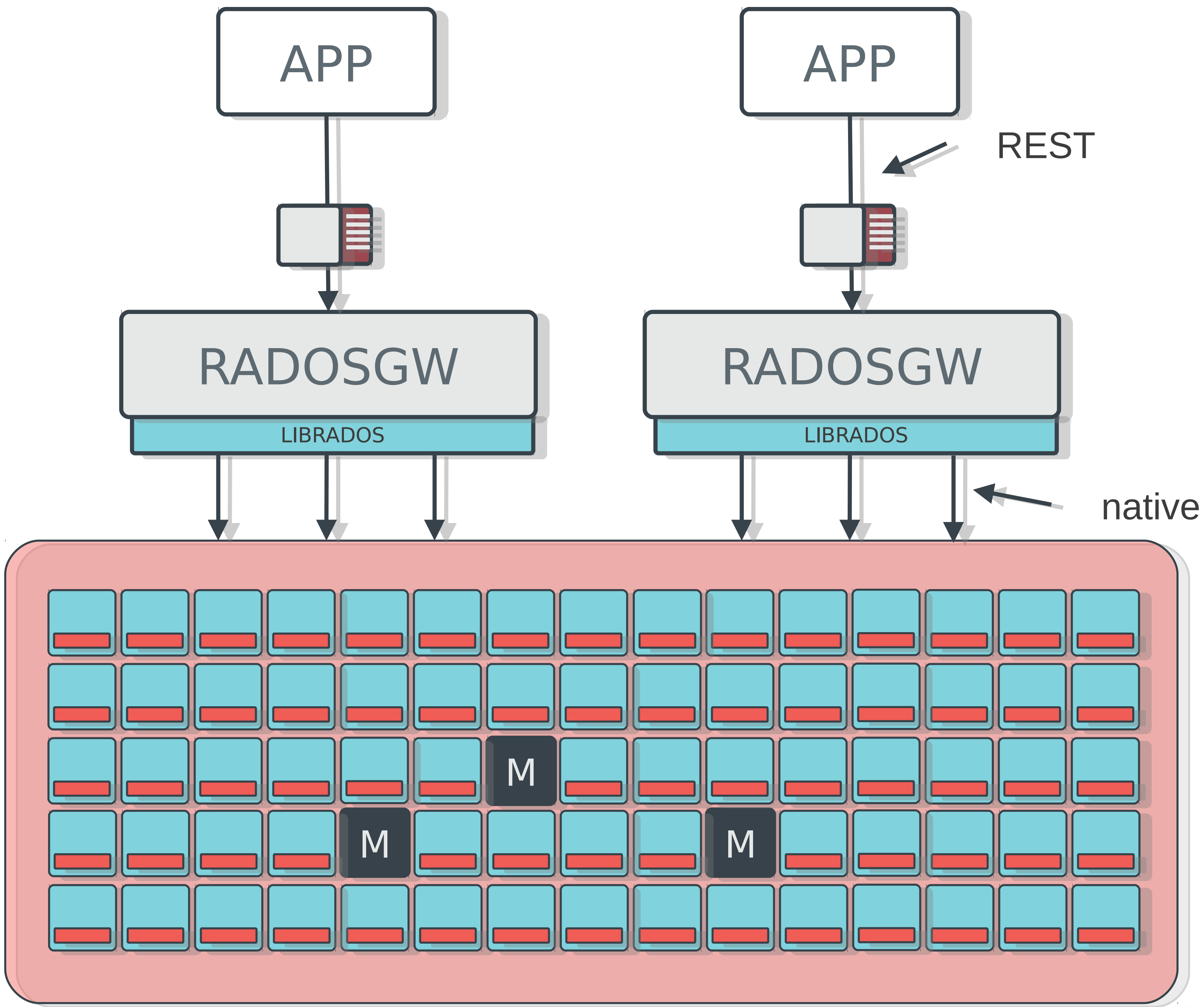
APP
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REST
RADOSGW
RADOSGW
LIBRADOS
LIBRADOS
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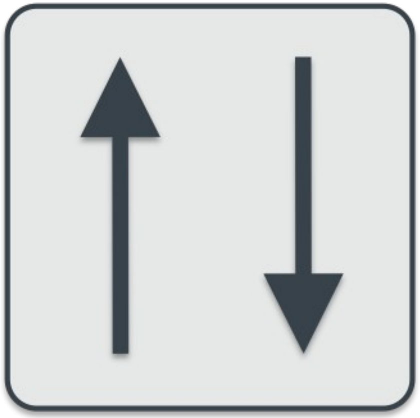
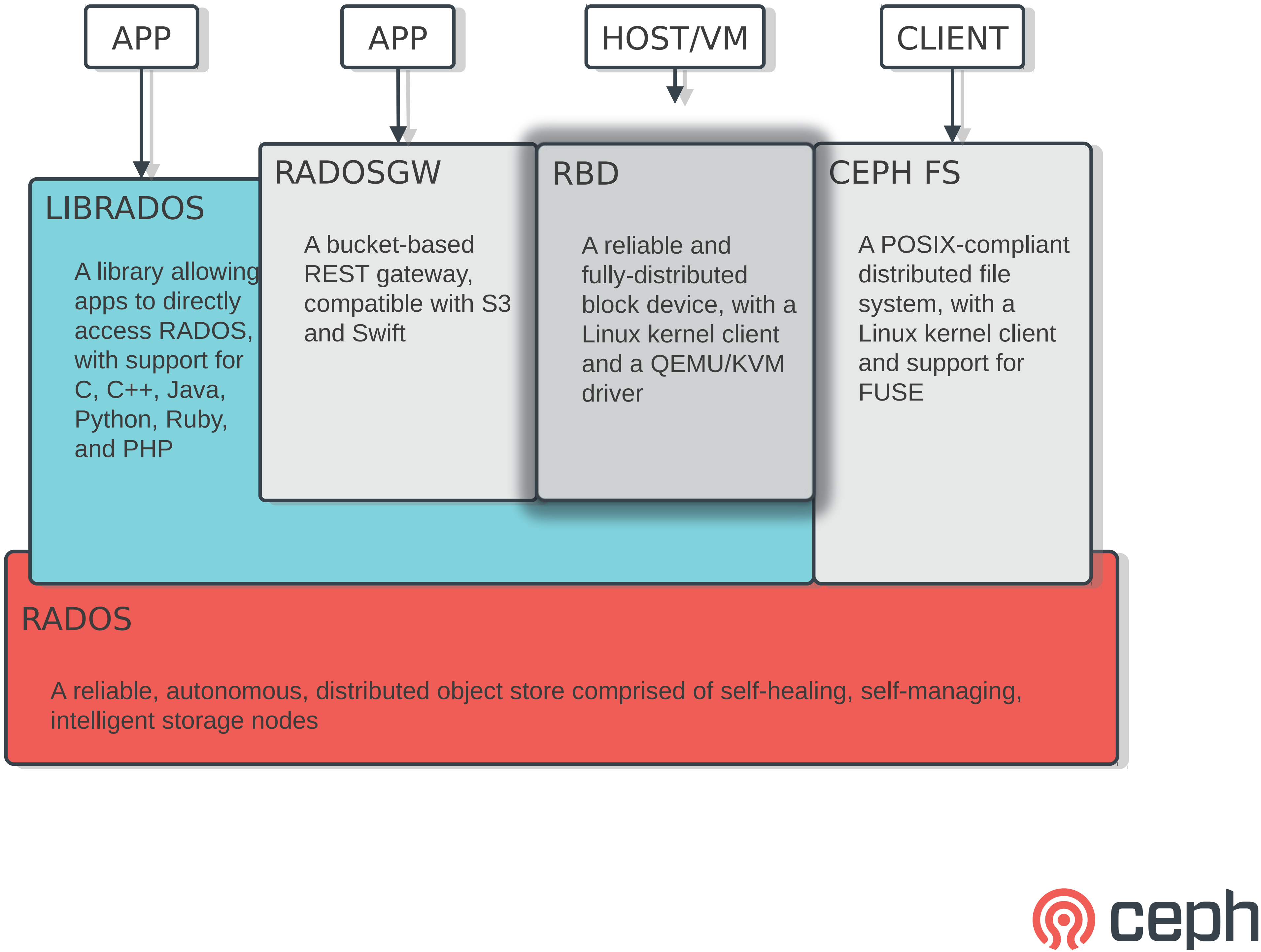


RADOS Gateway

- REST-based object storage proxy
- uses RADOS to store objects
- API supports buckets, accounting
- usage accounting for billing purposes
- compatible with S3, Swift APIs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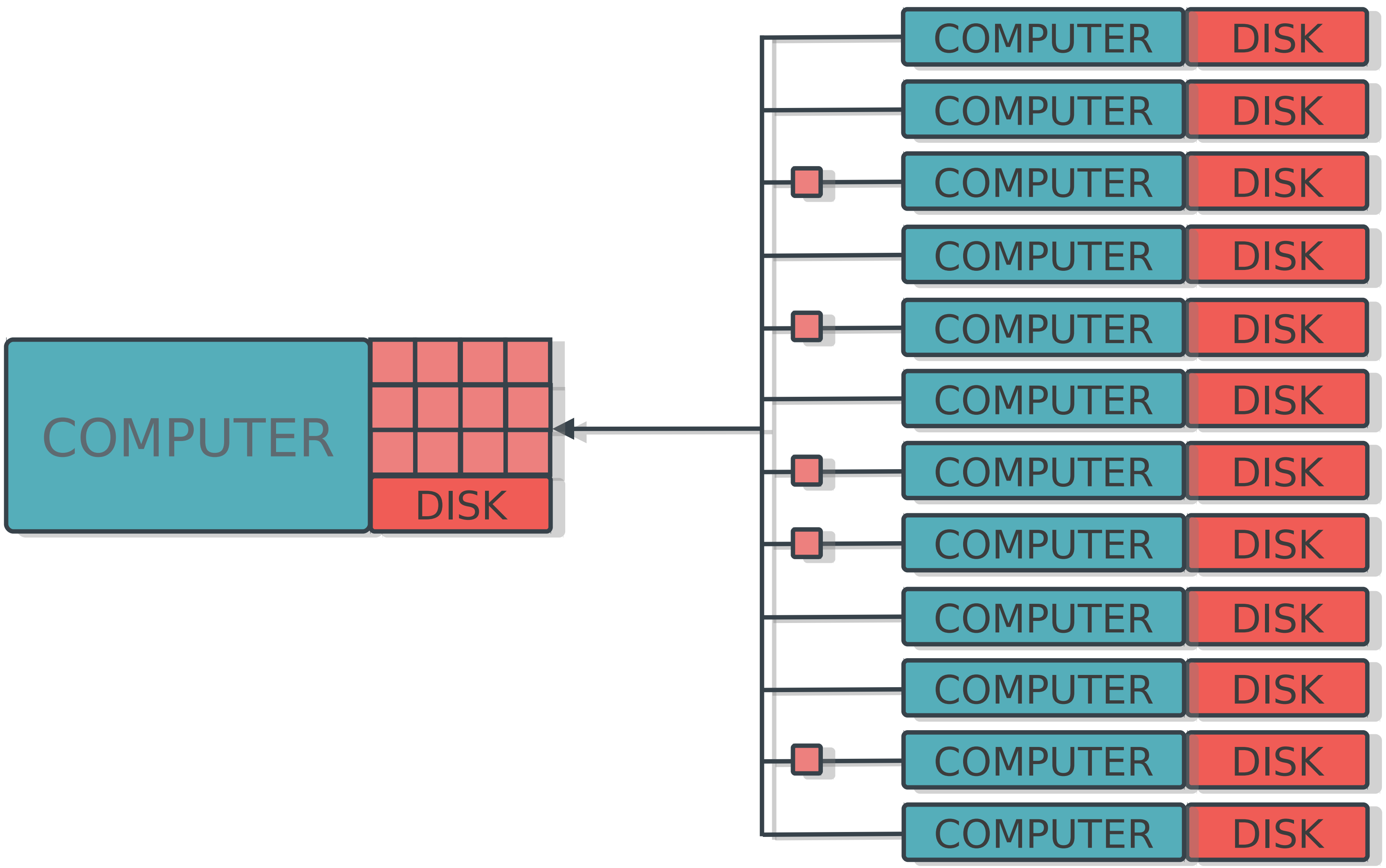
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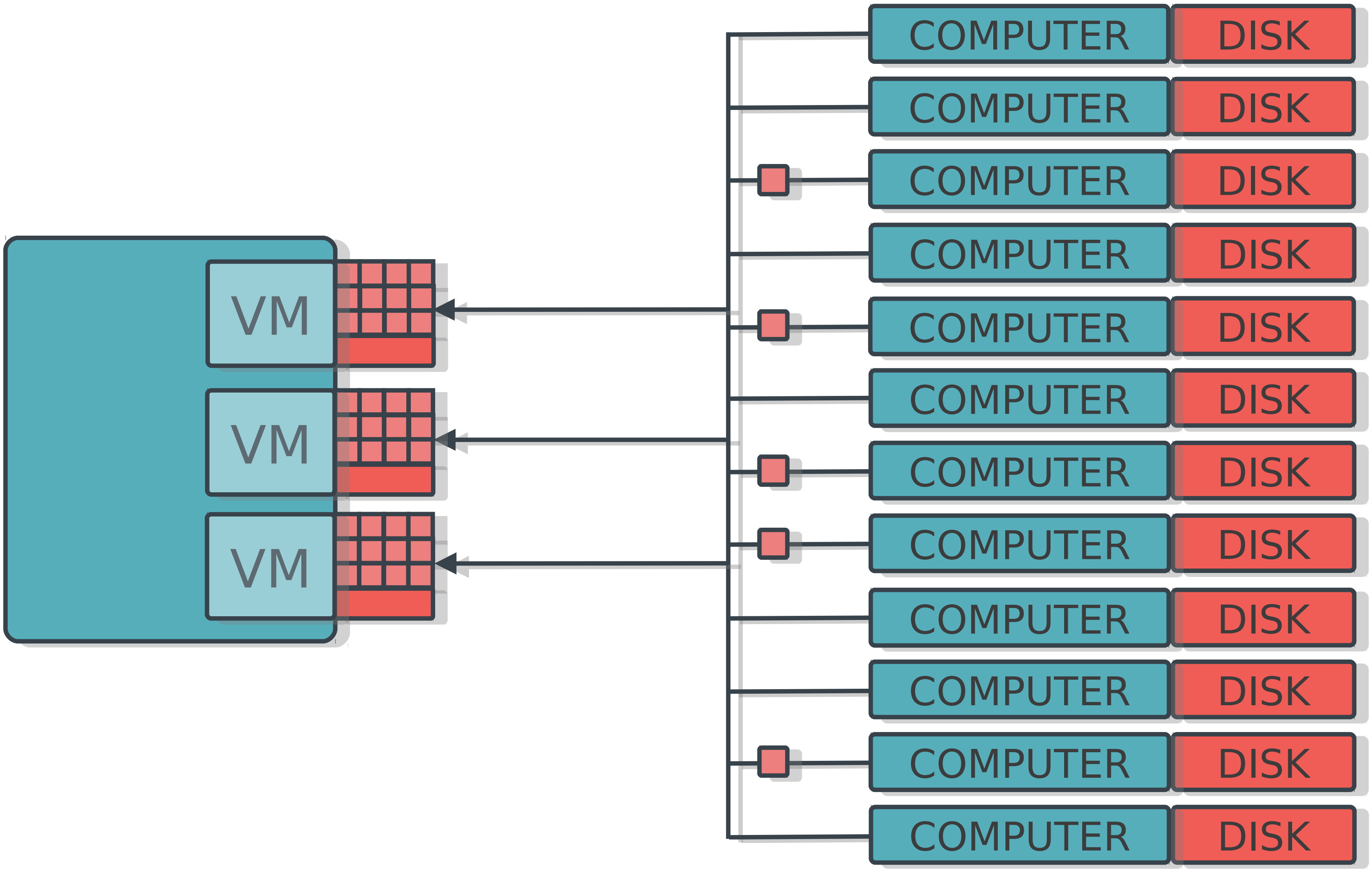
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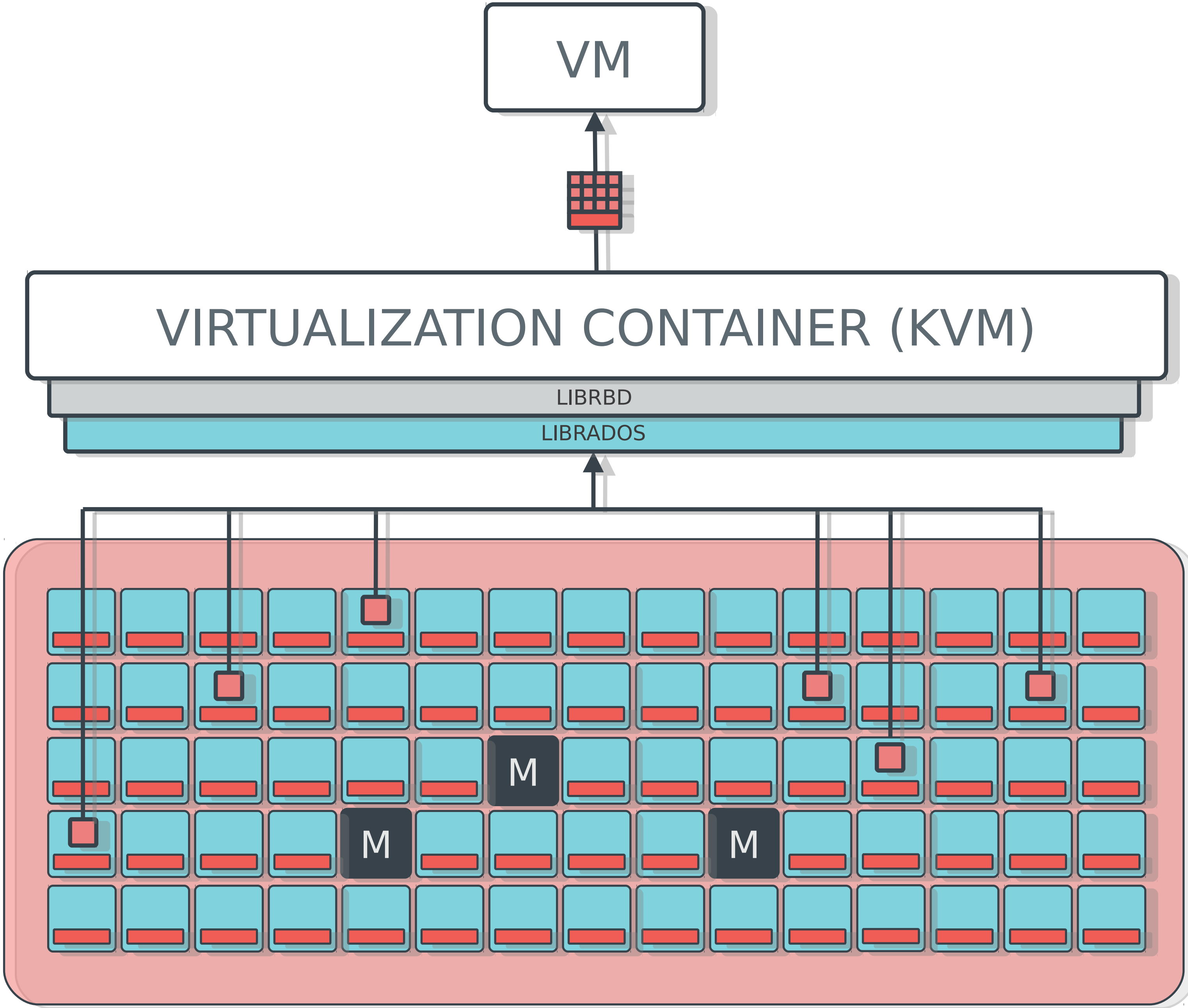
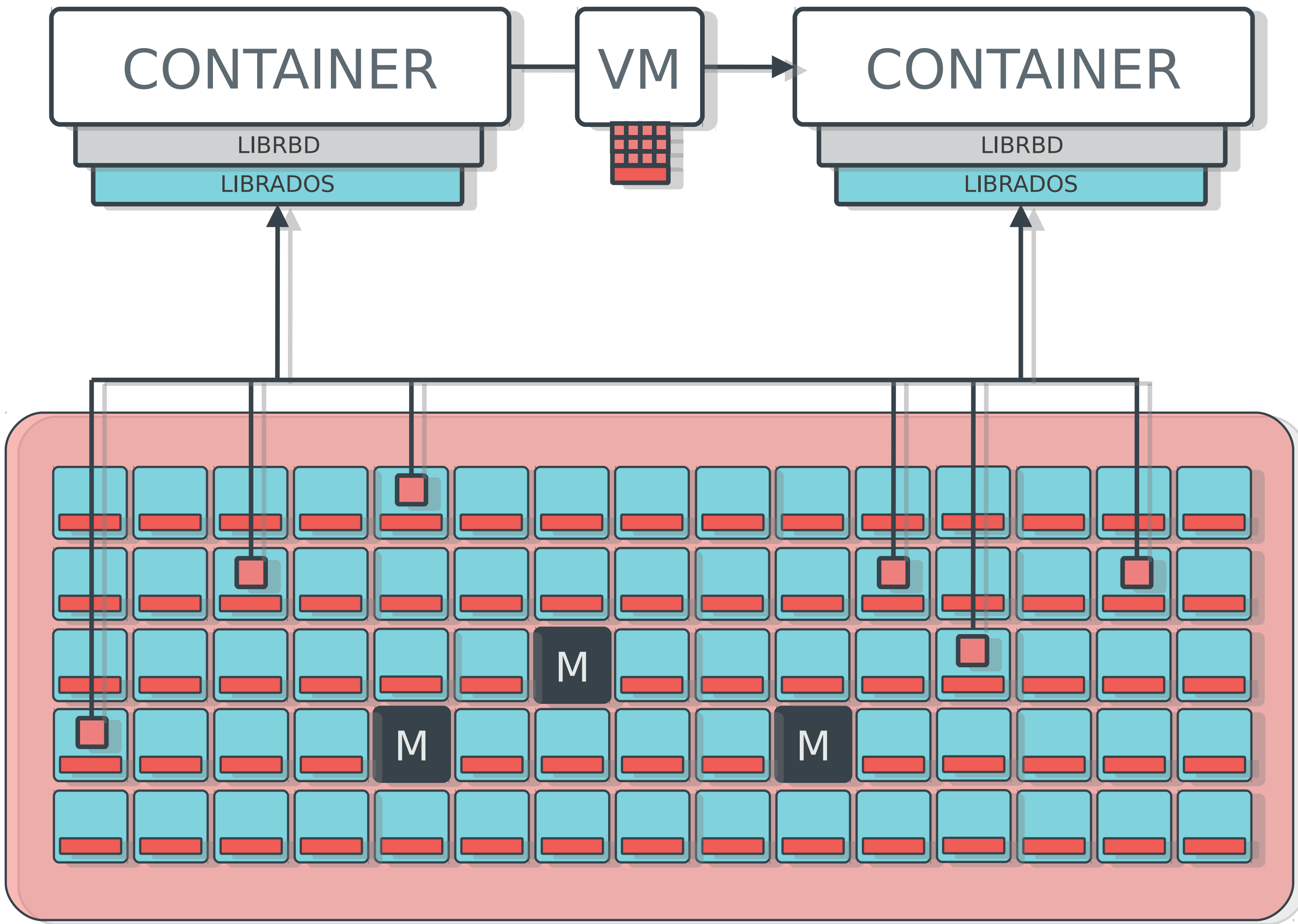


ceph


CONTAINER
VM
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LIBRBD
LIBRADOS
LIBRBD
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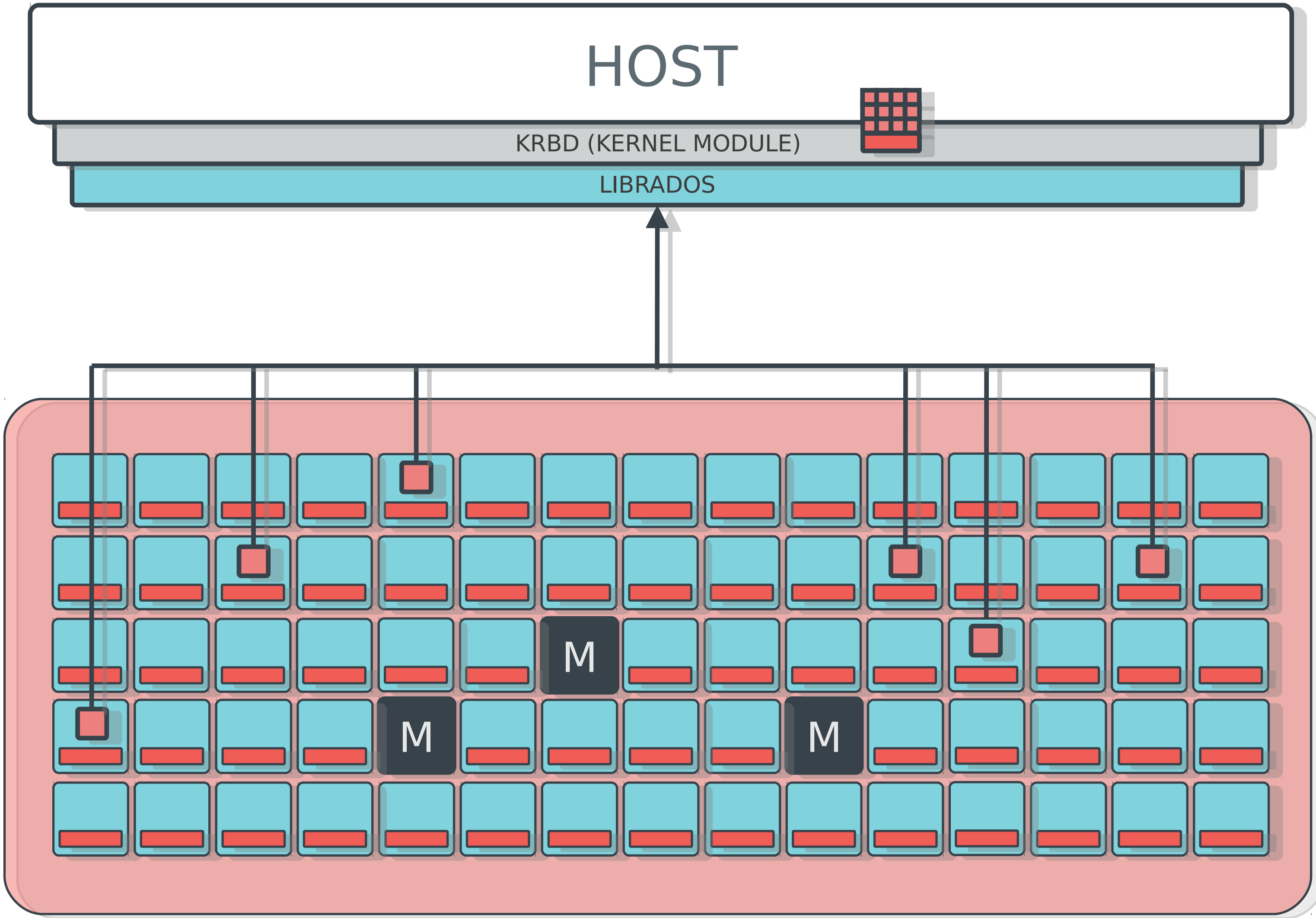
ceph


HOST
KRBD (KERNEL MODULE)
LIBRADOS
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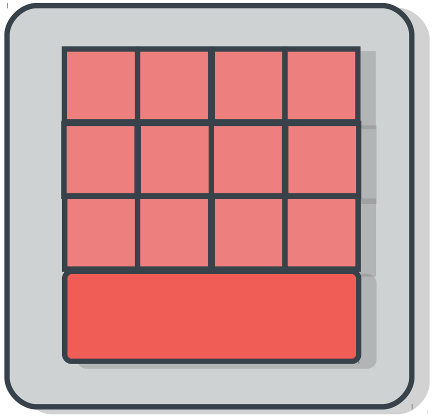
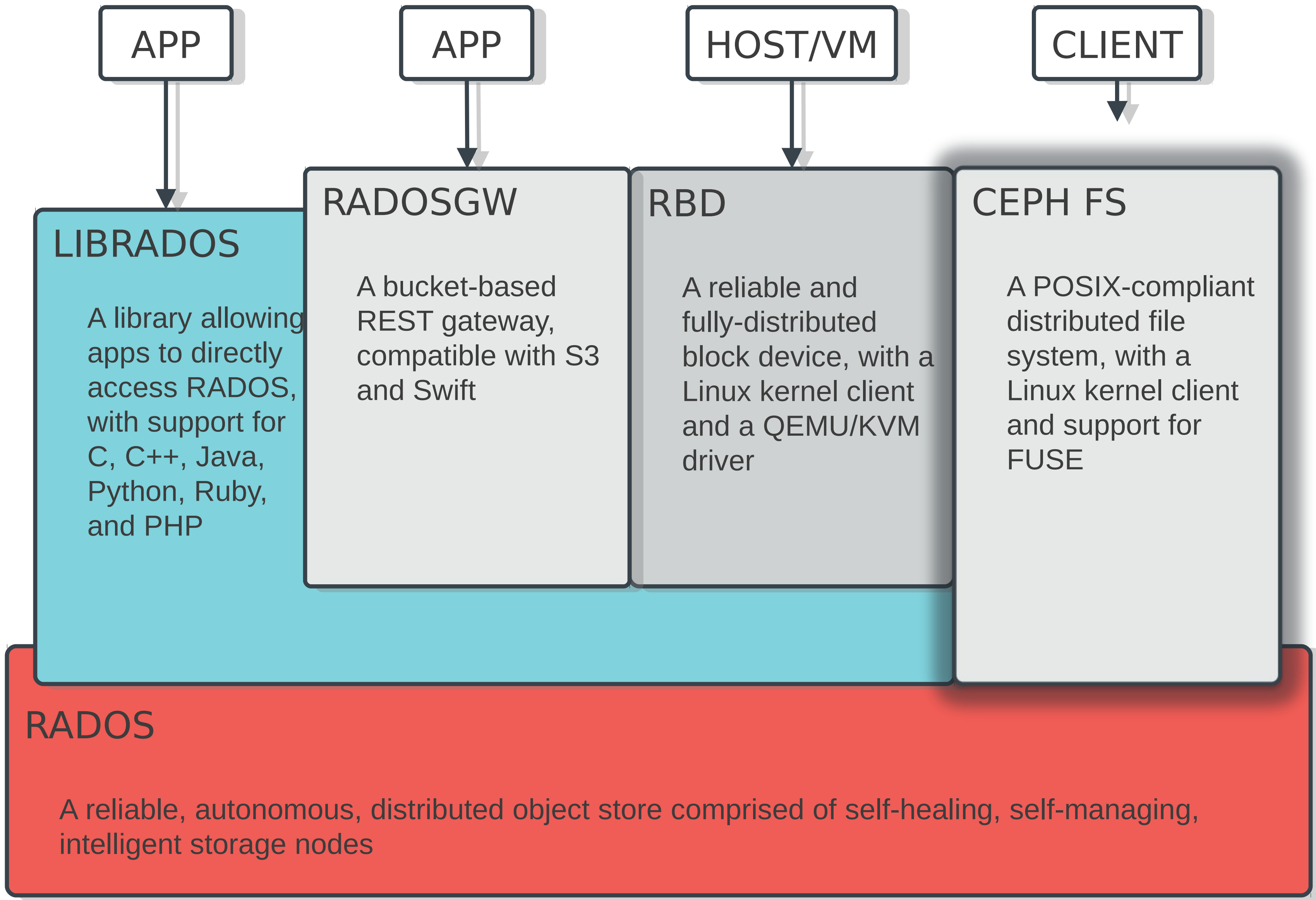


RADOS Block Device

- storage of disk images in RADOS
- decouple VM from host
- images striped across entire cluster (pool)
- snapshots
- copy-on-write clones
- support in
  - Qemu/KVM
  - mainline Linux kernel (2.6.39+)
  - OpenStack, CloudStack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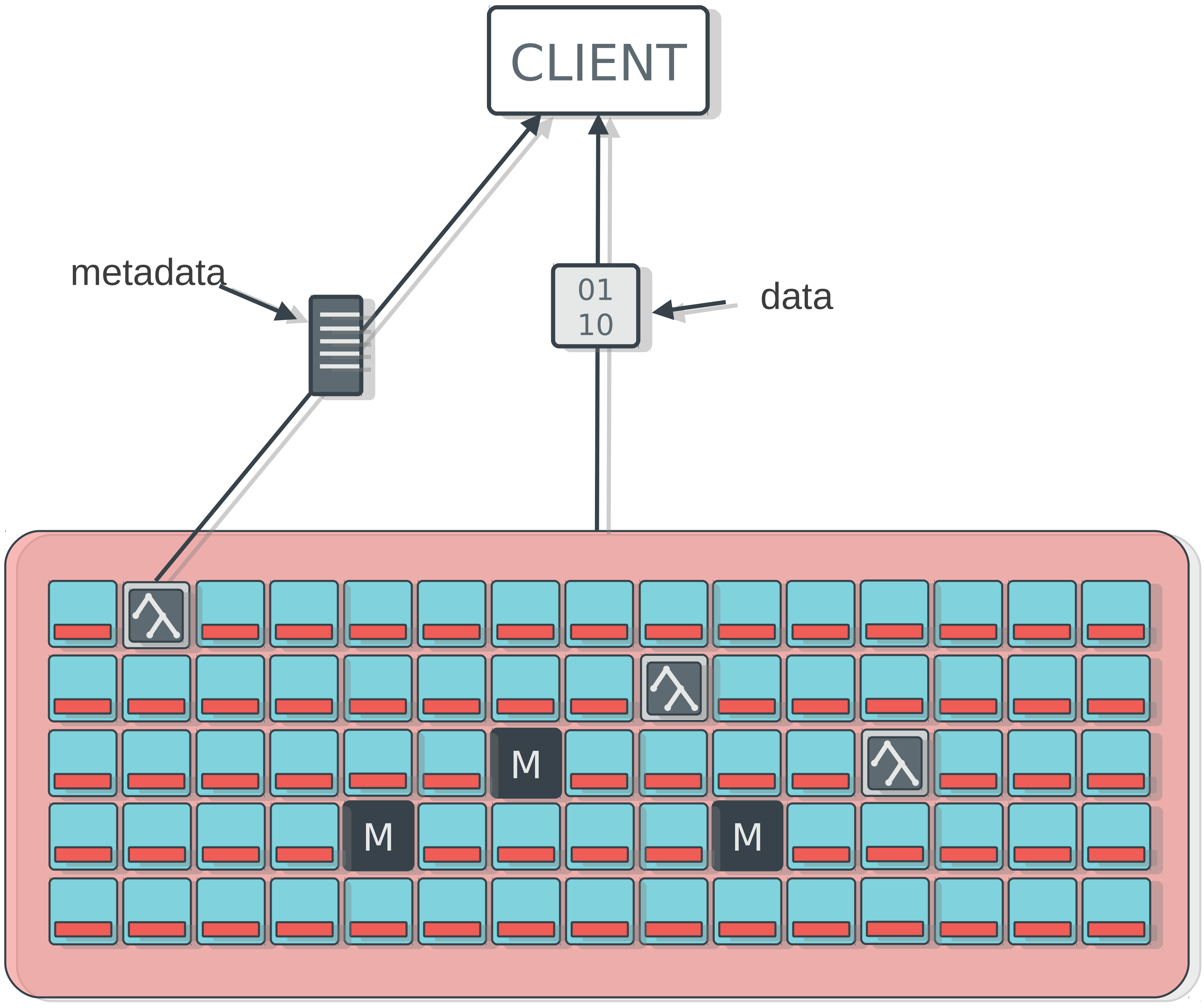
CLIENT
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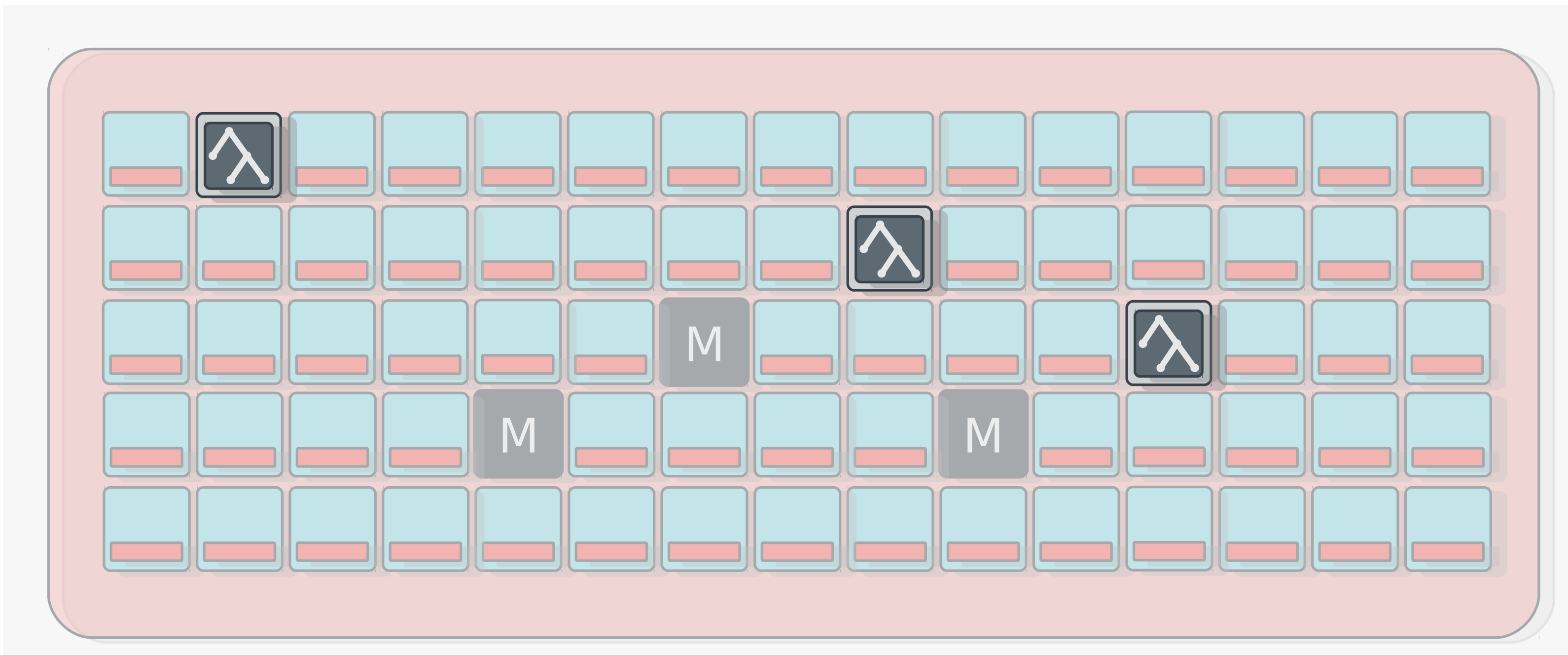
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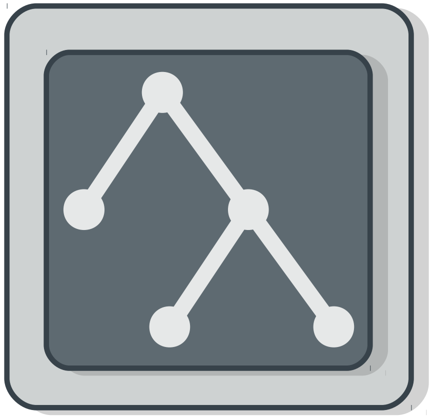
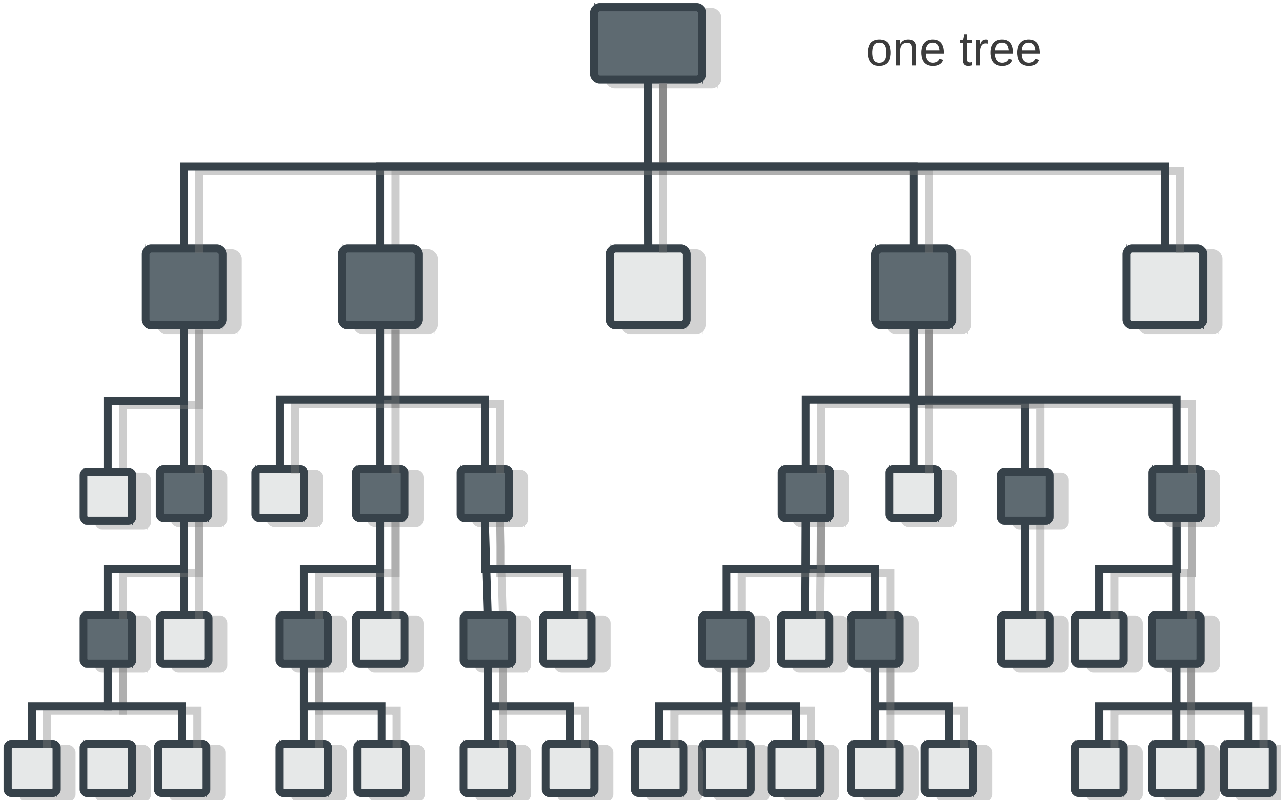


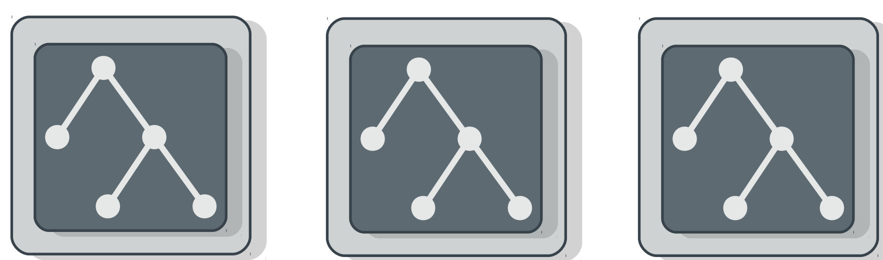
Metadata Server (MDS)

- manages metadata for POSIX shared file system
  - directory hierarchy
  - file metadata (size, owner, timestamps)
- stores metadata in RADOS
- does not serve file data to clients
- only required for the shared file system



one tree

three metadata servers



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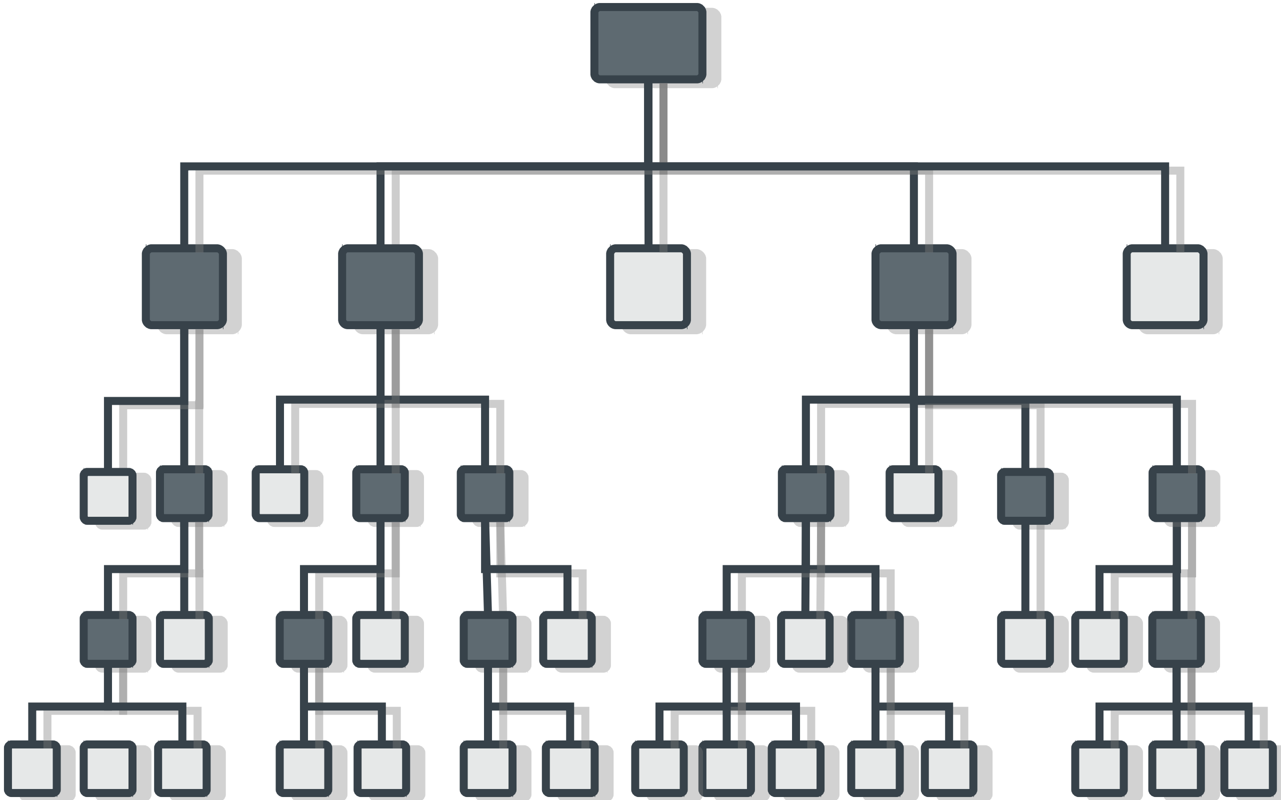

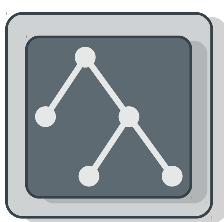

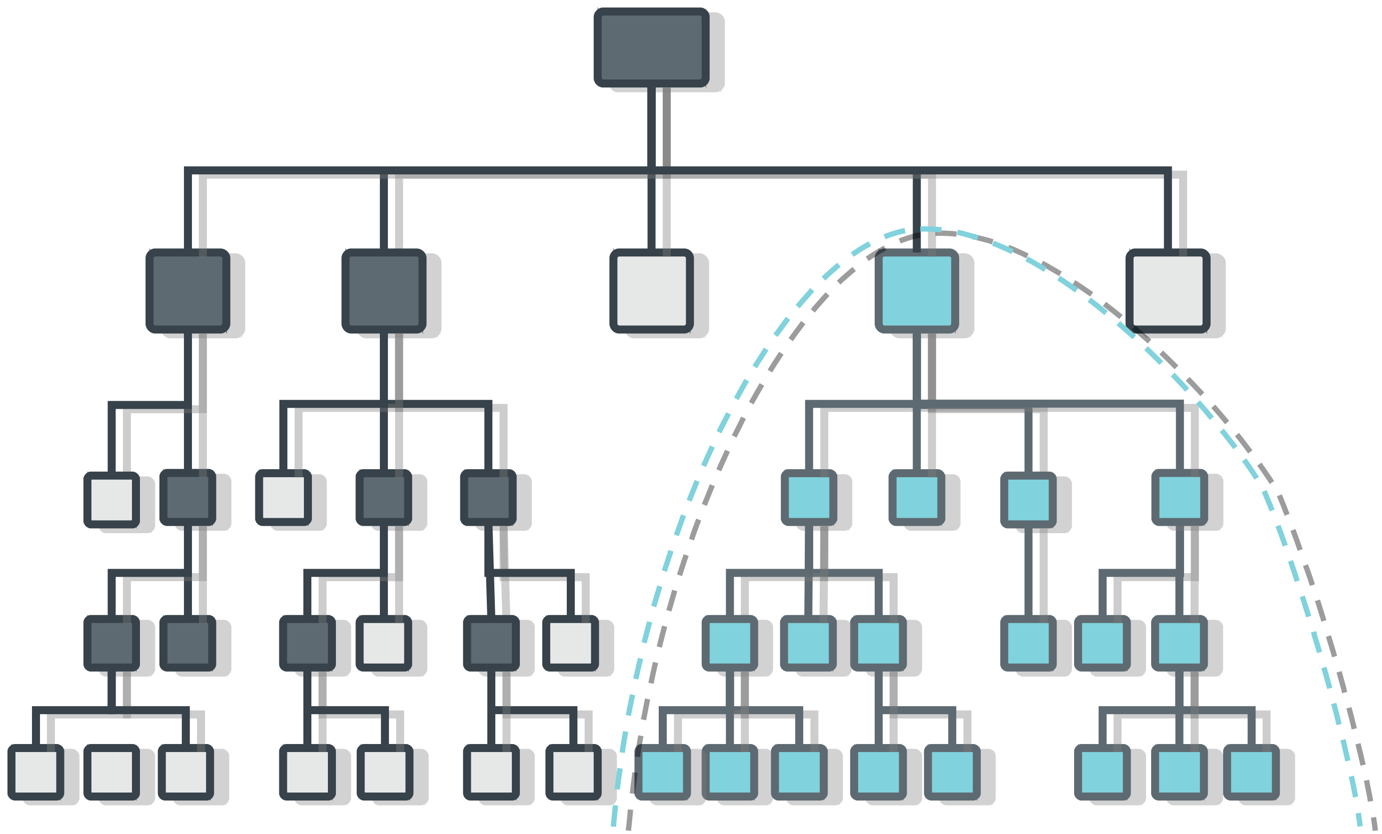

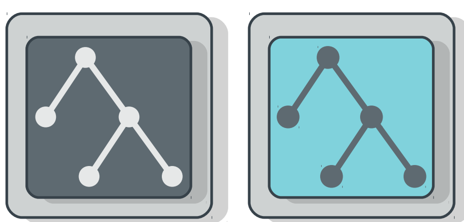

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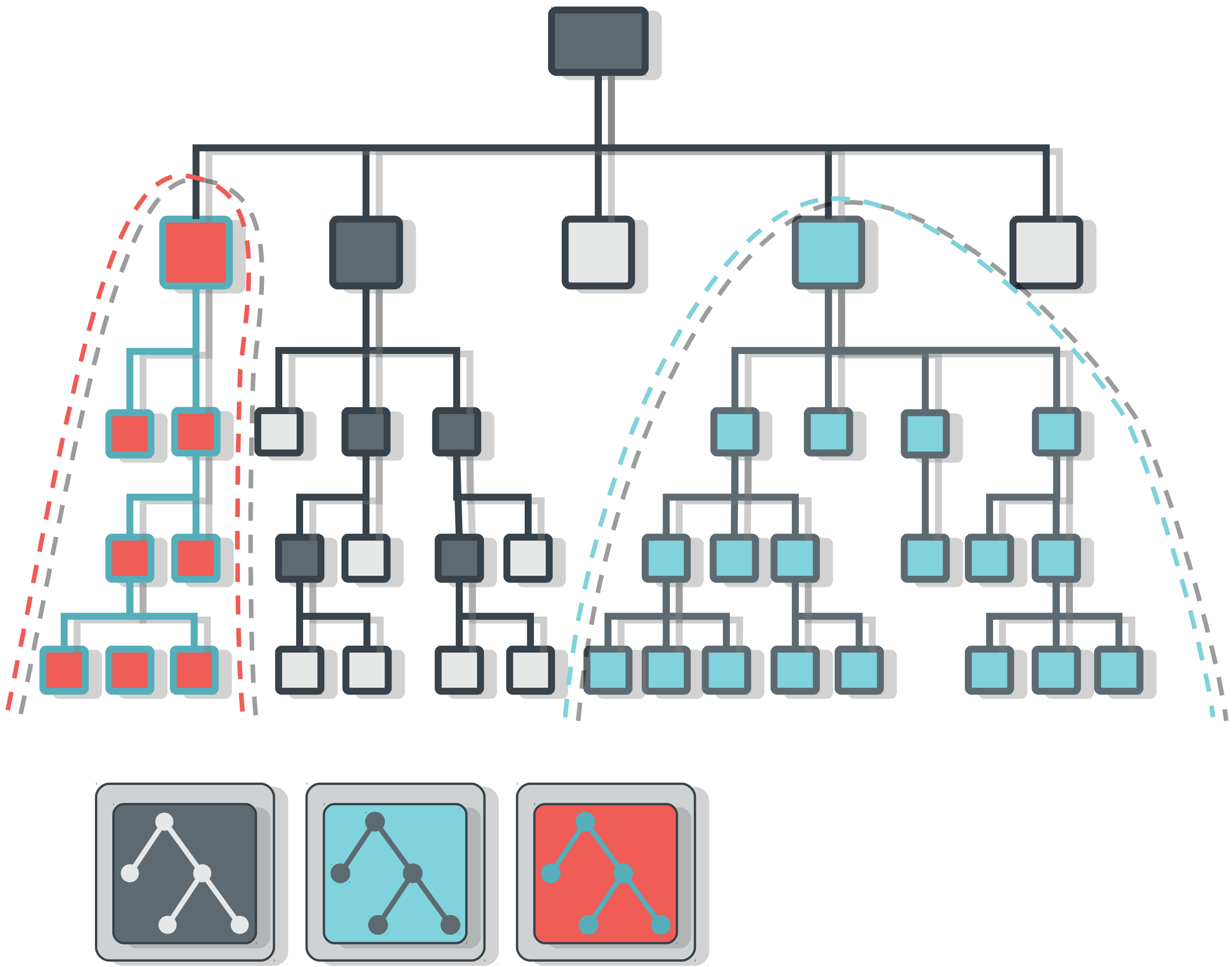

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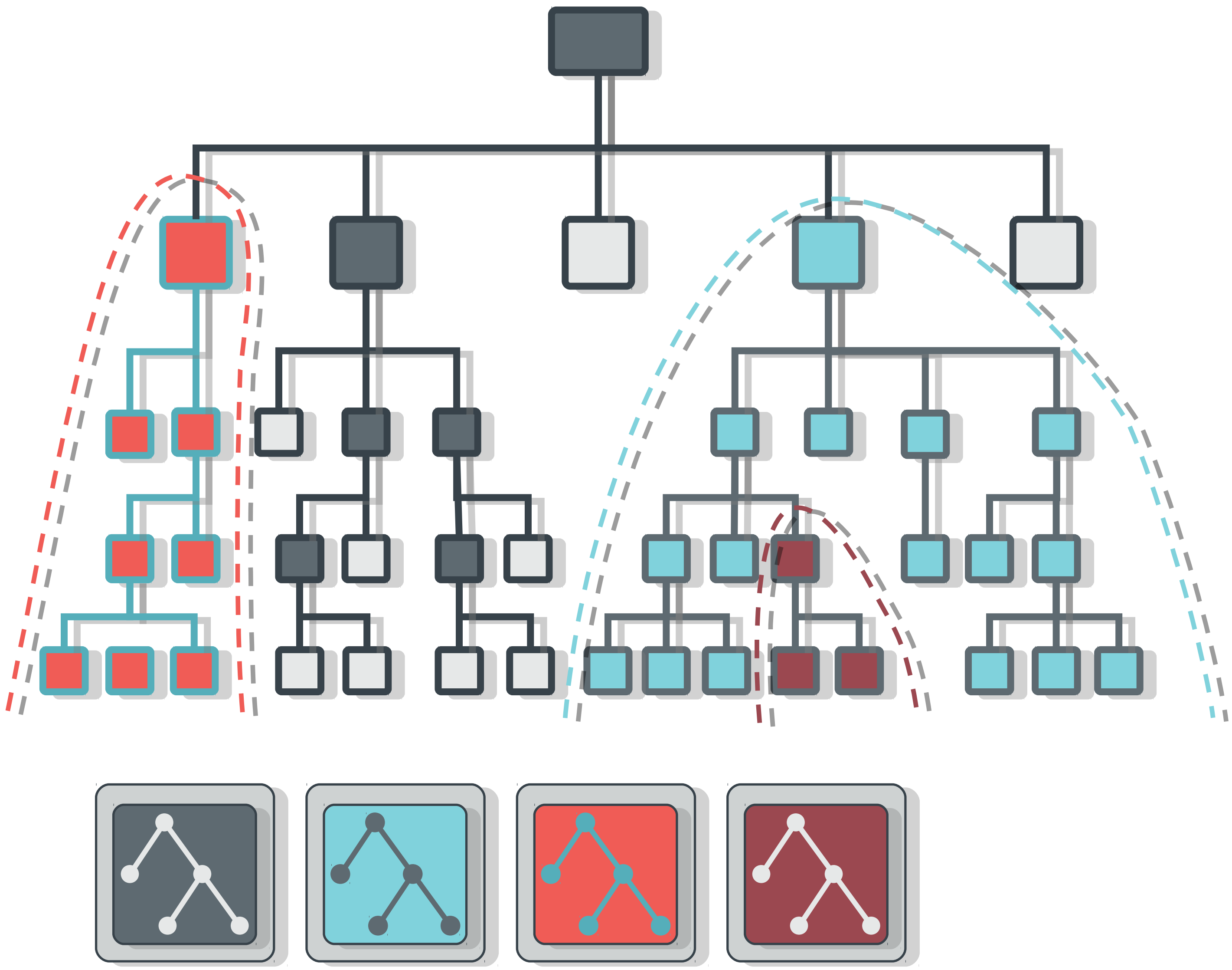

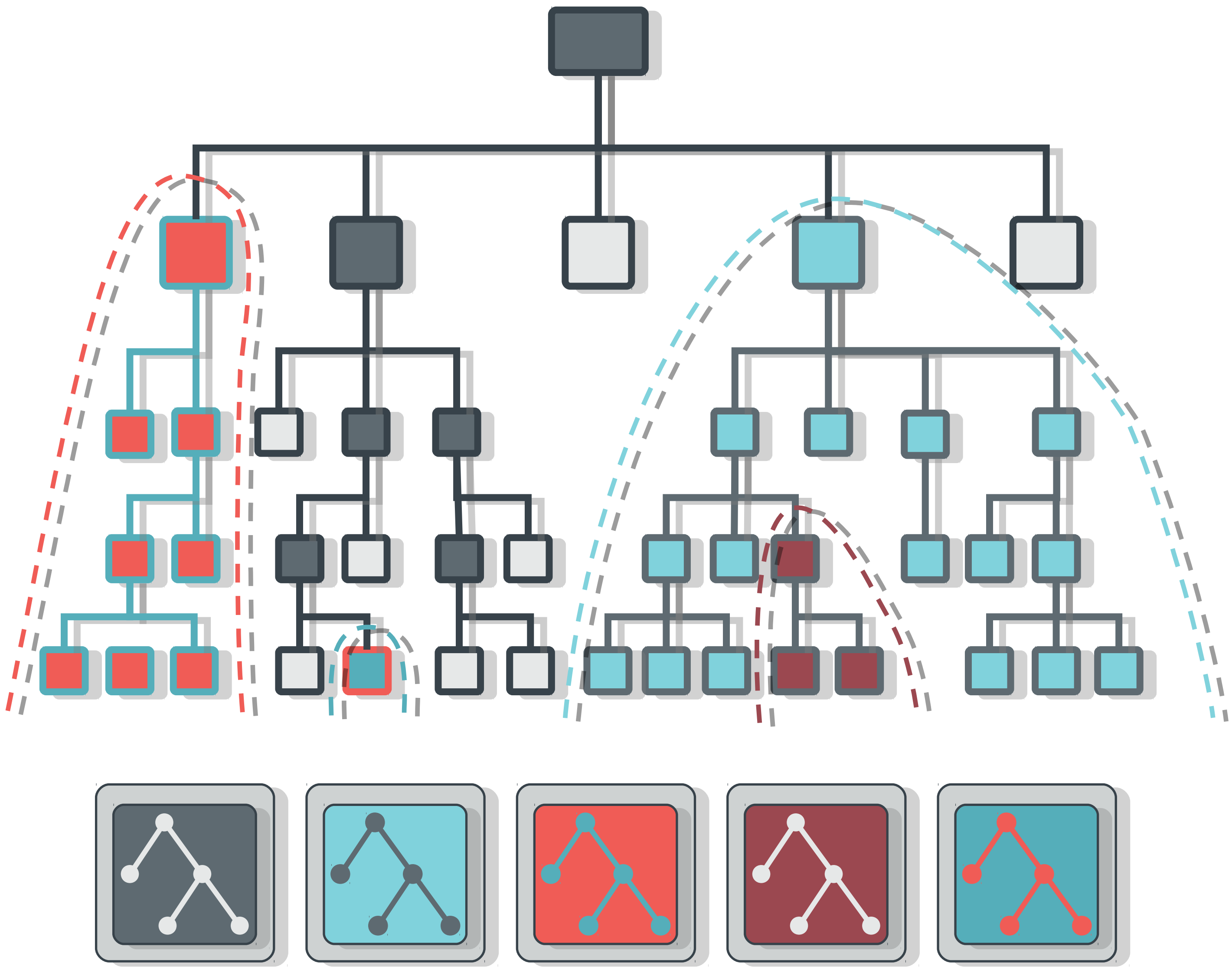

DYNAMIC SUBTREE PARTITIONING

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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 snapshots 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
```

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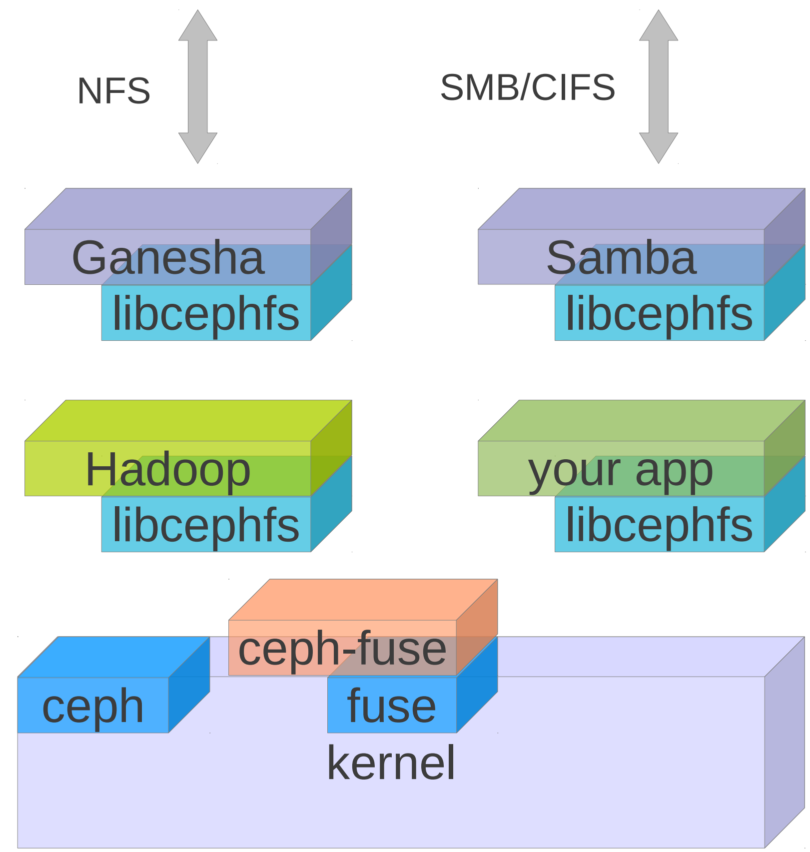
multiple protocols, implementations

- 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)



How do you deploy and manage all this stuff?

installation

- work closely with distros
  - packages in Debian, Fedora, Ubuntu, OpenSUSE
- build releases for all distros, recent releases
  - e.g., point to our deb src and apt-get install
- allow mixed-version clusters
  - upgrade each component individually, each host or rack one-by-one
  - protocol feature bits, safe data type encoding
- facilitate testing, bleeding edge
  - automatic build system generates packages for all branches in git
  - each to test new code, push hot-fixes

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configuration

- minimize local configuration
  - logging, local data paths, tuning options
  - cluster state is managed centrally by monitors
- specify option via
  - config file (global or local)
  - command line
  - adjusted for running daemon
- flexible configuration management options
  - global synced/copied config file
  - generated by management tools
    - Chef, Juju, Crowbar
- be flexible

provisioning

- embrace dynamic nature of the cluster
  - disks, hosts, rack may come online at any time
  - anything may fail at any time
- simple scriptable sequences

  'ceph osd create <uuid>' → allocate osd id

  'ceph-osd --mkfs -i <id>' → initialize local data dir

  'ceph osd crush …' → add to crush map
- identify minimal amount of central coordination
  - monitor cluster membership/quorum
- provide hooks for external tools to do the rest

old school HA

- deploy a pair of servers
- heartbeat
- move a floating IP between then
- clients contact same “server”, which floats

- cumbersome to configure, deploy
- the “client/server” model doesn't scale out

make client, protocol cluster-aware

- clients learn topology of the distributed cluster
  - all OSDs, current ips/ports, data distribution map
- clients talk to the server they want
  - servers scale out, client traffic distributes too
- servers dynamically register with the cluster
  - when a daemon starts, it updates its address in the map
  - other daemons and clients learn map updates via gossip
- servers manage heartbeat, replication
  - no fragile configuration
  - no fail-over pairs

ceph disk management

- label disks
  - GPT partition type (fixed uuid)
- udev
  - generate event when disk is added, on boot
- 'ceph-disk-activate /dev/sdb'
  - mount the disk in the appropriate location (/var/lib/ceph/osd/NNN)
  - possibly adjust cluster metadata about disk location (host, rack)
- upstart, sysvinit, …
  - start the daemon
  - daemon "joins" the cluster, brings itself online
- no manual per-node configuration

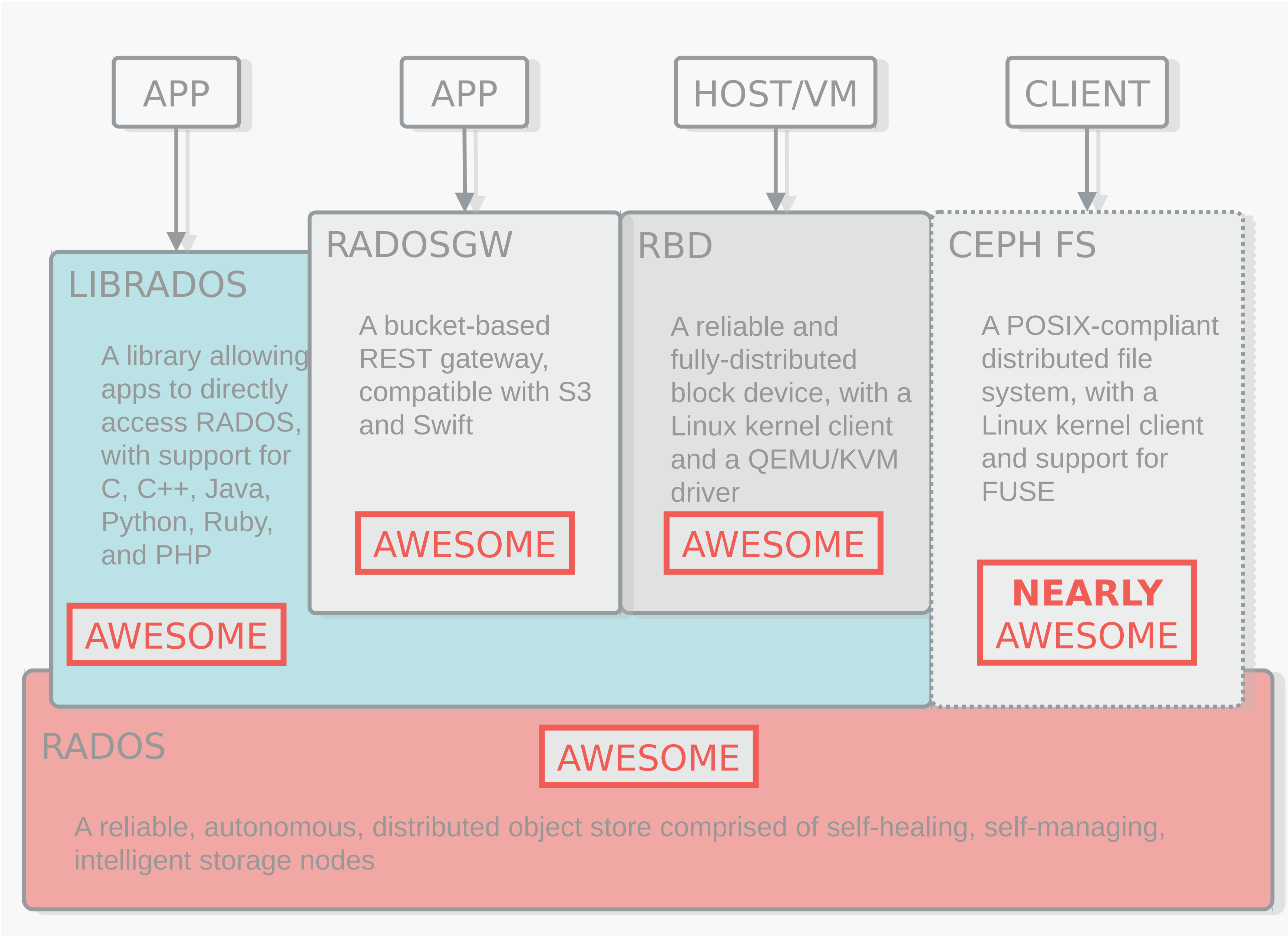
distributed system health

- ceph-mon collects, aggregates basic system state
  - daemon up/down, current IPs
  - disk utilization
- simple hooks query system health
  - 'ceph health [detail]'
  - trivial plugins for nagios, etc.
- daemons instrumentation
  - query state of running daemon
  - use external tools to aggregate
    - collectd, graphite
    - statsd

many paths

- do it yourself
  - use ceph interfaces directly
- Chef
  - ceph cookbooks, DreamHost cookbooks
- Crowbar
- Juju
- pre-packaged solutions
  - Piston AirFrame, Dell OpenStack-Powered Cloud Solution, Suse Cloud, etc.

Project status and roadmap


APP
APP
HOST/VM
CLIENT
LIBRADOS
A library allowing apps to directly access RADOS, with support for C, C++, Java, Python, Ruby, and PHP
AWESOME
RADOSGW
A bucket-based REST gateway, compatible with S3 and Swift
AWESOME
RBD
A reliable and fully-distributed block device, with a Linux kernel client and a QEMU/KVM driver
AWESOME
CEPH FS
A POSIX-compliant distributed file system, with a Linux kernel client and support for FUSE
NEARLY AWESOME
RADOS
AWESOME
A reliable, autonomous, distributed object store comprised of self-healing, self-managing, intelligent storage nodes

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current status

- argonaut stable release v0.48
  - rados, RBD, radosgw
- bobtail stable release v0.56
  - RBD cloning
  - improved performance, scaling, failure behavior
  - radosgw API, performance improvements
  - release in 1-2 weeks

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cuttlefish roadmap

- file system
  - pivot in engineering focus
  - CIFS (Samba), NFS (Ganesha), Hadoop
- RBD
  - Xen integration, iSCSI
- radosgw
  - multi-side federation, disaster recovery
- RADOS
  - geo-replication, disaster recovery
  - ongoing performance improvements

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why we do this

- limited options for scalable open source storage
- proprietary solutions
  - expensive
  - don't scale (well or out)
  - marry hardware and software
- users hungry for alternatives
  - scalability
  - cost
  - features
  - open, interoperable

licensing

<yawn>

- promote adoption
- enable community development
- prevent ceph from becoming proprietary
- allow organic commercialization

LGPLv2

- “copyleft”
  - free distribution
  - allow derivative works
  - changes you distribute/sell must be shared
- ok to link to proprietary code
  - allow proprietary products to incude and build on ceph
  - does not allow proprietary derivatives of ceph

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fragmented copyright

- we do not require copyright assignment from contributors
  - no single person or entity owns all of ceph
  - no single entity can make ceph proprietary
- strong community
  - many players make ceph a safe technology bet
  - project can outlive any single business

why it's important

- ceph is an ingredient
  - we need to play nice in a larger ecosystem
  - community will be key to success
- truly open source solutions are disruptive
  - frictionless integration with projects, platforms, tools
  - freedom to innovate on protocols
  - leverage community testing, development resources
  - open collaboration is efficient way to build technology

who we are

- Ceph created at UC Santa Cruz (2004-2007)
- developed by DreamHost (2008-2011)
- supported by Inktank (2012)
  - Los Angeles, Sunnyvale, San Francisco, remote
- growing user and developer community
  - Linux distros, users, cloud stacks, SIs, OEMs

http://ceph.com/

inktank ceph

thanks

sage weil

sage@inktank.com

@liewegas

http://github.com/ceph

http://ceph.com/

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