ceph – a unified distributed storage system

sage weil
cloudopen – august 29, 2012

outline

- why you should care
- what is it, what it does
- how it works
  - architecture
- how you can use it
  - librados
  - radosgw
  - RBD
  - file system
- who we are, why we do this

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why should you care about another storage system?

requirements

- diverse storage needs
  - 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

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time

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

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cost

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

what is ceph?

unified storage system

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

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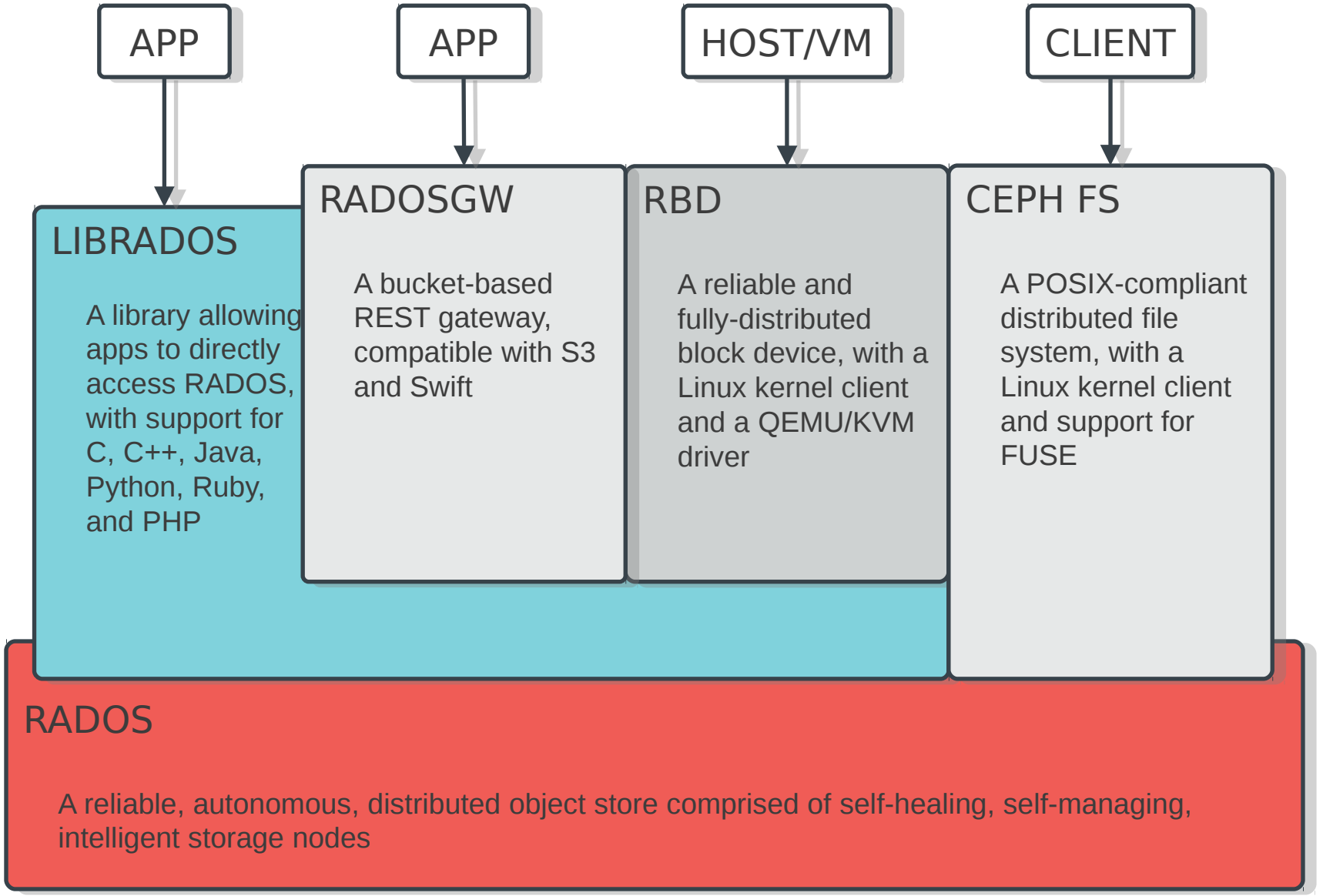
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open source

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

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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

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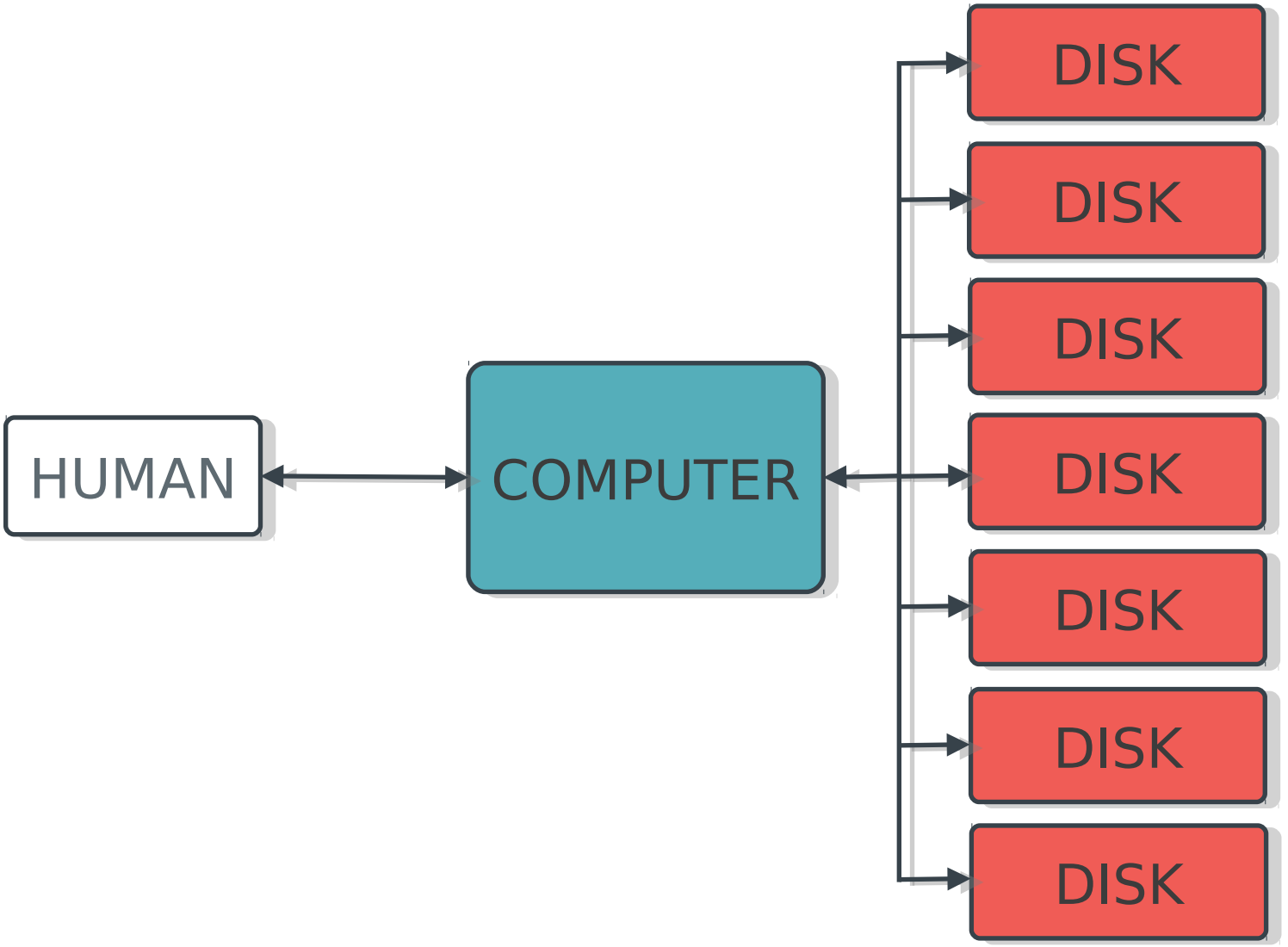
ceph object model

- pools
  - 1s to 100s
  - independent namespaces or object 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 single flat namespace
  - variable size
  - simple API with rich semantics
- more scalable than files
  - no hard-to-distribute hierarchy
  - update semantics do not span objects
  - workload is trivially parallel



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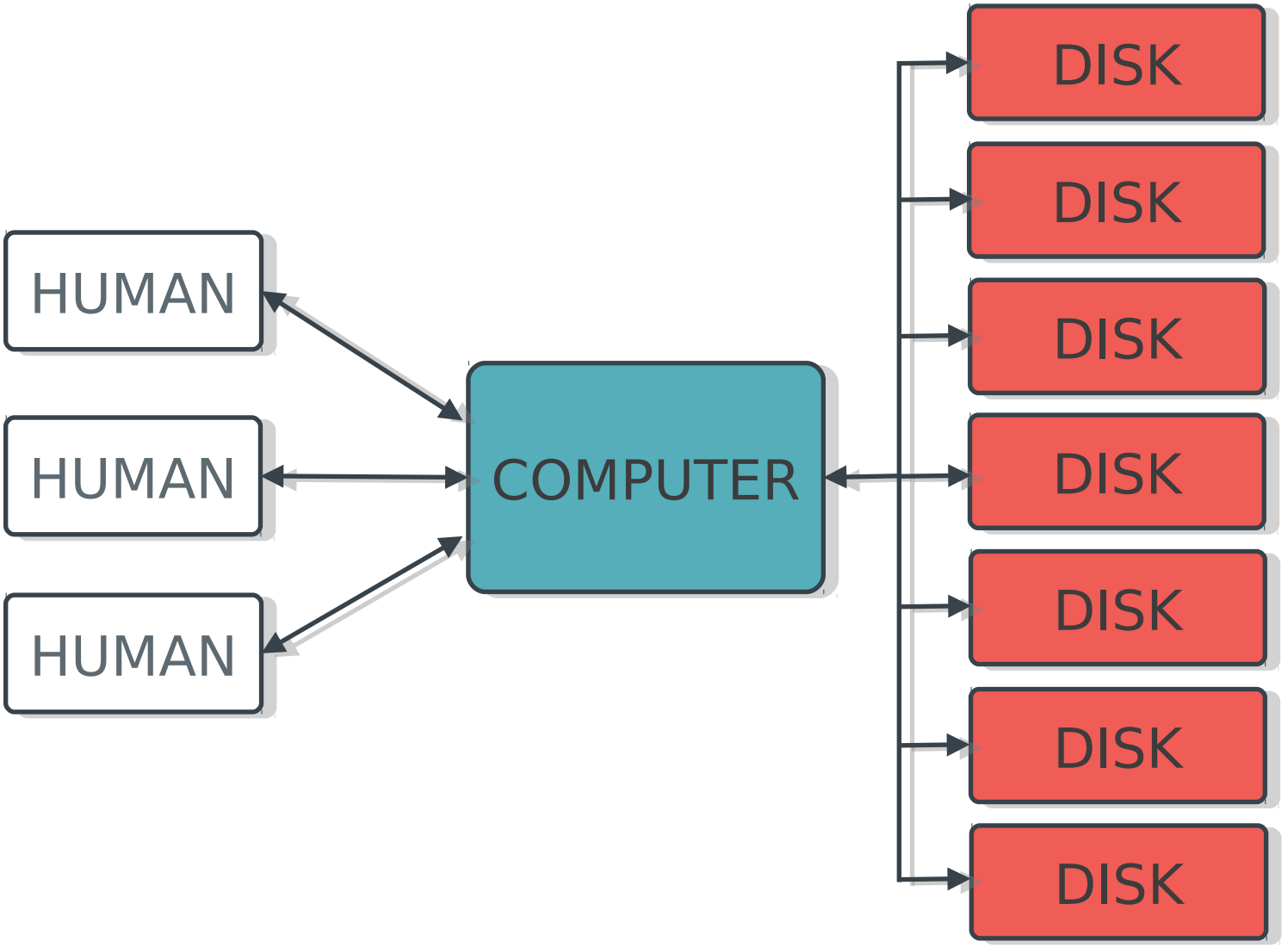
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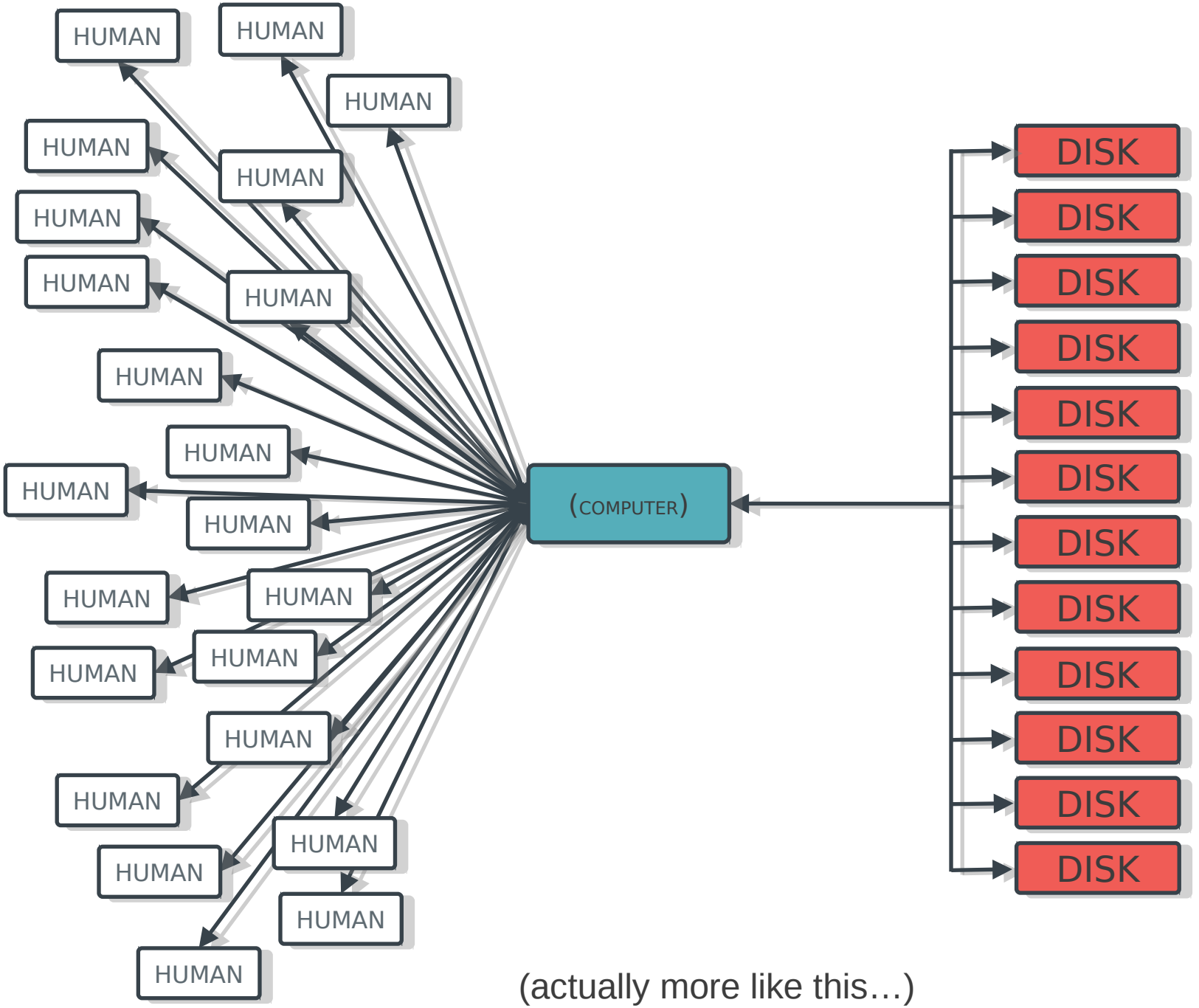

(actually more like this…)

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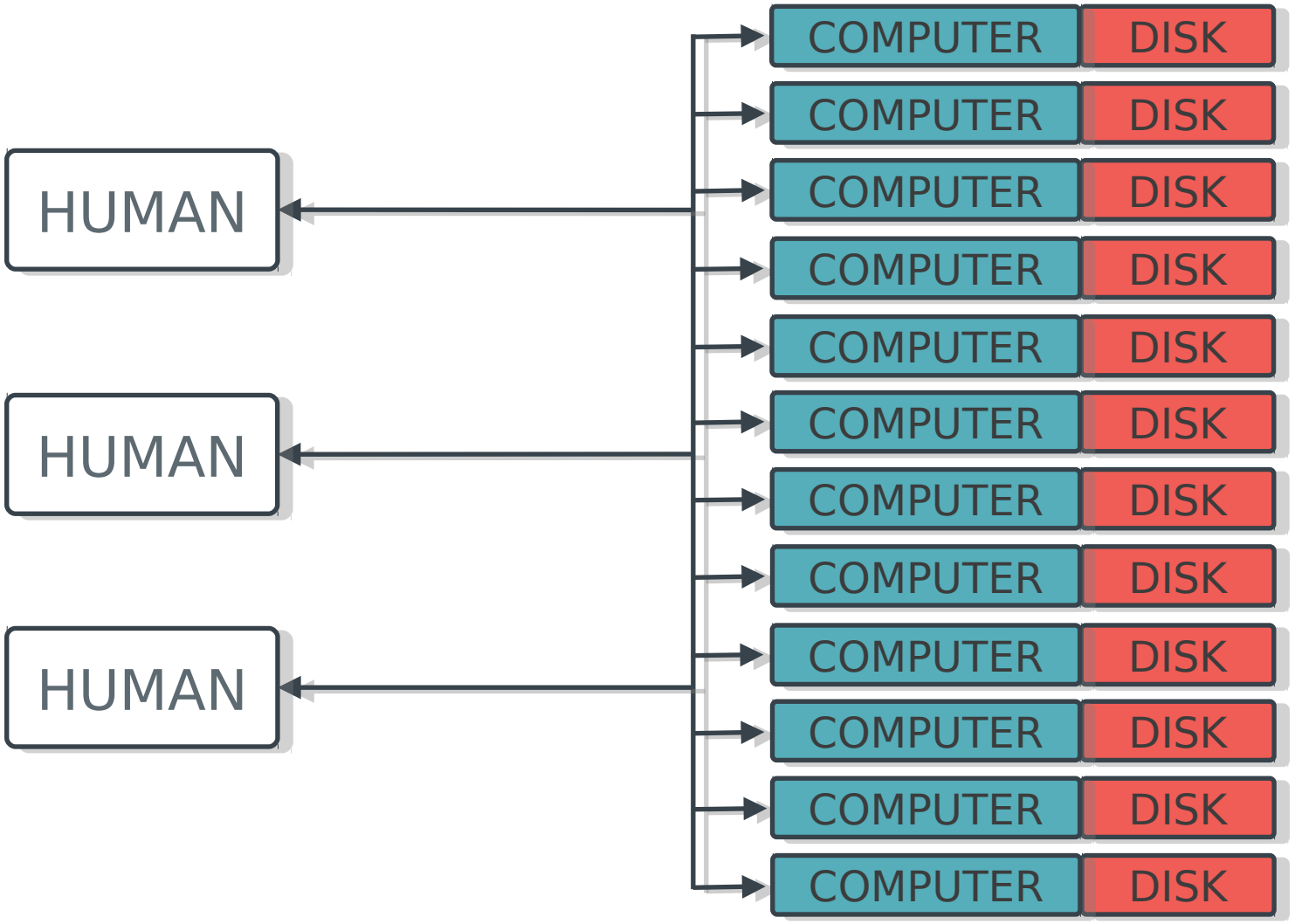
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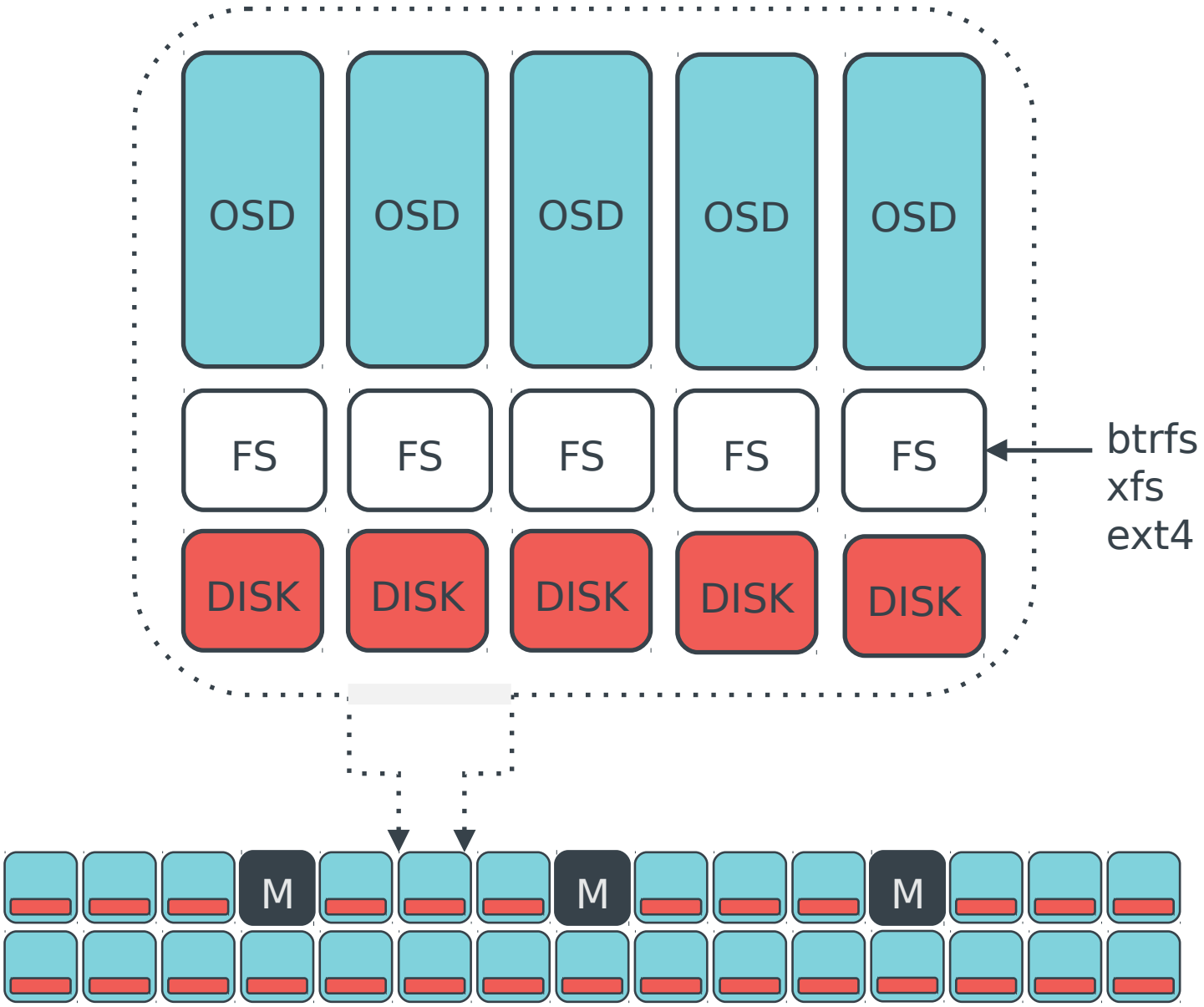
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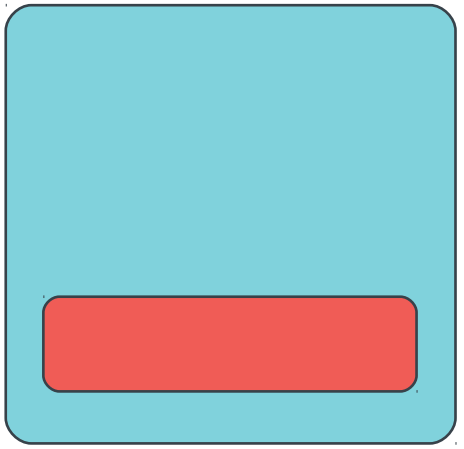
Monitors:

- Maintain cluster membership and state
- Provide consensus for distributed decision-making
- Small, odd number
- These do **not** serve stored objects to clients



Object Storage Daemons (OSDs):

- At least three in a cluster
- One per disk or RAID group
- Serve stored objects to clients
- Intelligently peer to perform replication tasks

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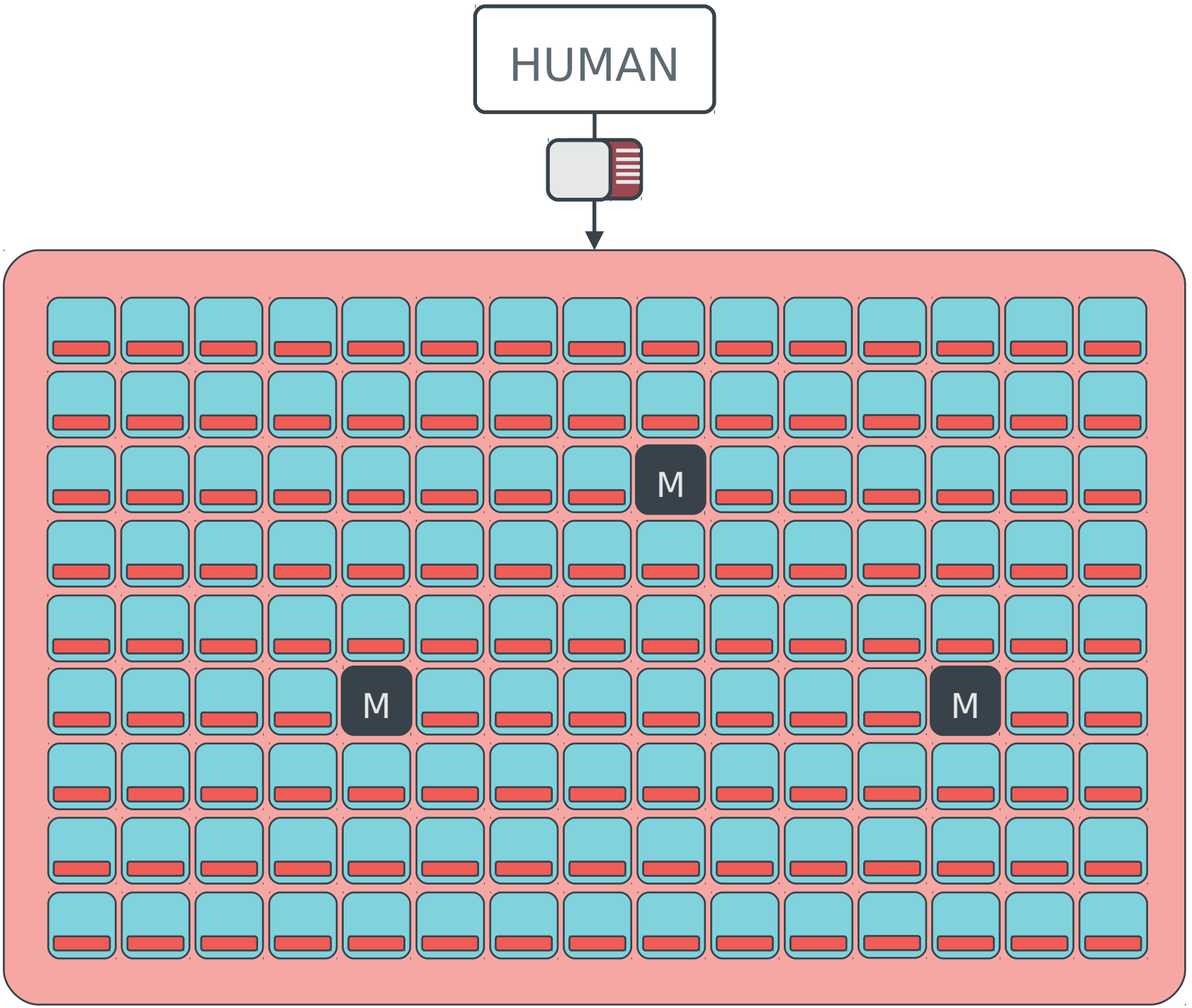

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data distribution

- 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

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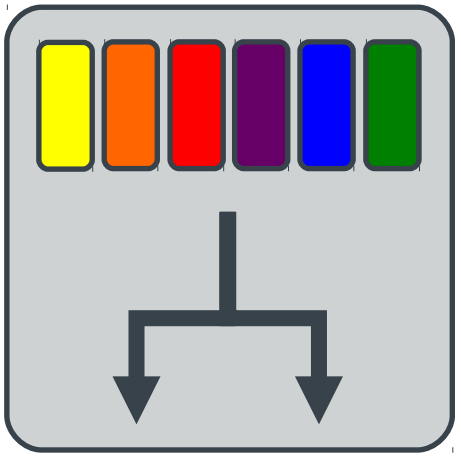

CRUSH

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

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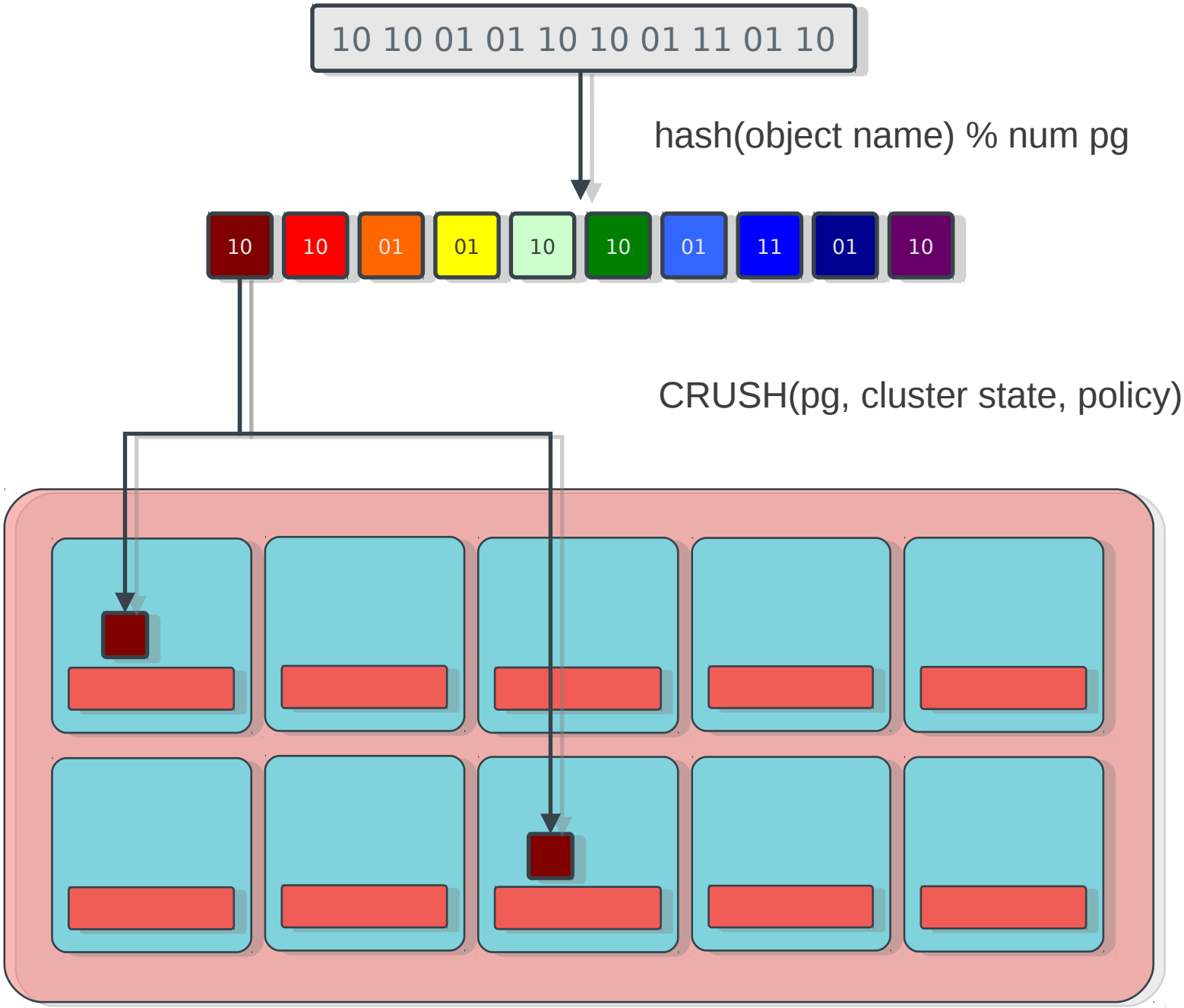
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CRUSH(pg, cluster state, policy)

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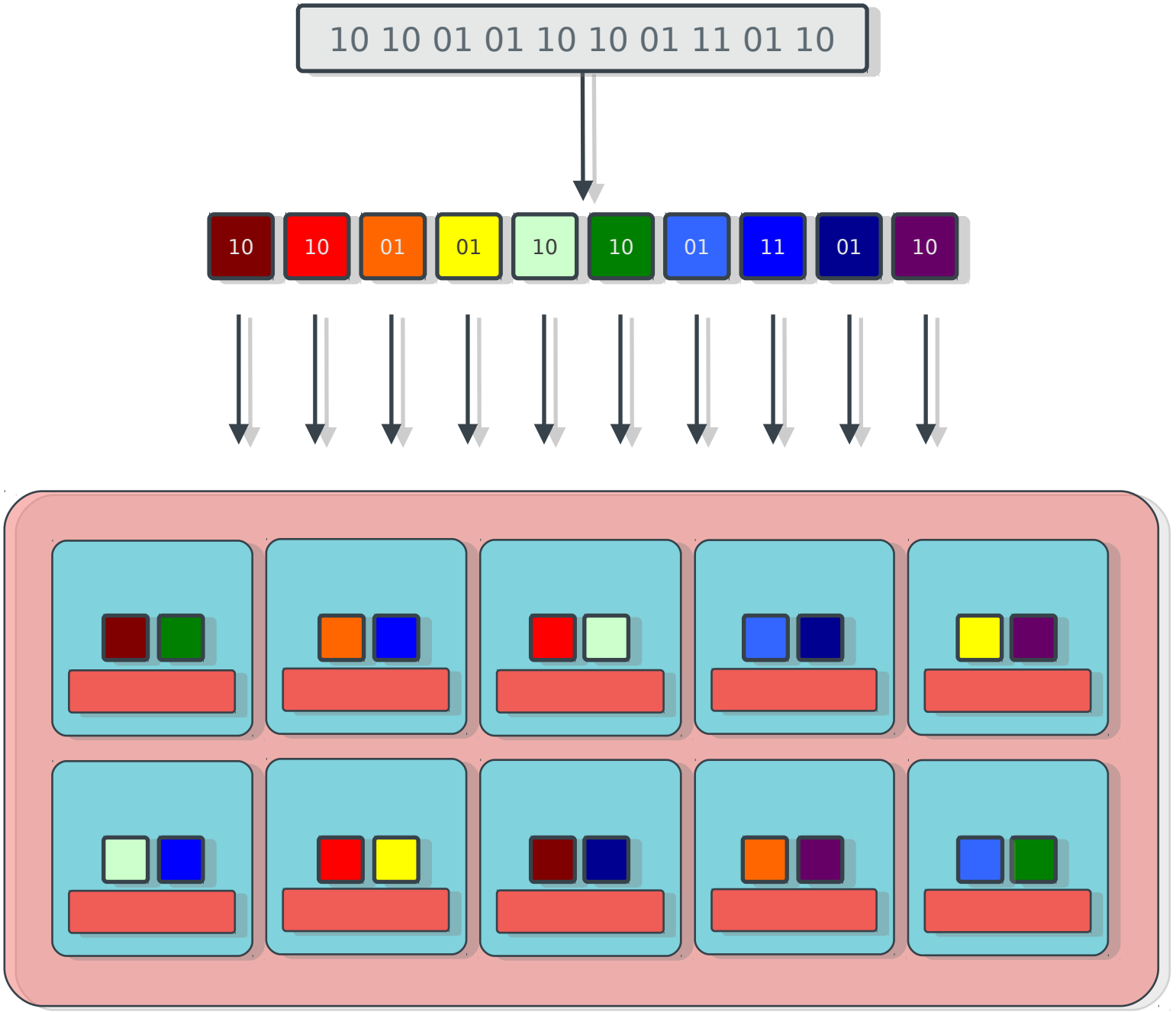

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RADOS

- 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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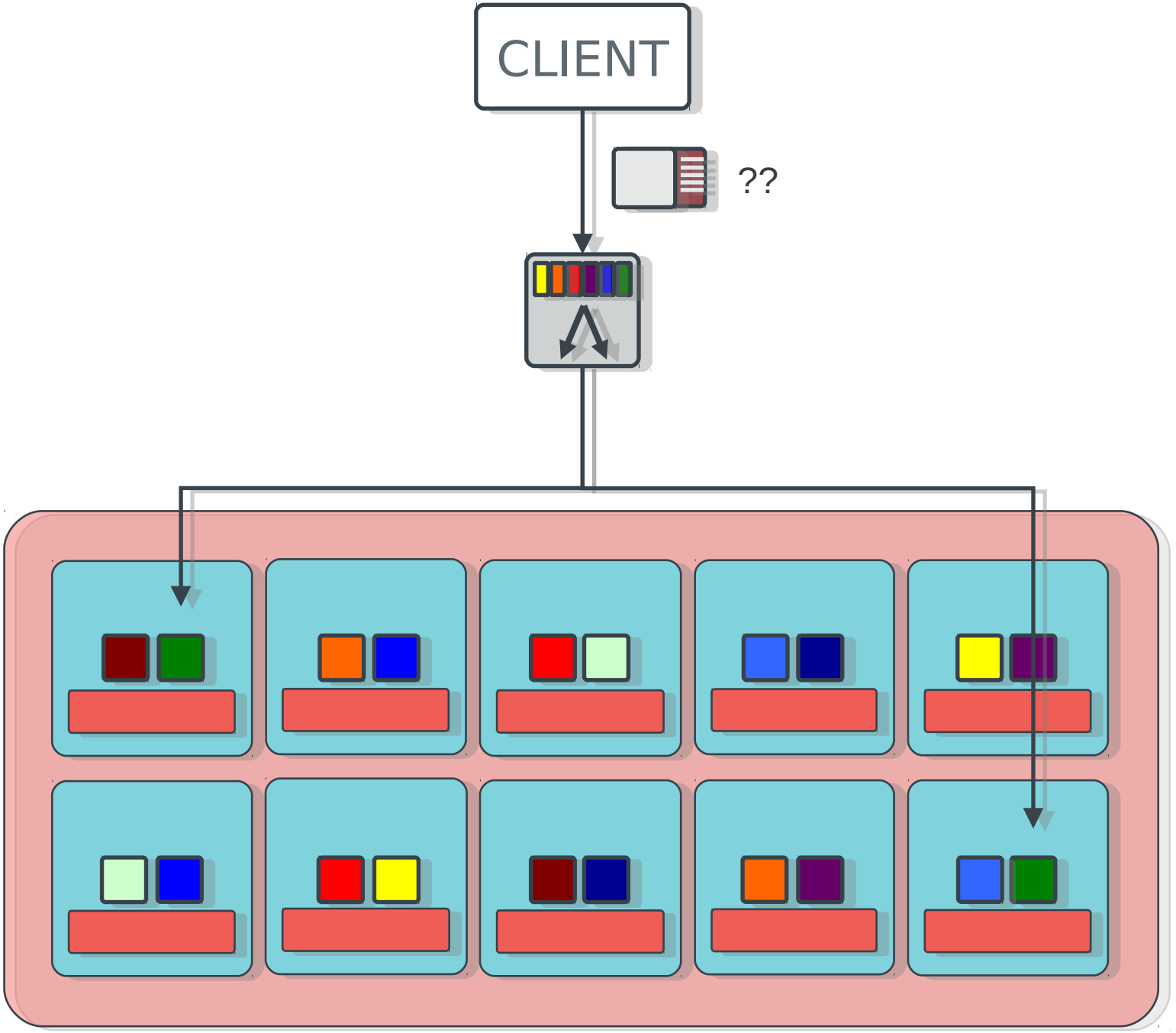

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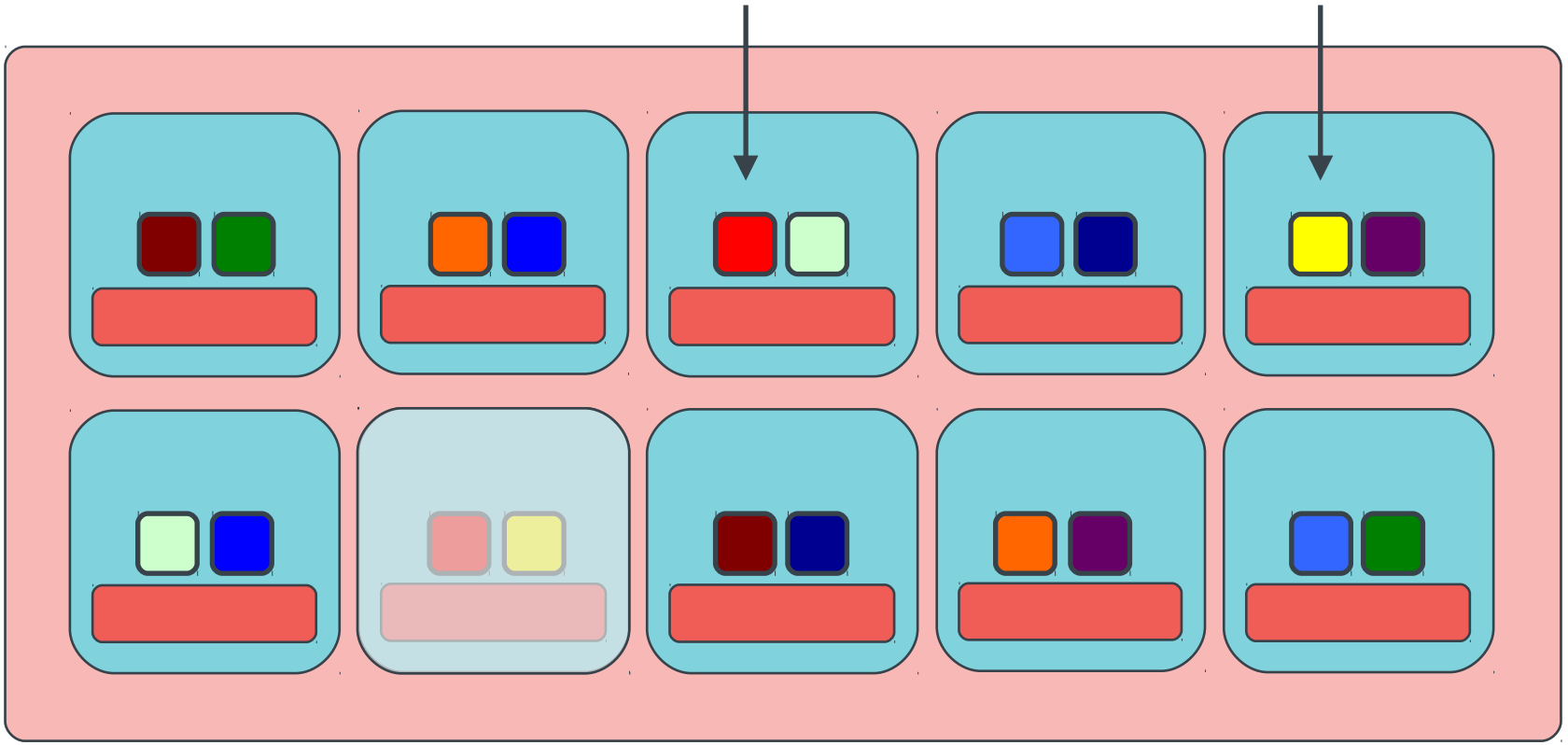

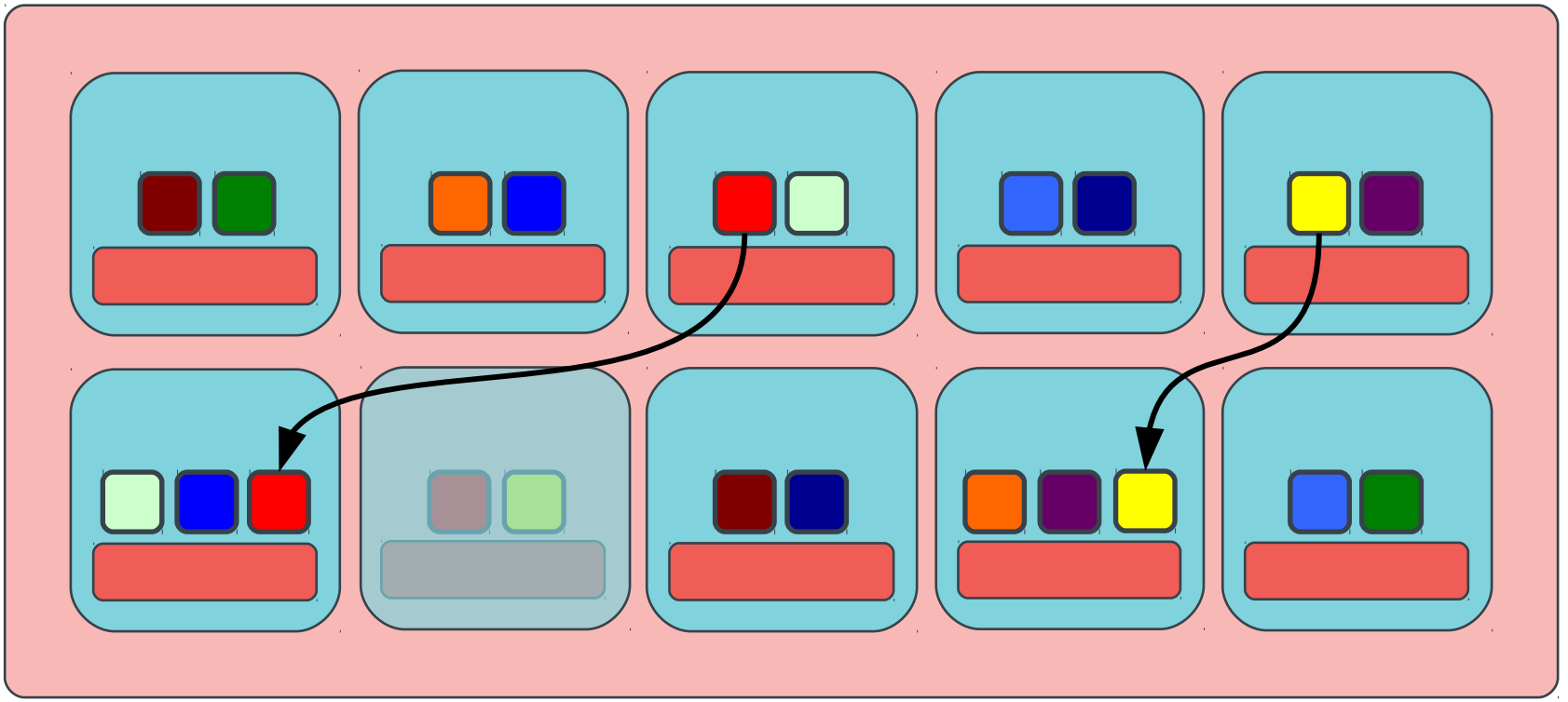

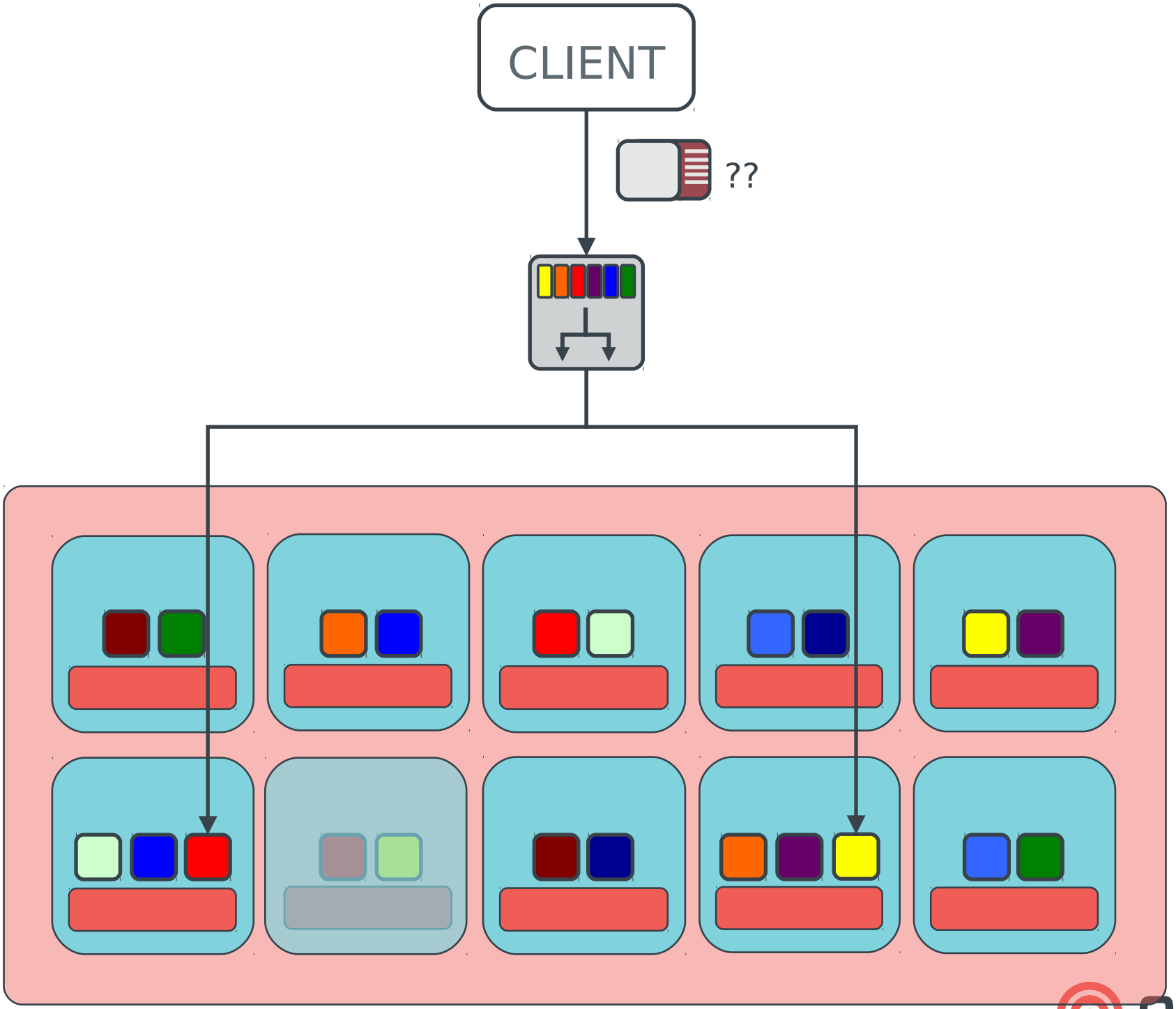

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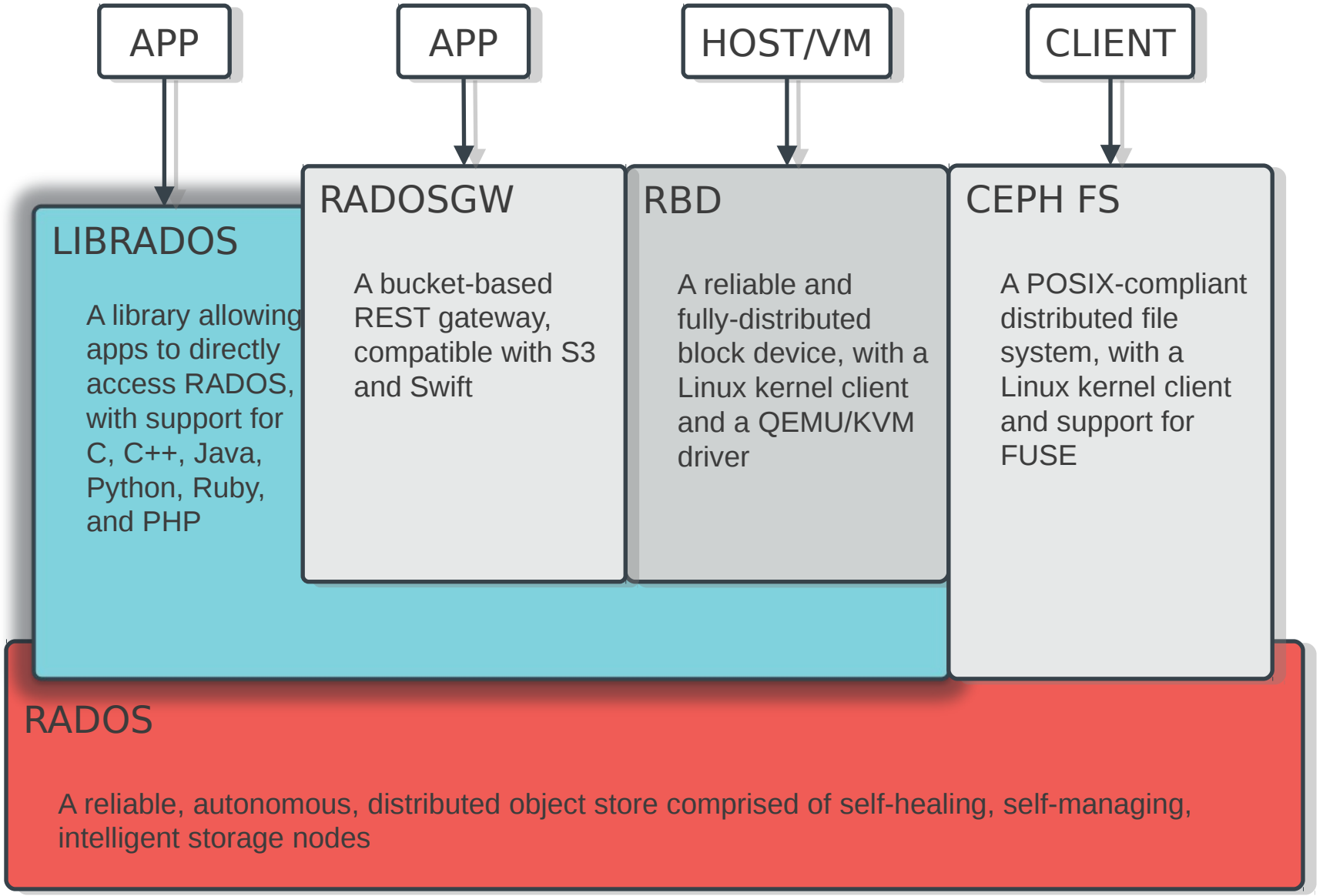
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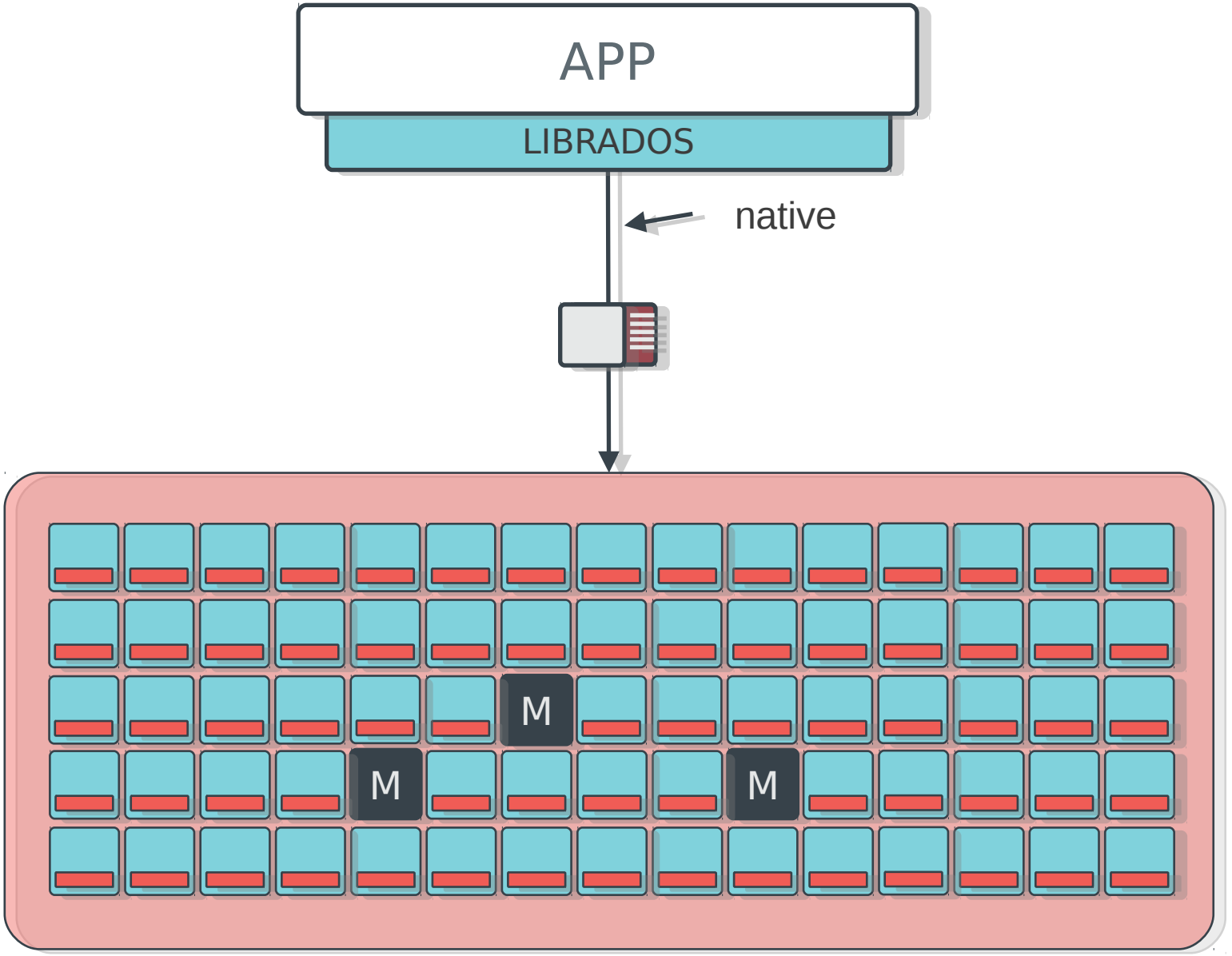

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LIBRADOS

- Provides direct access to RADOS for applications
- C, C++, Python, PHP, Java
- No HTTP overhead

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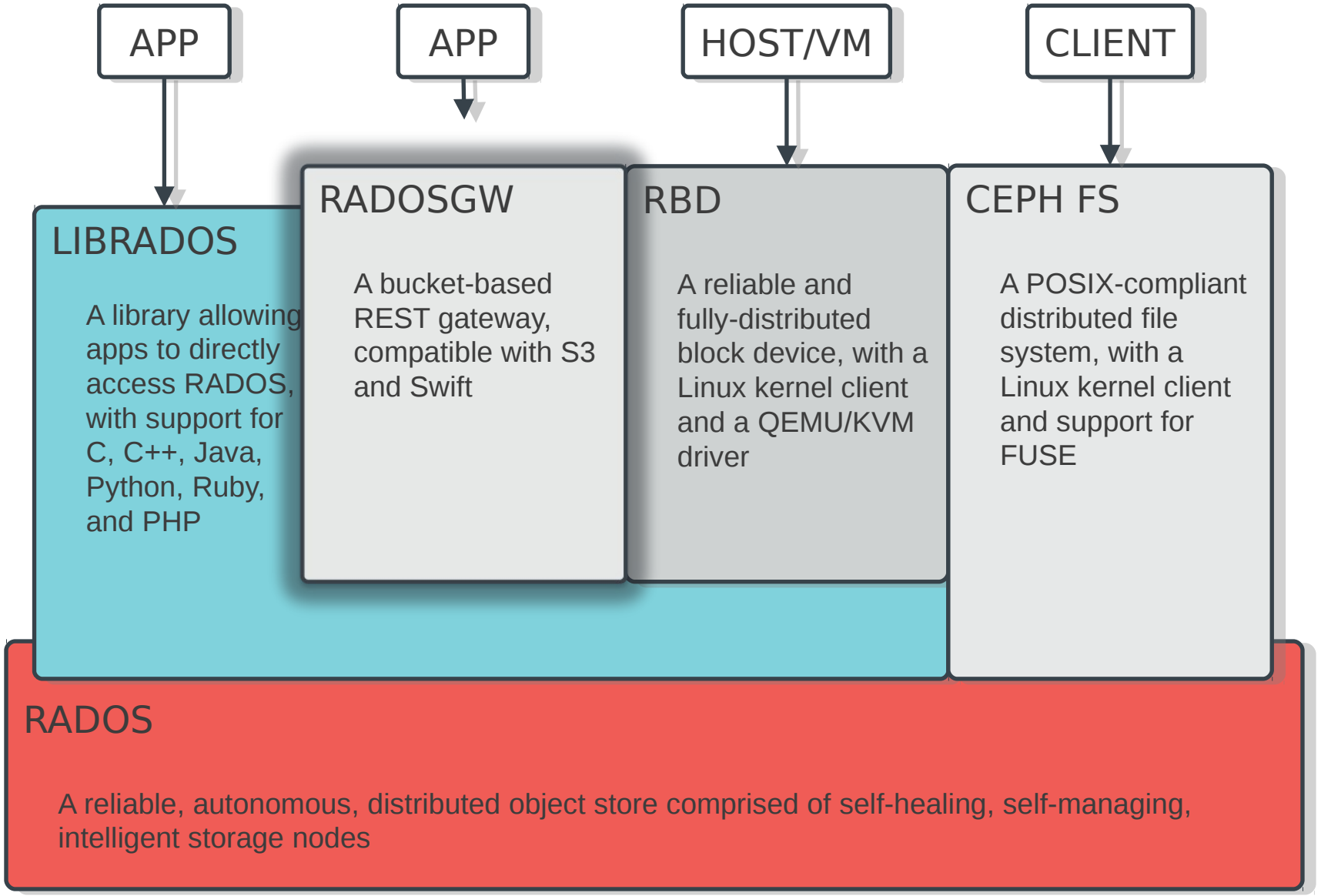
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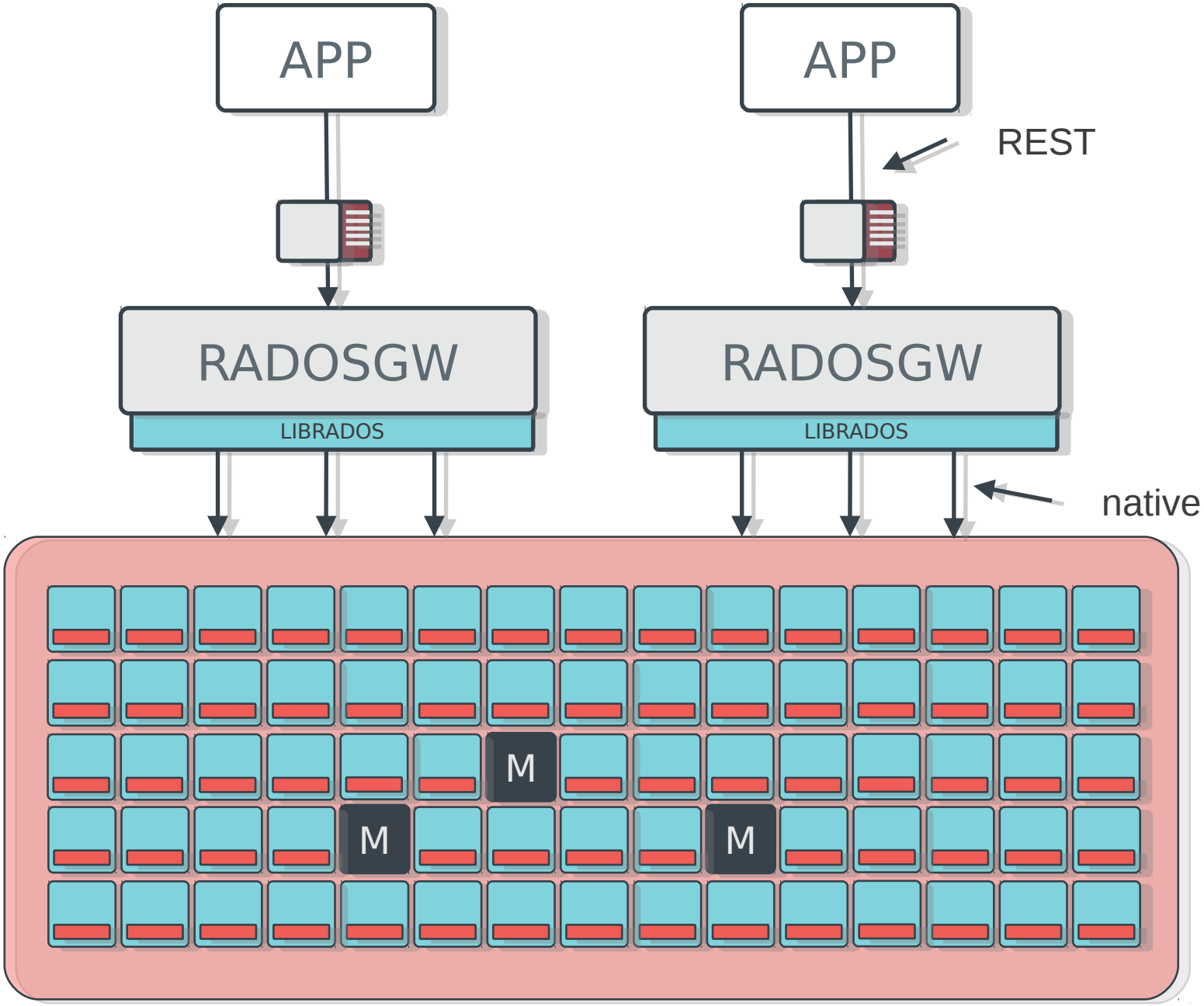

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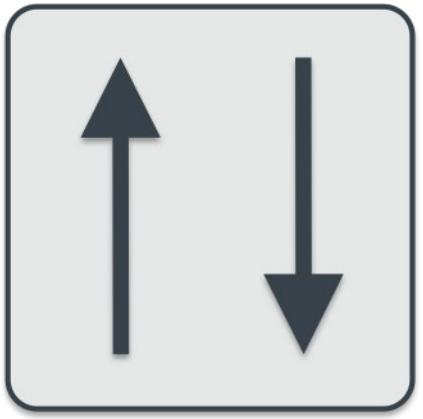

RADOS Gateway:

- REST-based interface to RADOS
- Supports buckets, accounting
- Compatible with S3 and Swift applications

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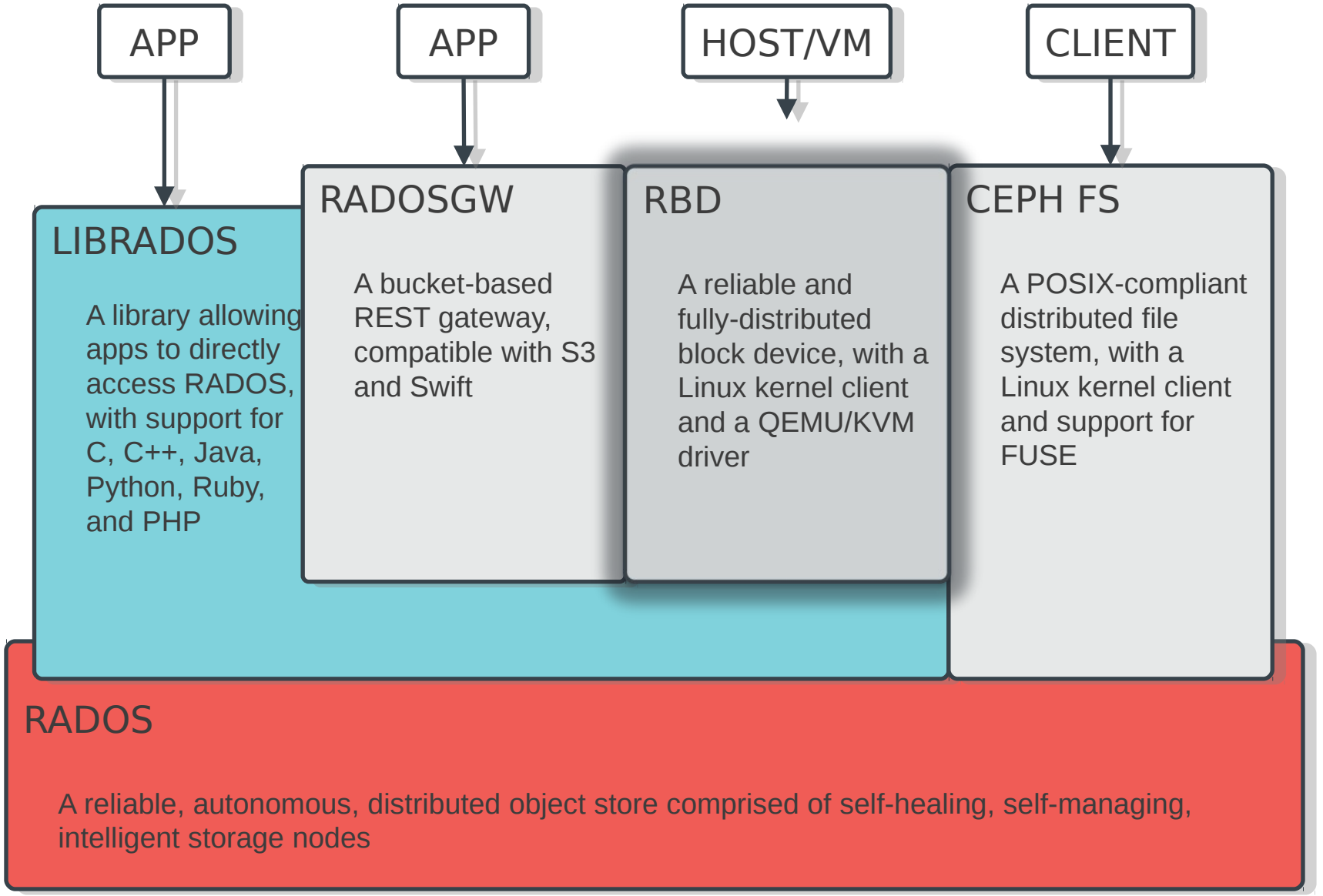
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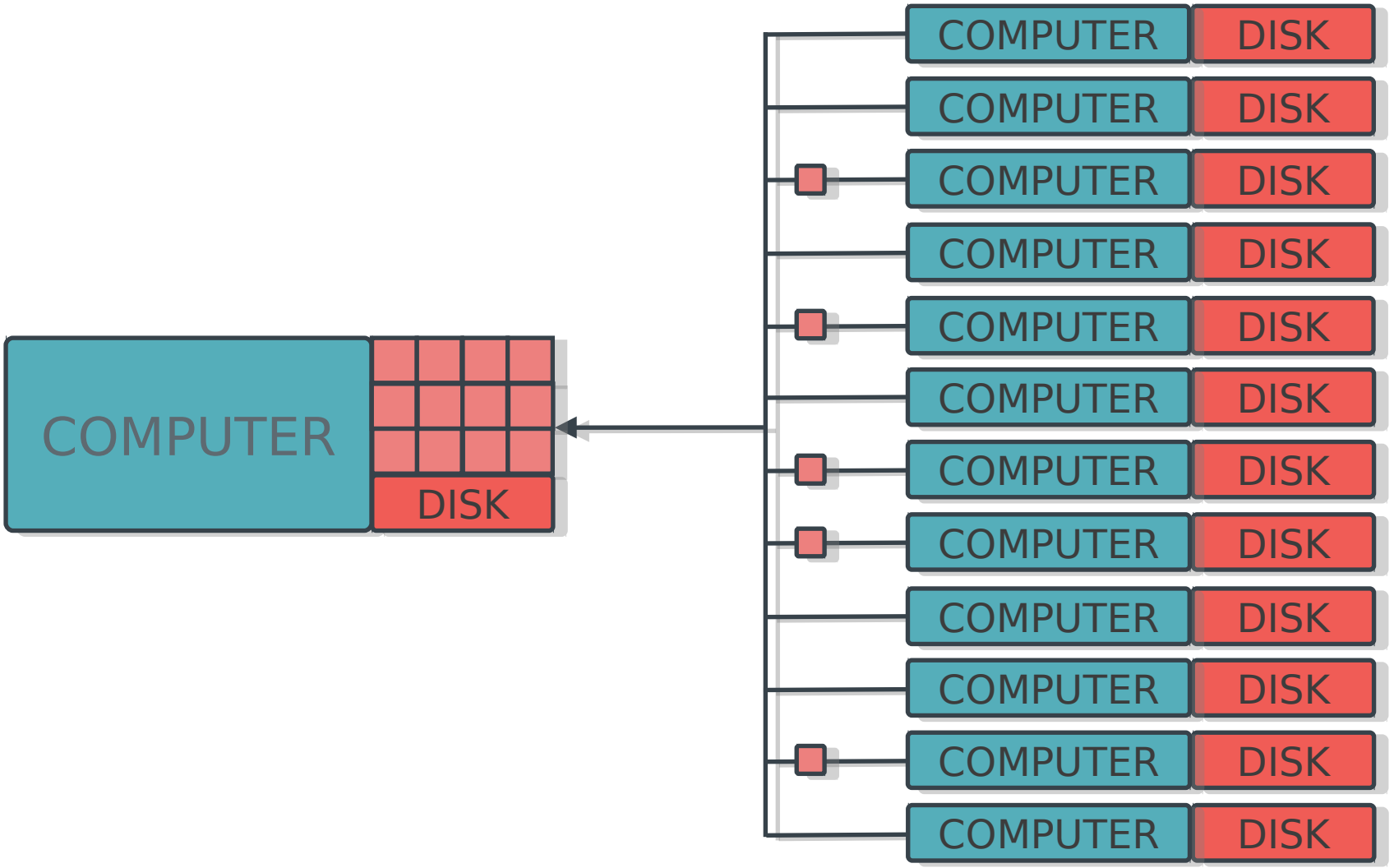
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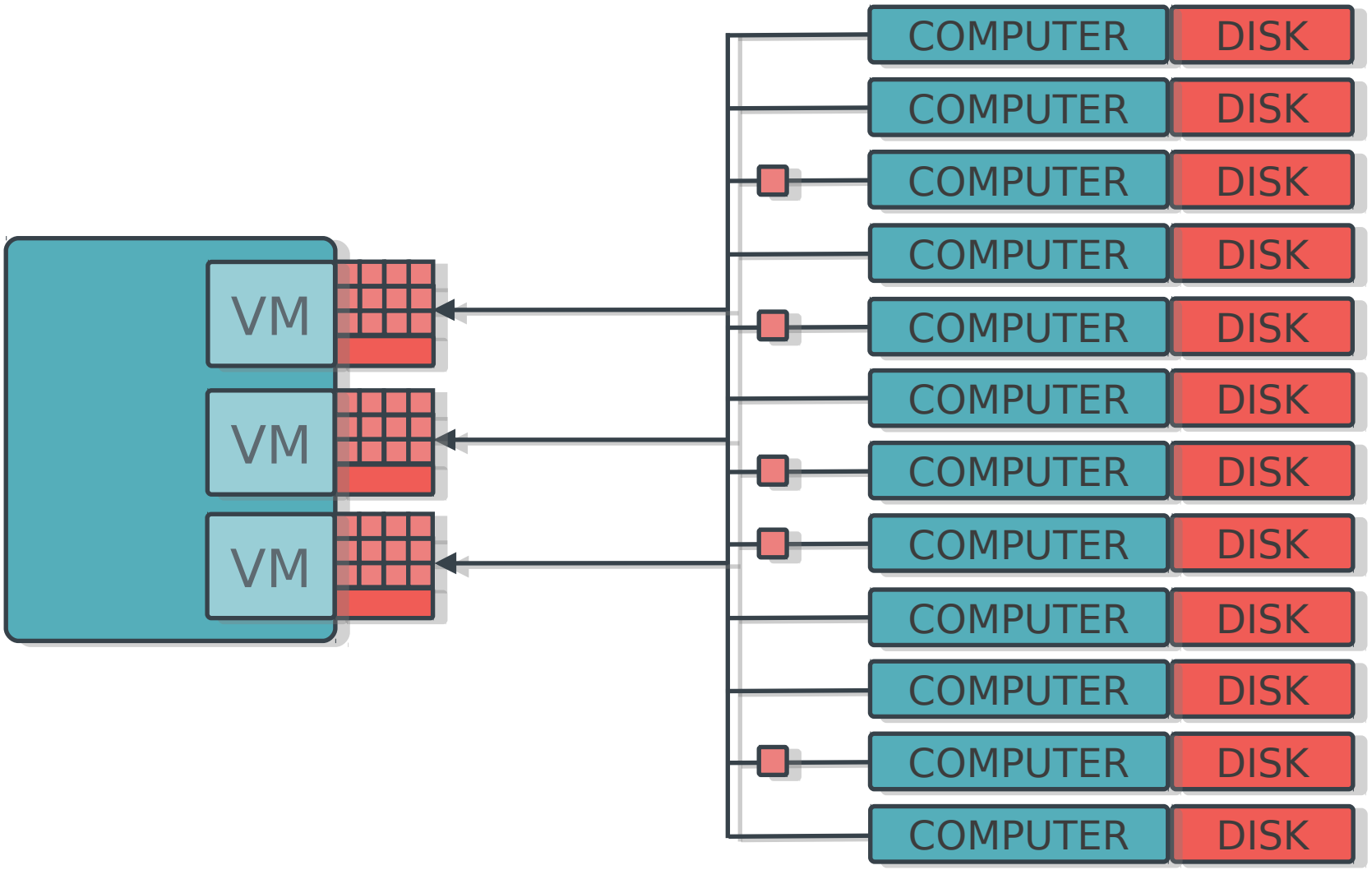
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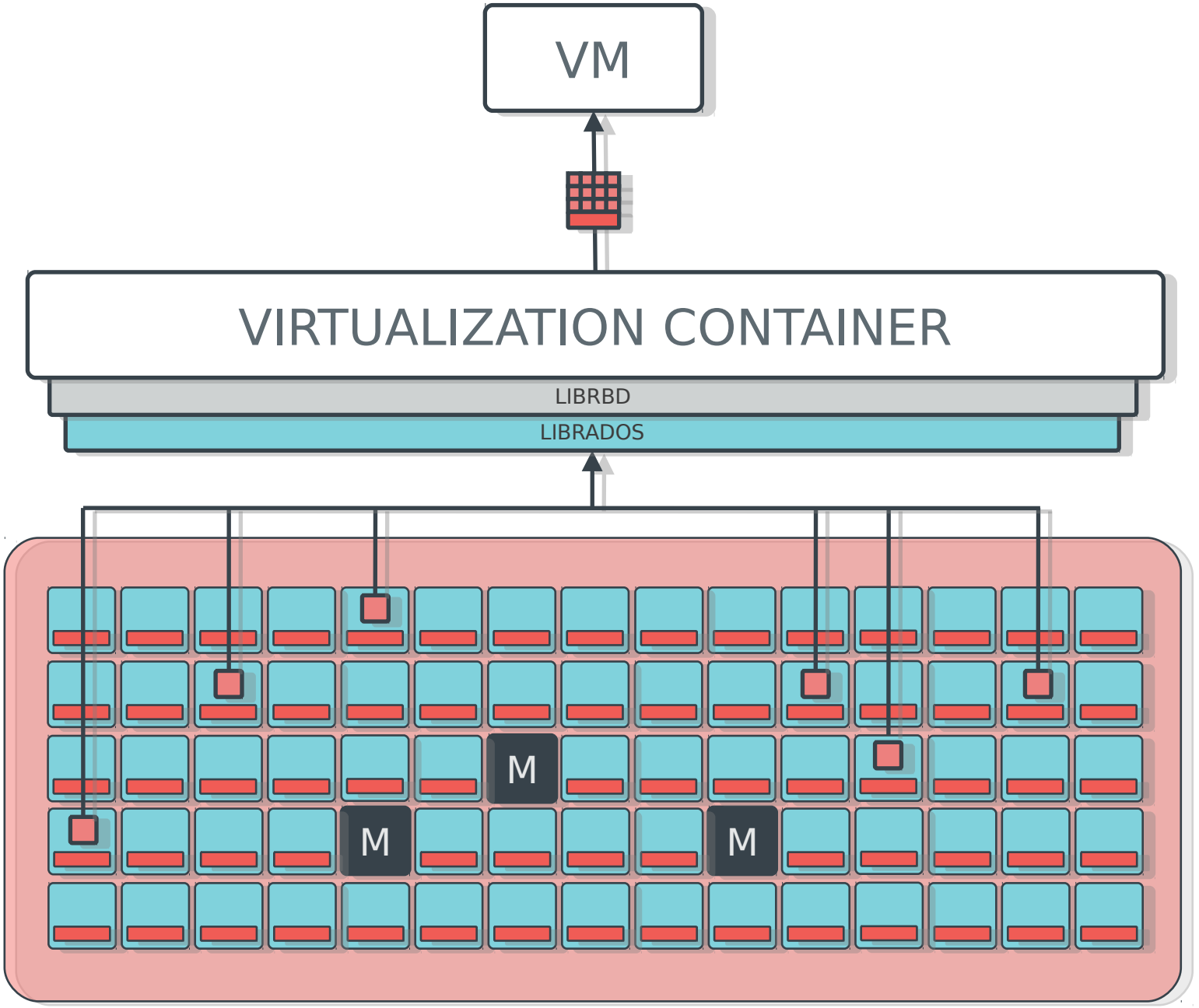

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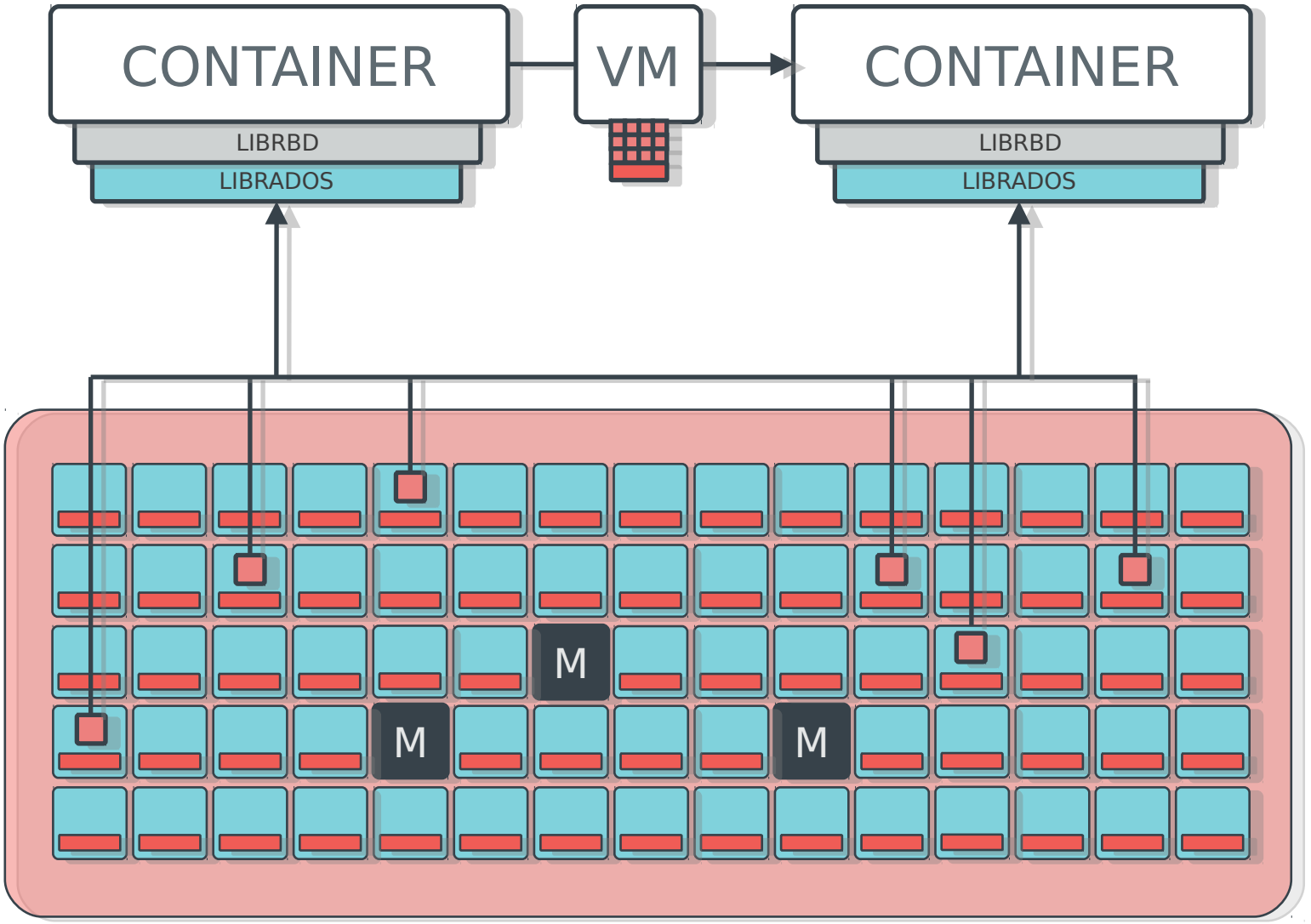
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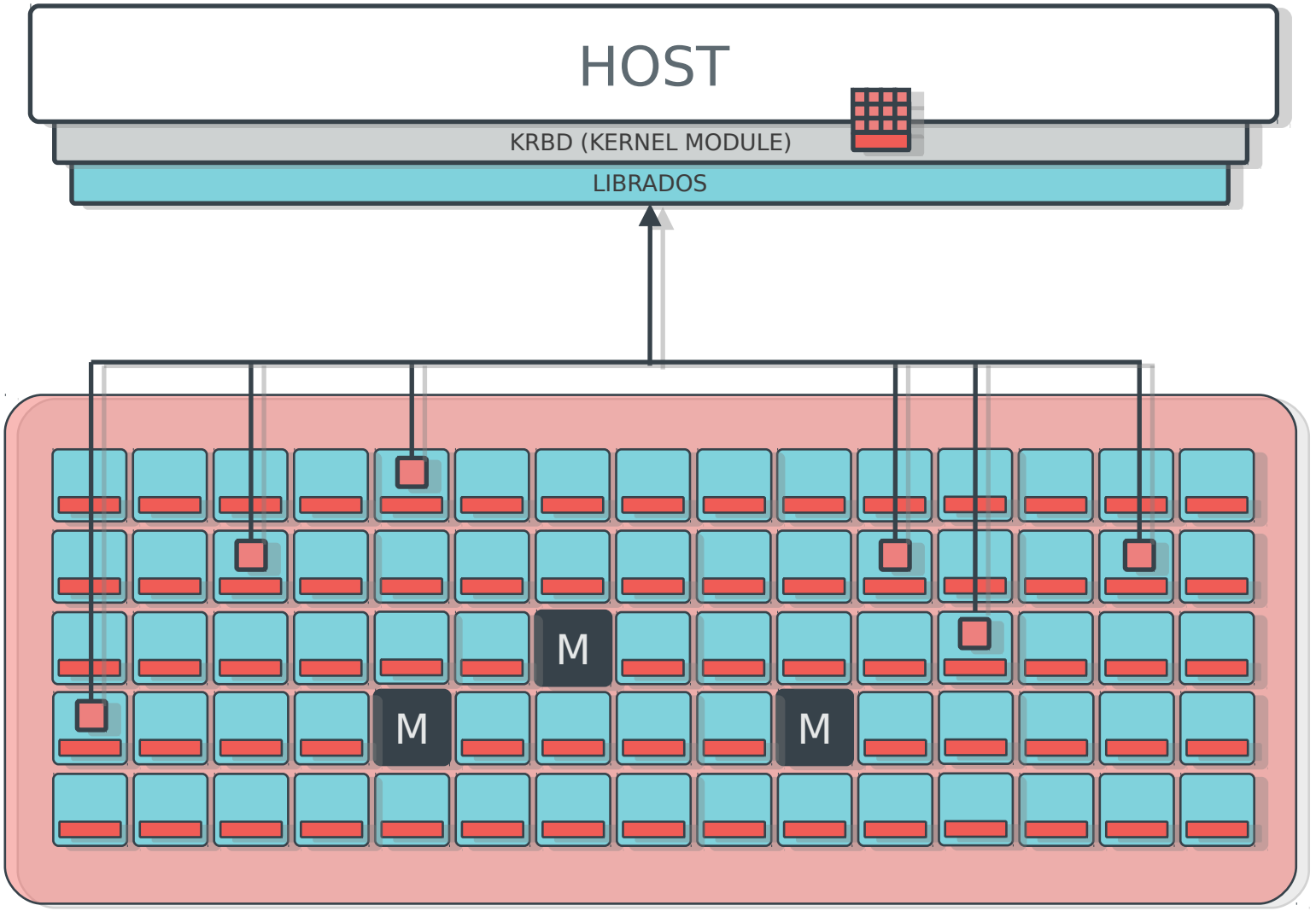

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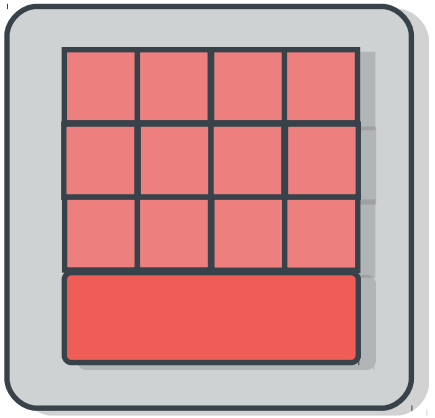

RADOS Block Device:

- Storage of virtual disks in RADOS
- Decouples VMs and containers
  - Live migration!
- Images are striped across the cluster
- Snapshots!
- Support in
  - Qemu/KVM
  - OpenStack, CloudStack
  - Mainline Linux kernel

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HOW DO YOU

SPIN UP

THOUSANDS OF VMs

INSTANTLY

AND

EFFICIENTLY?

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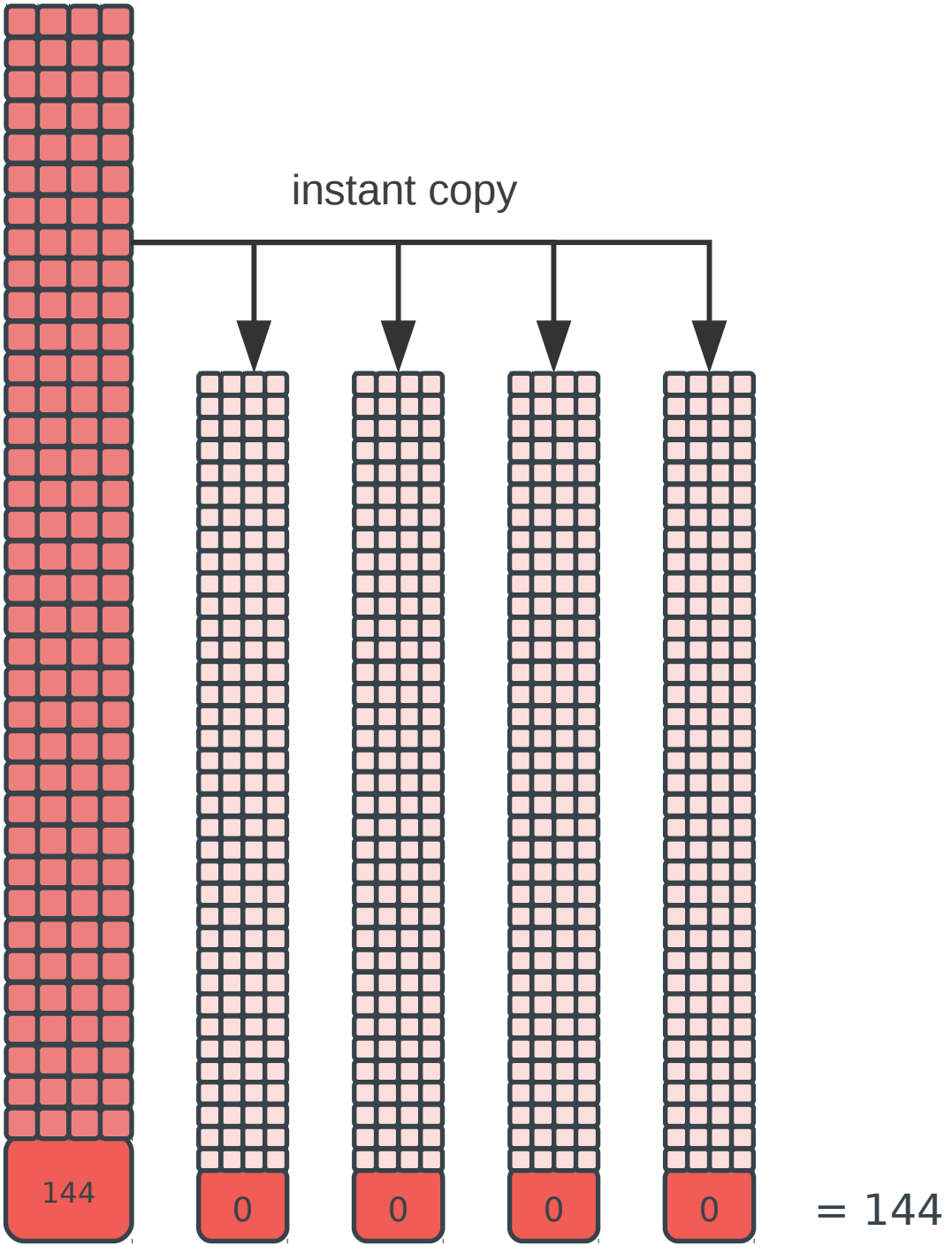

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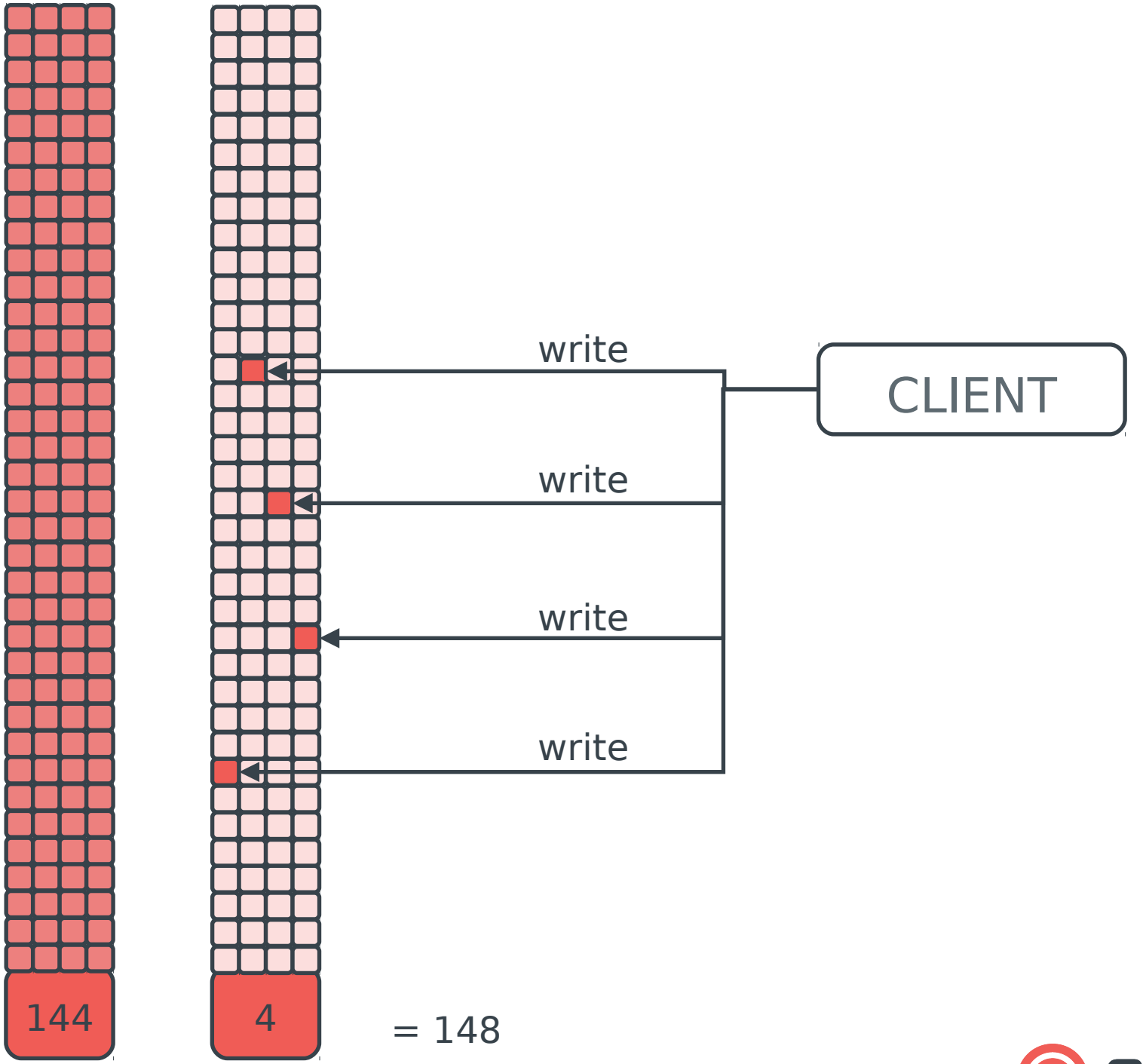

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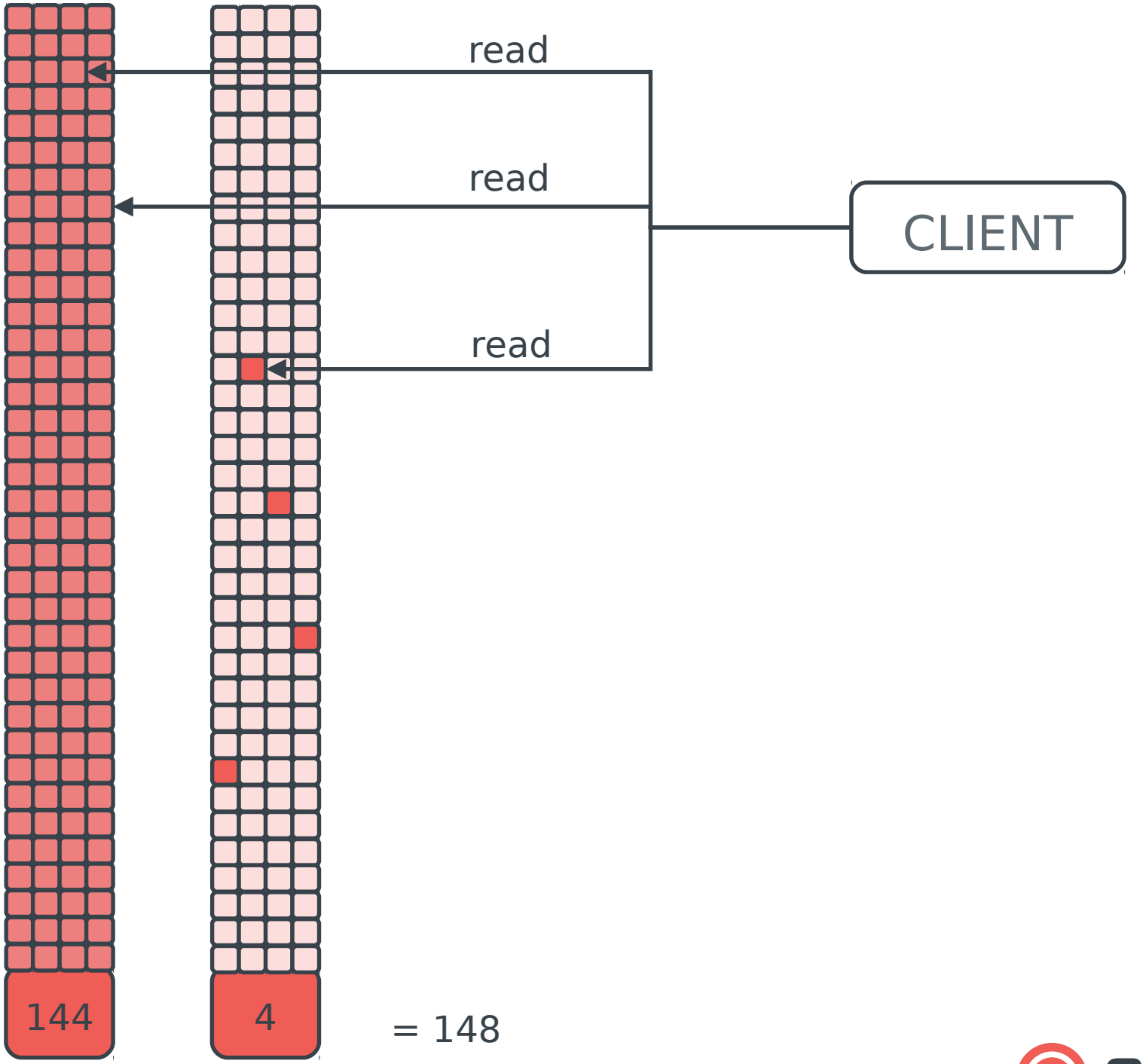

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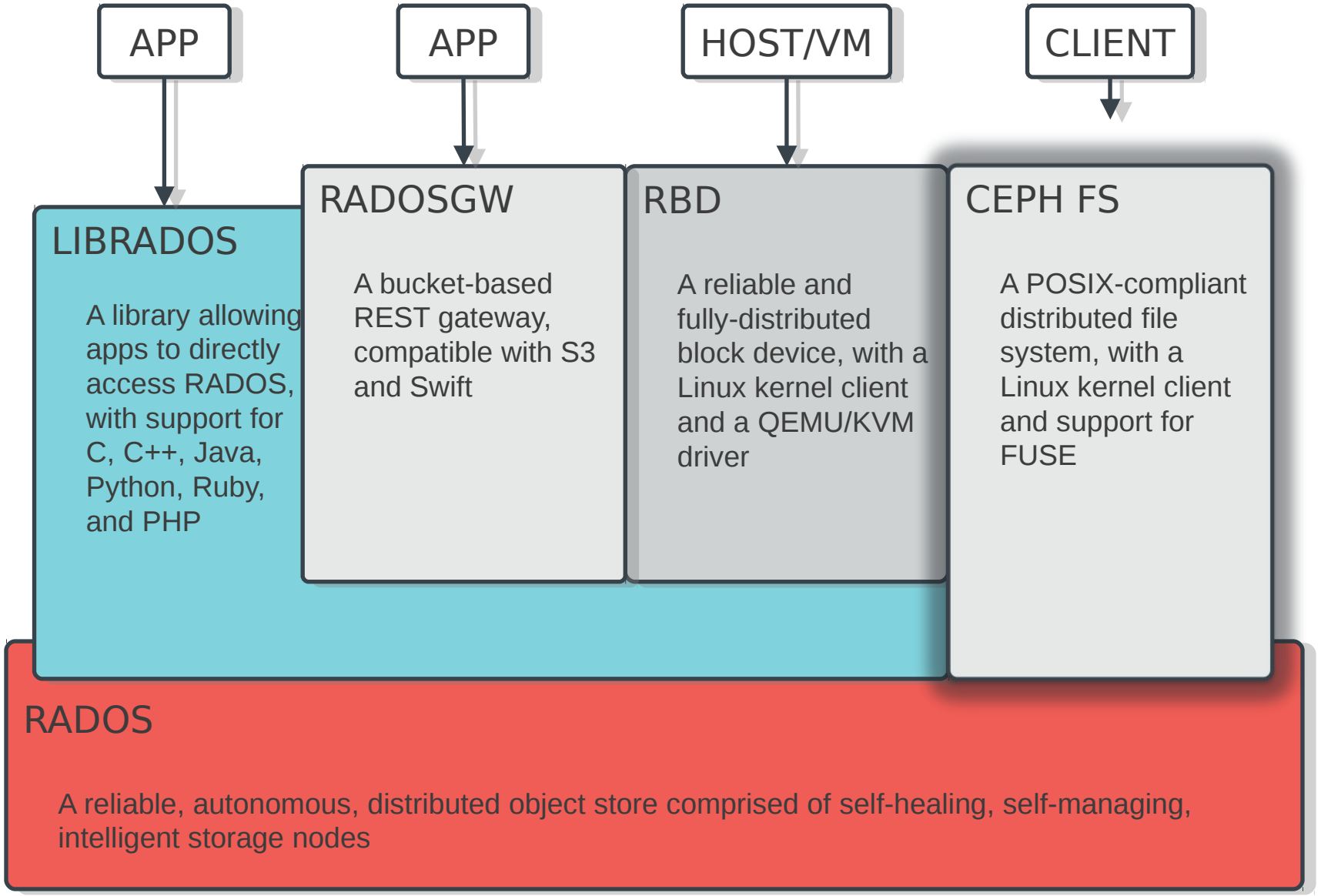
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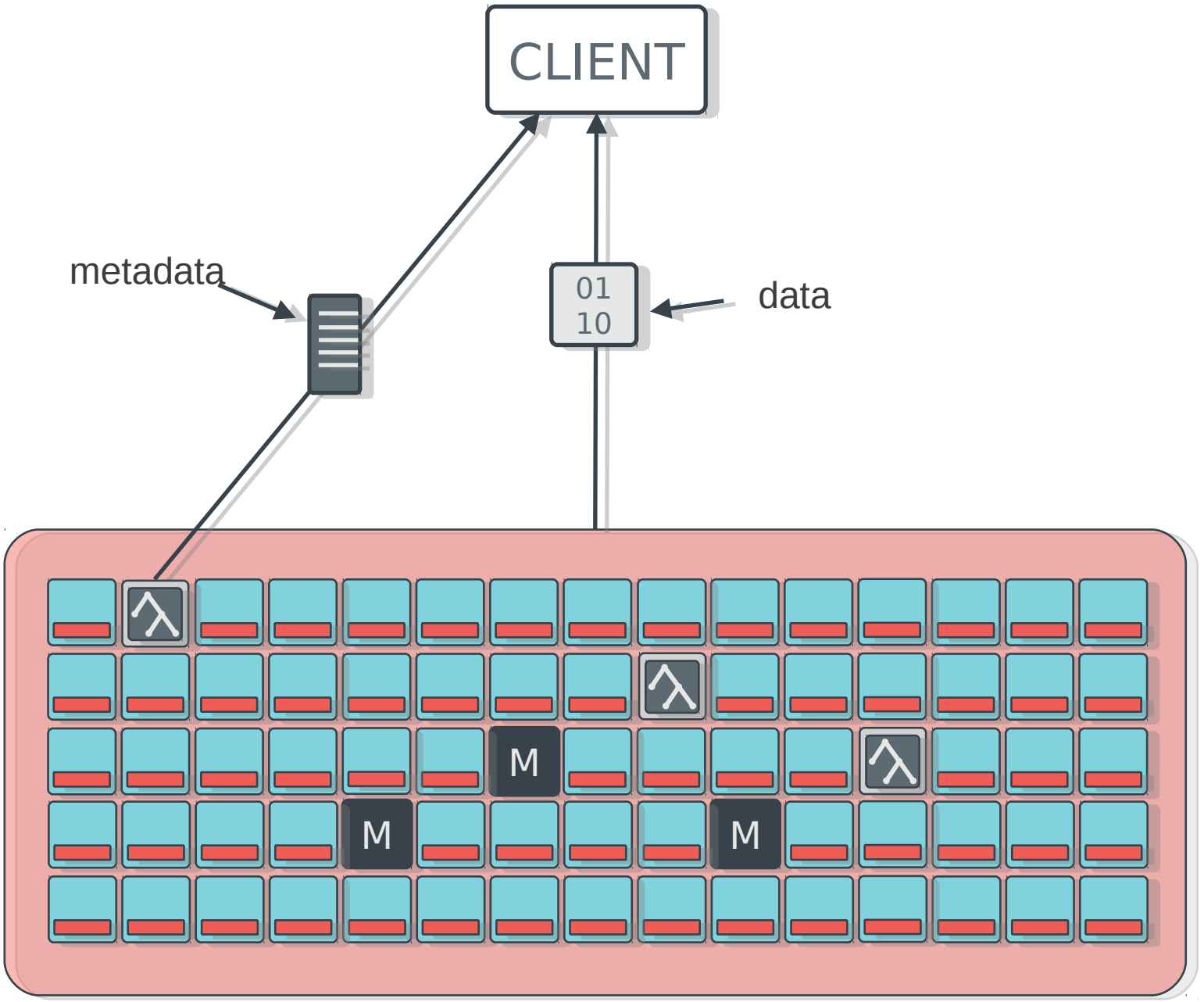

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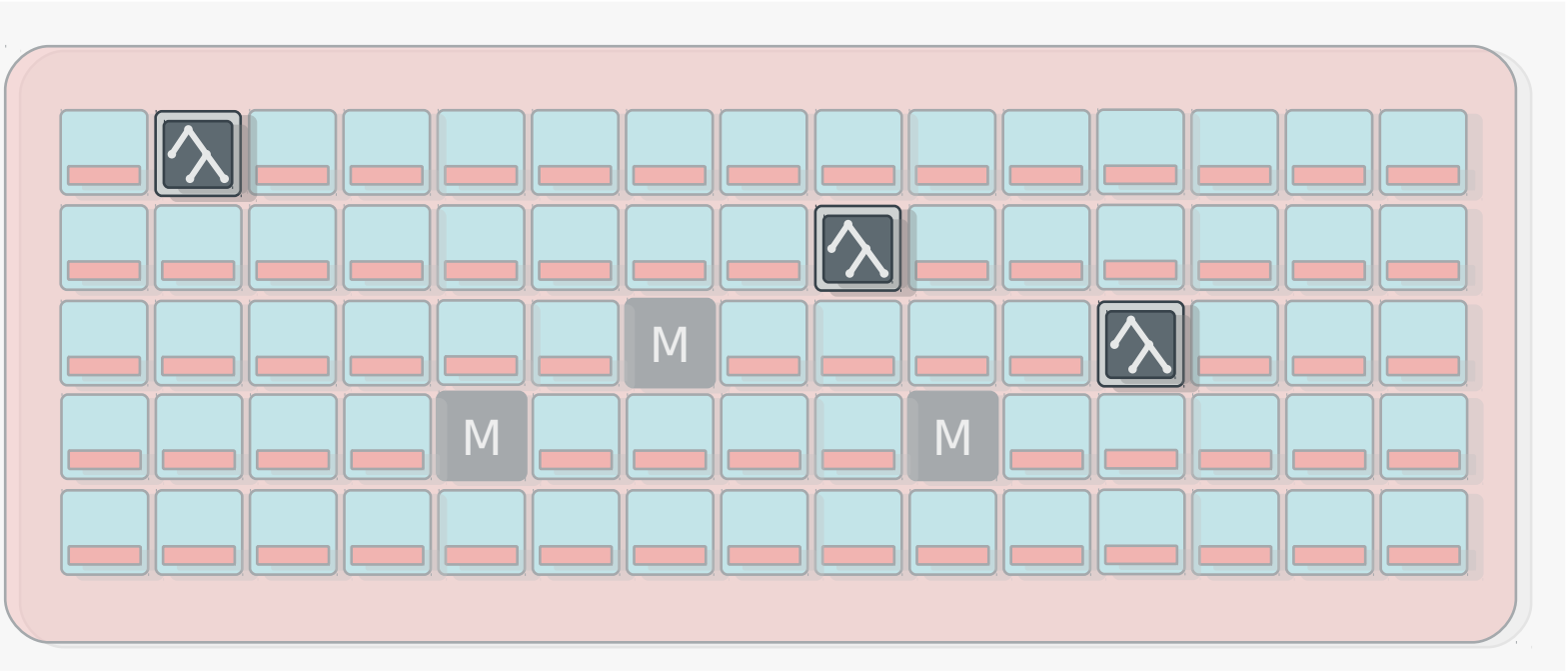

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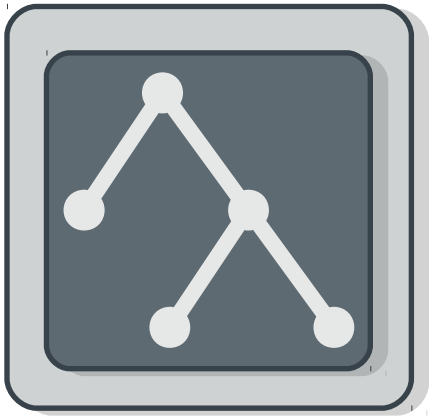
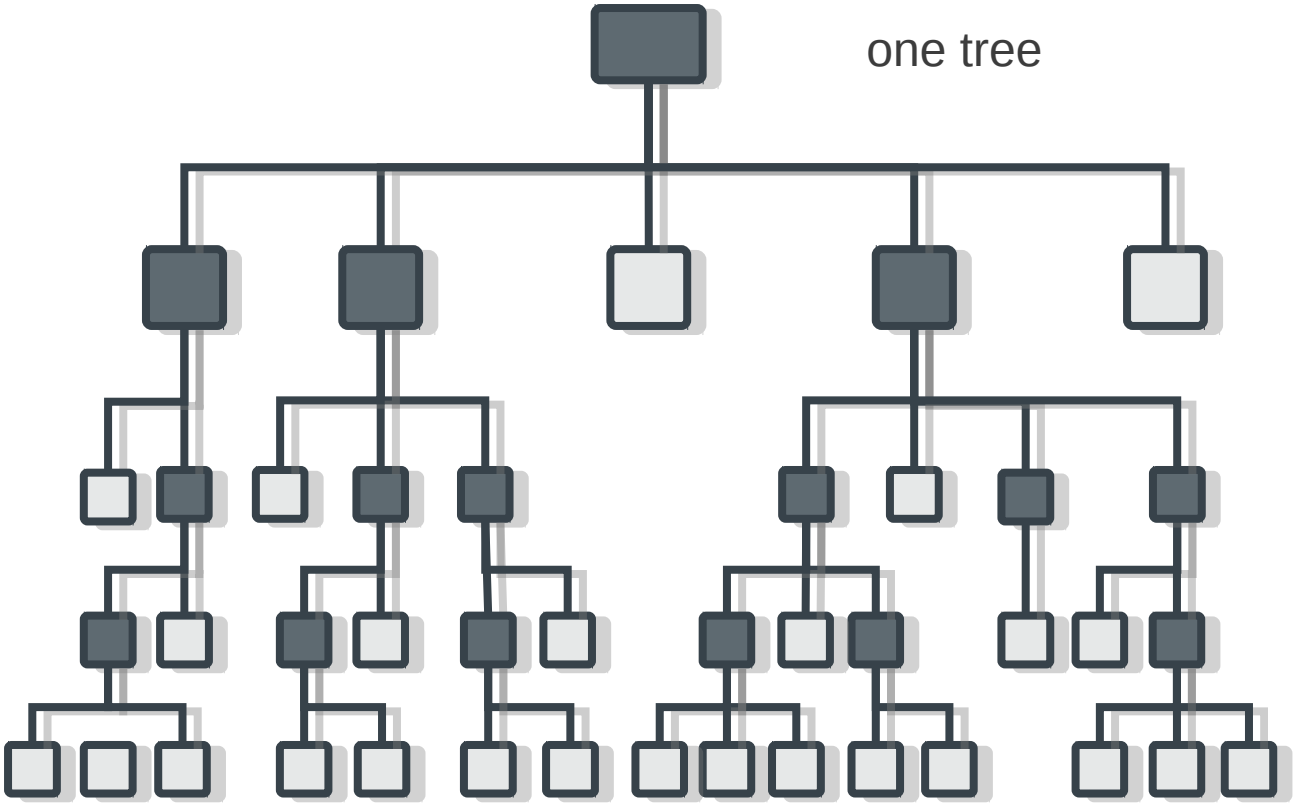
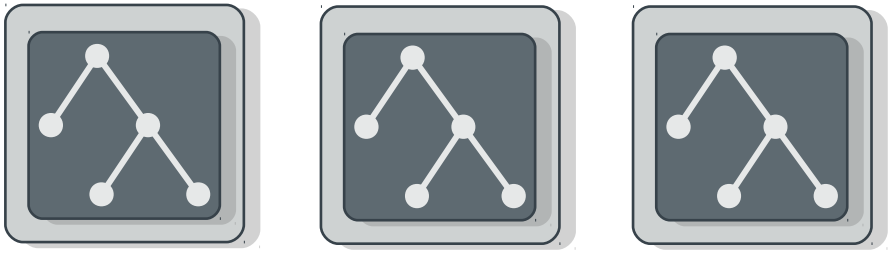


Metadata Server

- Manages metadata for a POSIX-compliant shared filesystem
  - Directory hierarchy
  - File metadata (owner, timestamps, mode, etc.)
- Stores metadata in RADOS
- Does not serve file data to clients
- Only required for shared filesystem



three metadata servers



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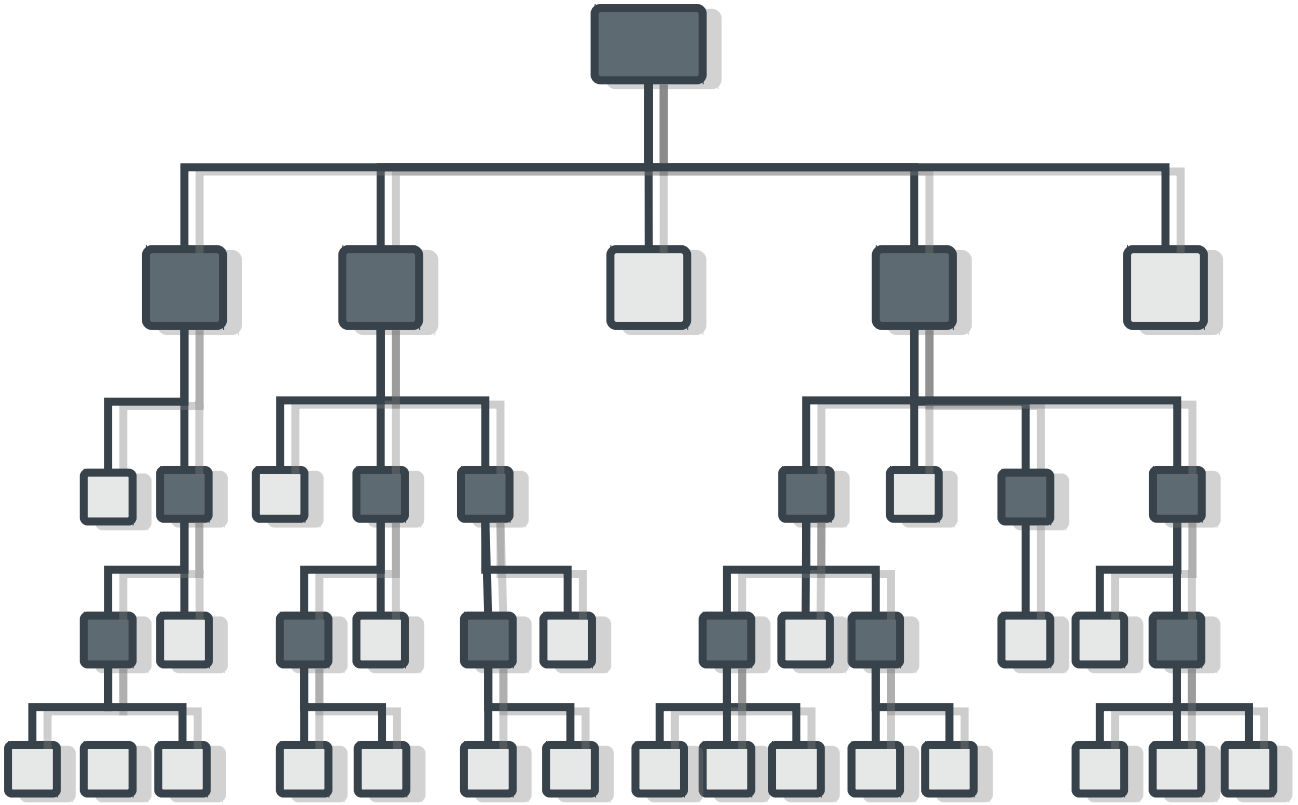

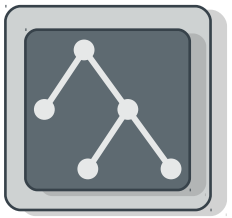

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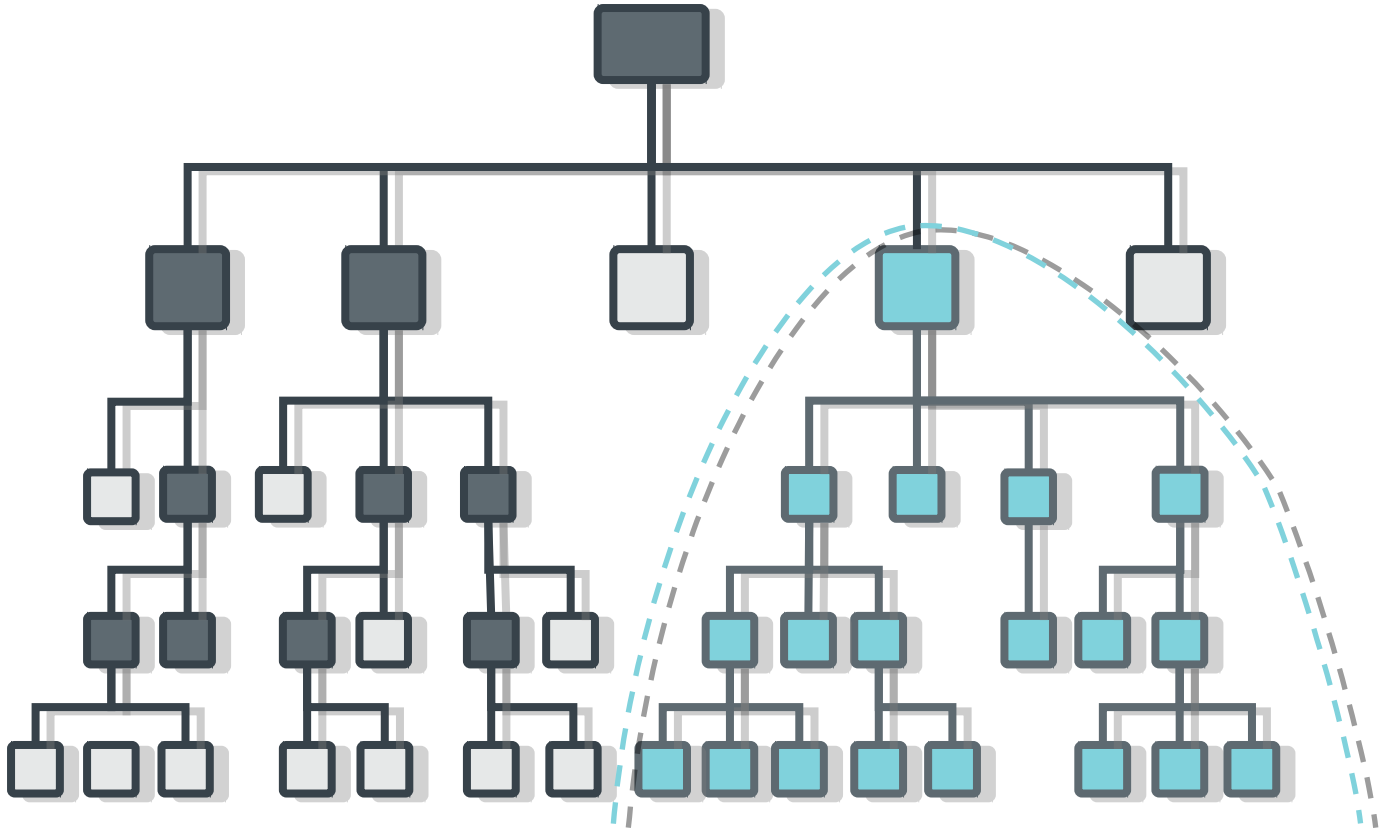

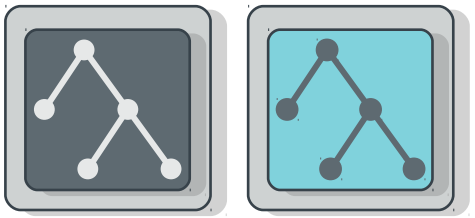

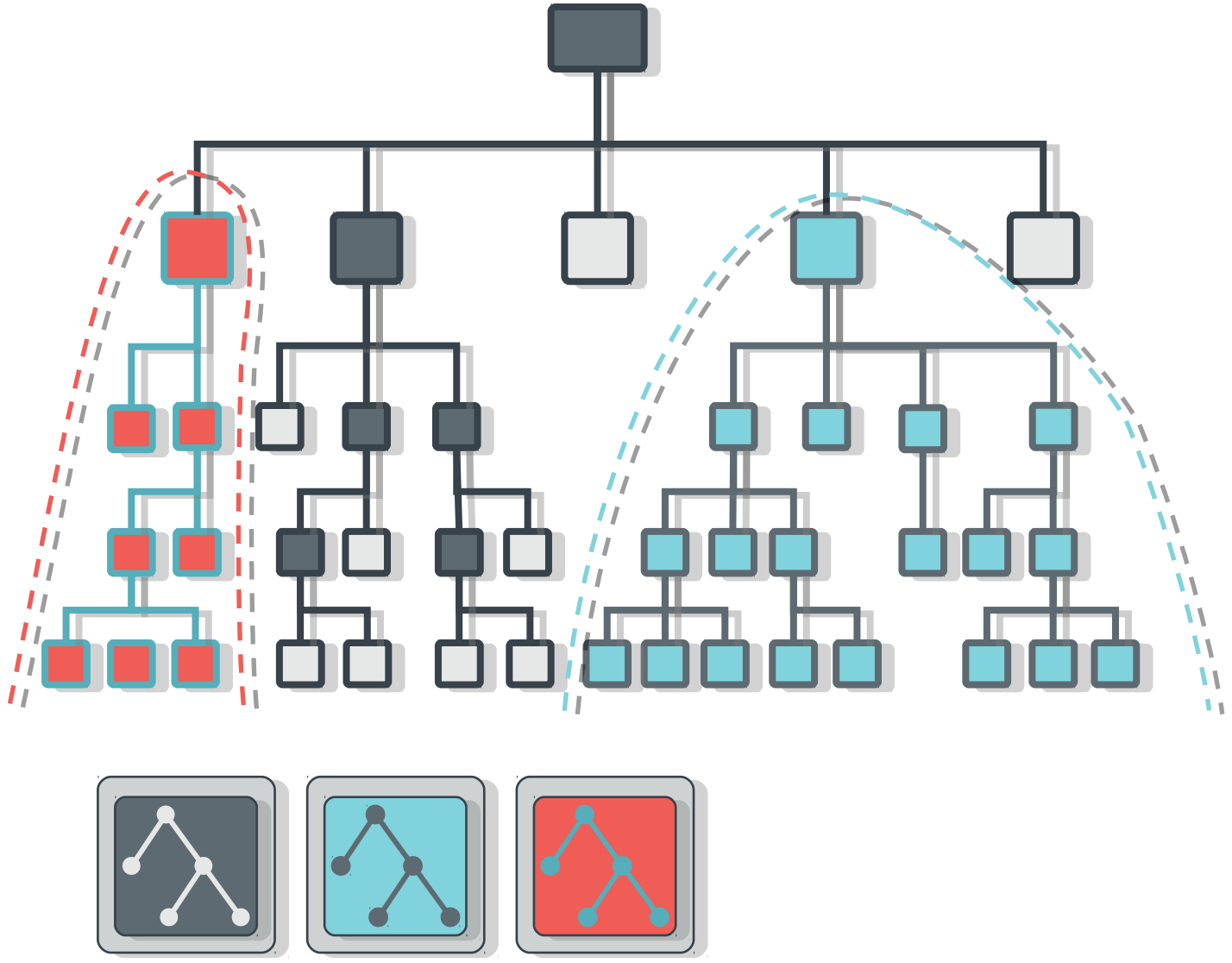

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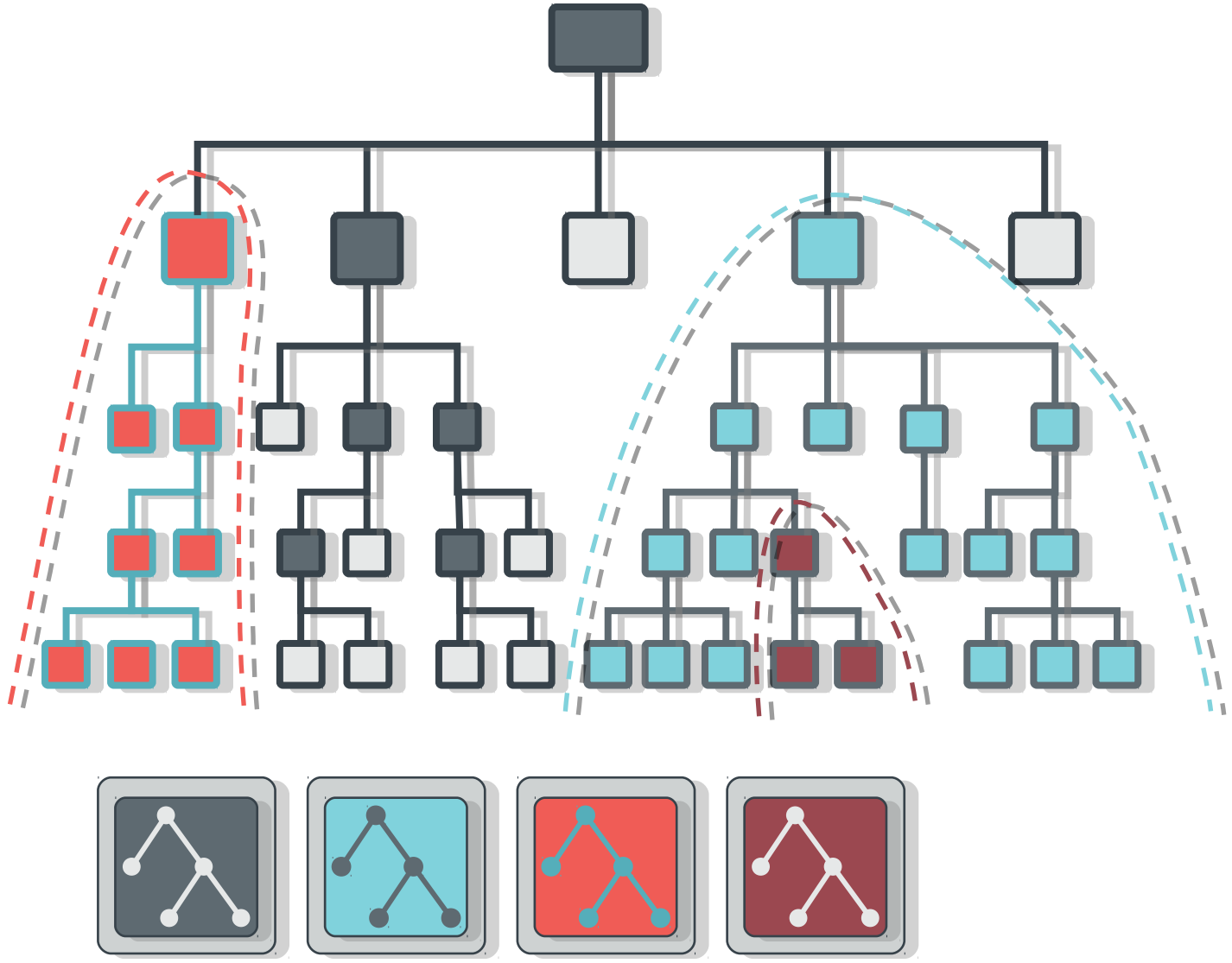

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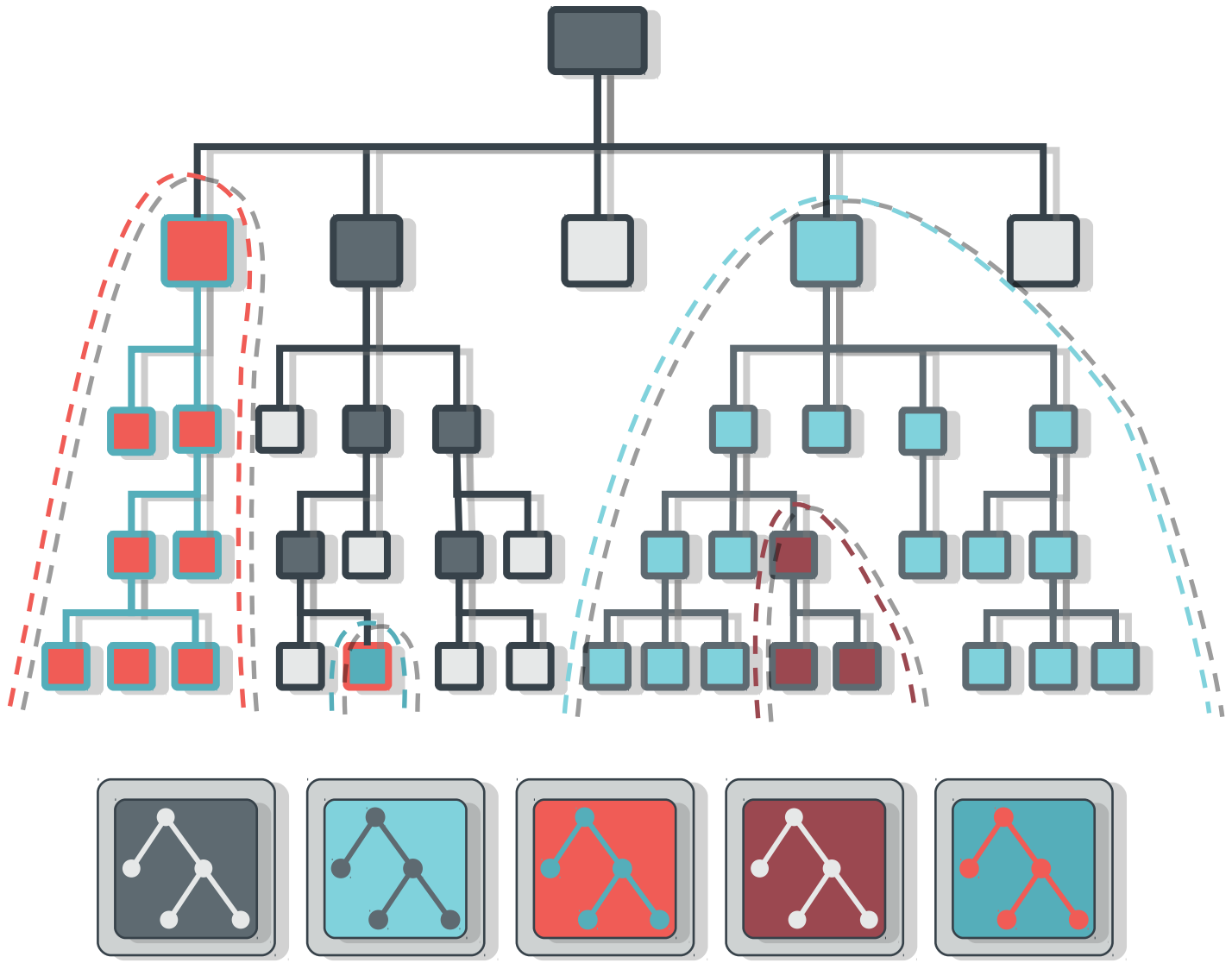

DYNAMIC SUBTREE PARTITIONING

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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
```

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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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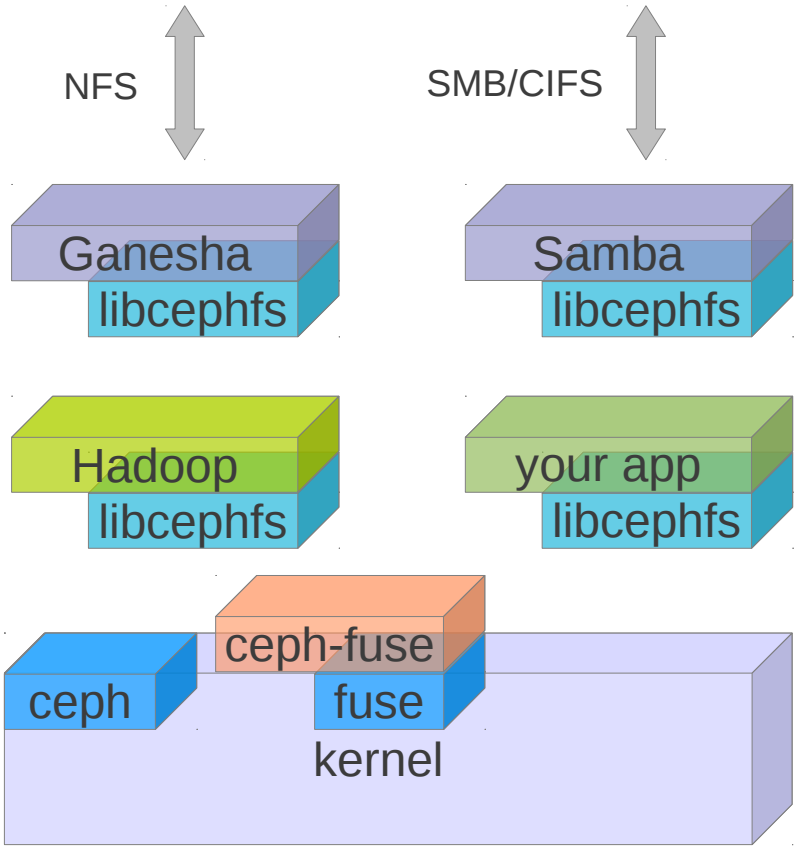
multiple protocols, implementations

- 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)



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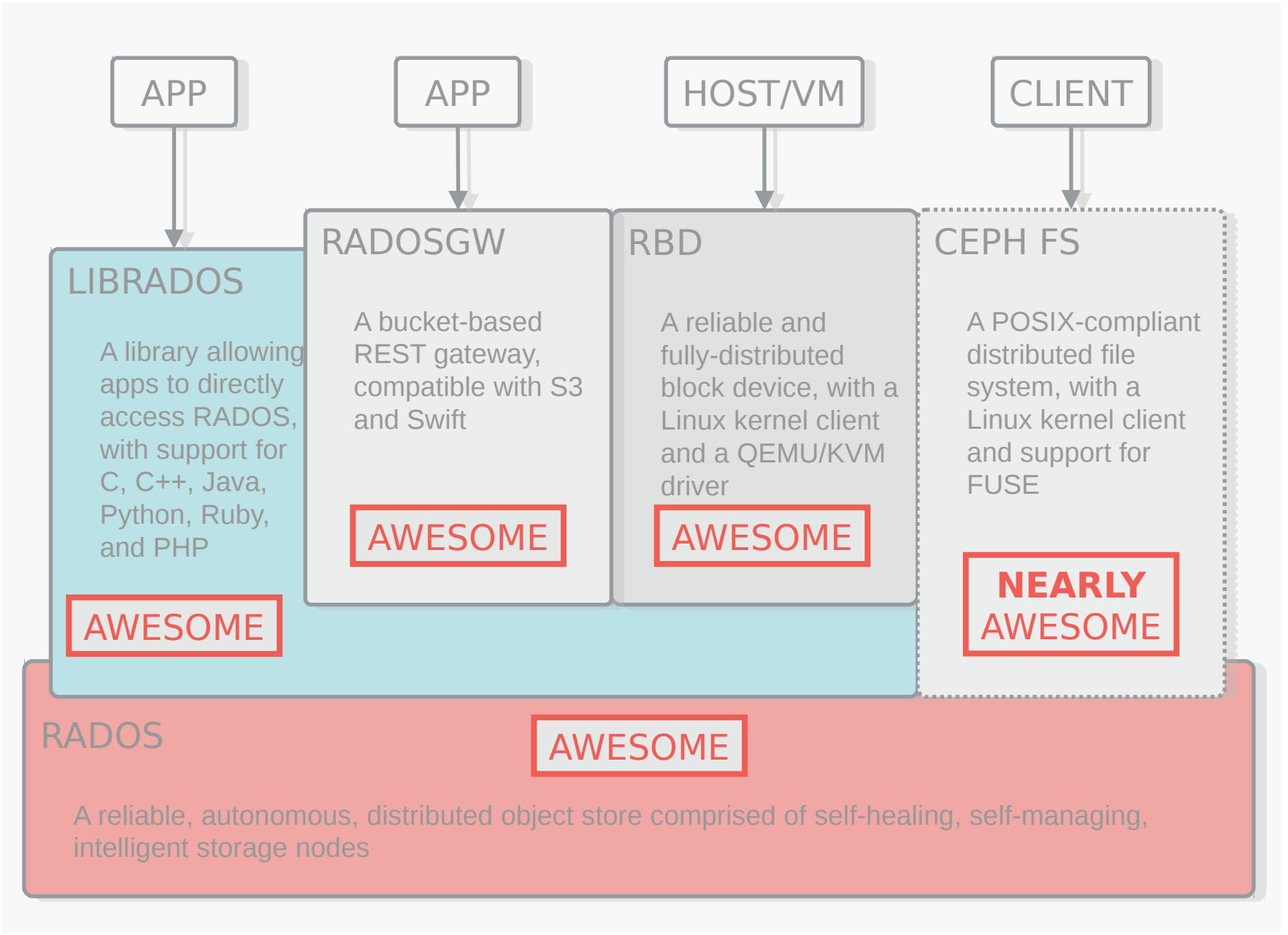
APP
APP
HOST/VM
CLIENT
LIBRADOS
A library allowing apps to directly access RADOS, with support for C, C++, Java, Python, Ruby, and PHP
AWESOME
RADOSGW
A bucket-based REST gateway, compatible with S3 and Swift
AWESOME
RBD
A reliable and fully-distributed block device, with a Linux kernel client and a 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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why we do this

- limited options for scalable open source storage
- proprietary solutions
  - expensive
  - don't scale (well or out)
  - marry hardware and software

- industry needs to change

who we are

- Ceph created at UC Santa Cruz (2007)
- supported by DreamHost (2008-2011)
- 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

BoF tonight @ 5:15

sage weil

sage@inktank.com

@liewegas

http://github.com/ceph

http://ceph.com/

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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

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