STORAGE DEVELOPER CONFERENCE
SDC 21
BY Developers FOR Developers

Virtual Conference
September 28-29, 2021

On Asymmetrical Distributed Storage Implementation

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Agenda

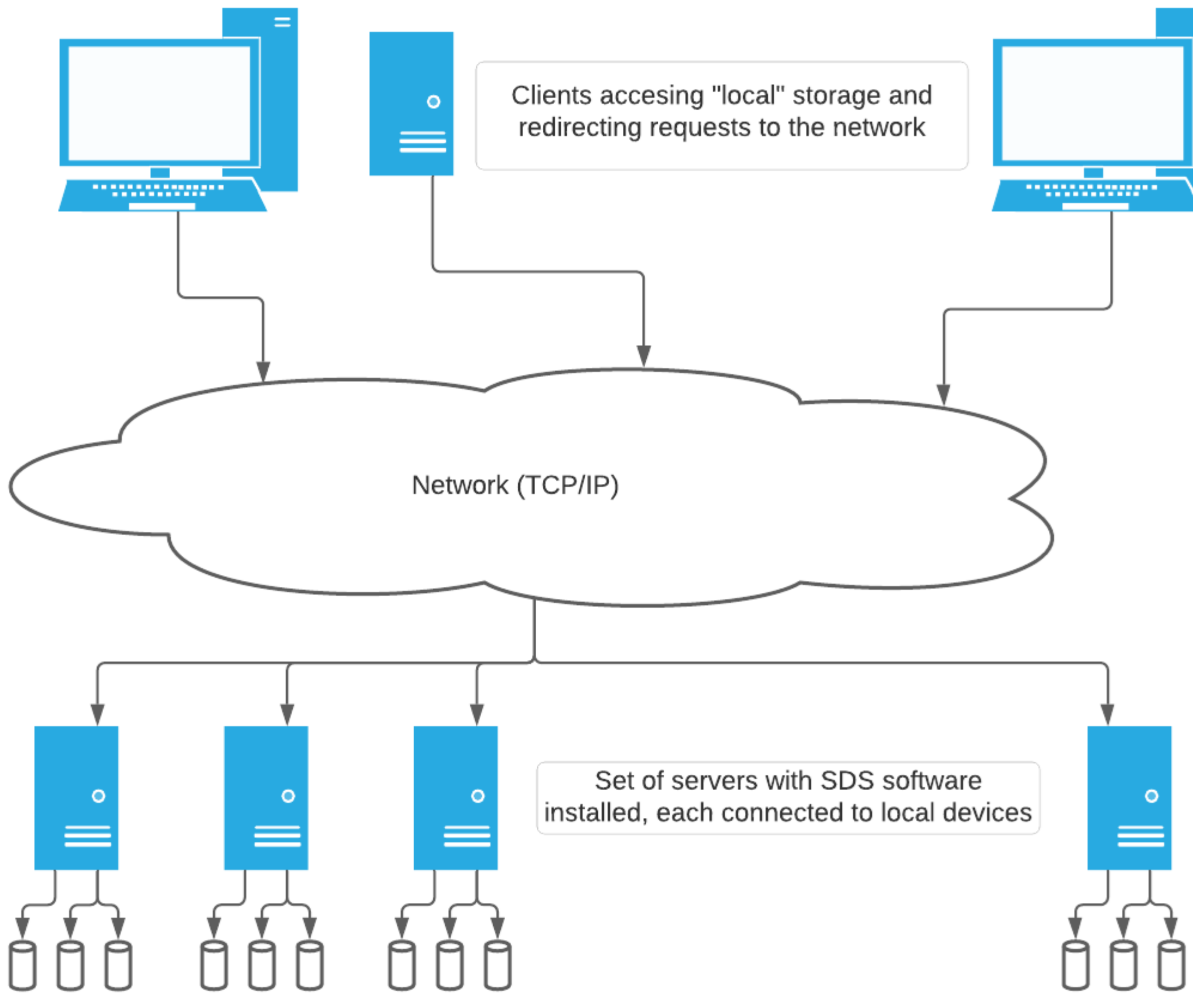
- Why symmetry is important in Software Defined Storage?
- Asymmetrical Software Defined Storage Architecture
- Ceph asymmetrical architecture

Software Defined Storage and Ceph

What is Software Defined Storage (SDS)

- Software only
- Run on commodity hardware:
  - Standard servers
  - Standard disks
  - Standard networking
- Distributed and Highly Available
- Elastic
  - Easy to expand
- Scalable

Distributed Software Defined Storage (SDS) Architecture

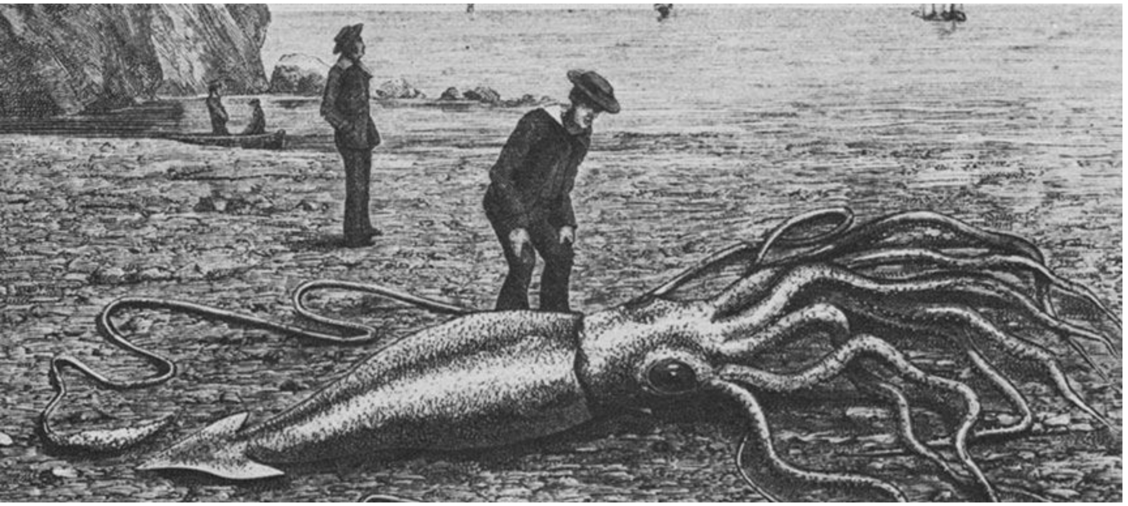

Clients accesing "local" storage and redirecting requests to the network
Network (TCP/IP)
Set of servers with SDS software installed, each connected to local devices

- Client access the storage remotely
- Data is distributed randomly across the devices
- Replicated data reads are performed from a single device and writes involve multiple devices

Ceph

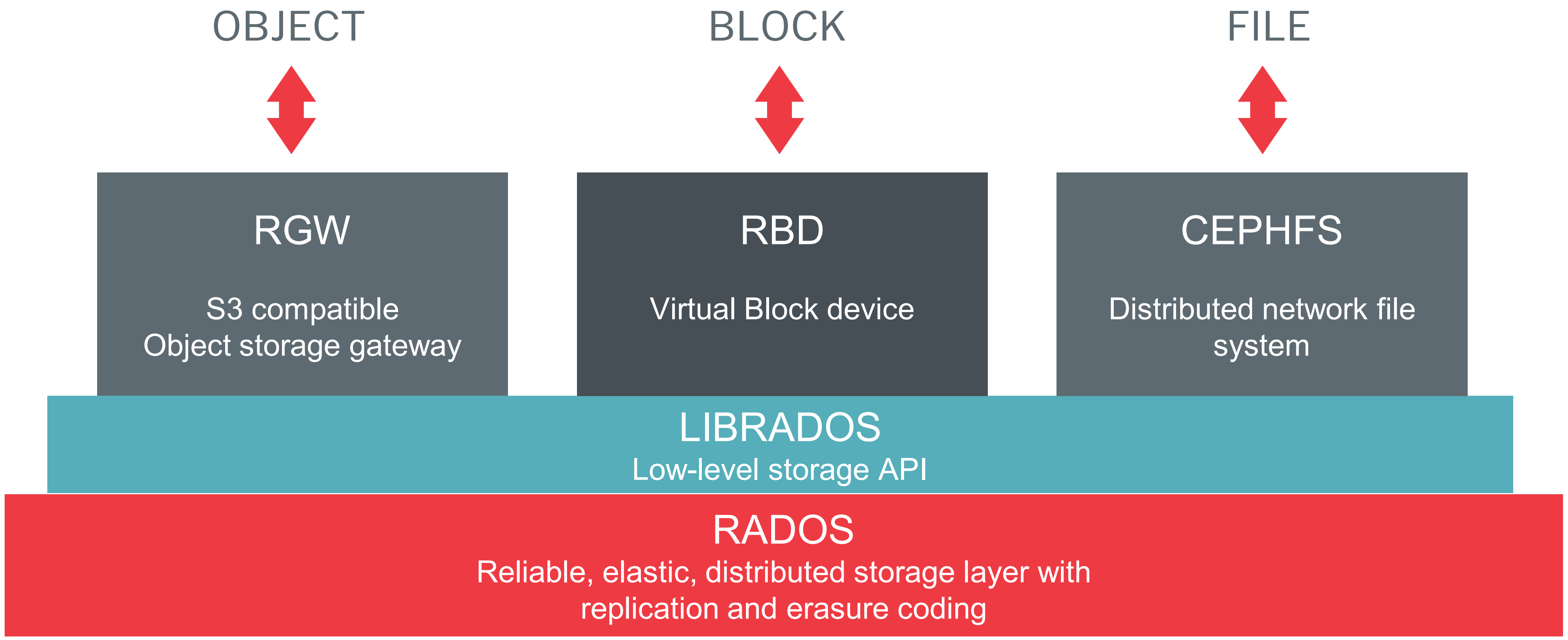
https://ceph.com/en/
https://github.com/ceph/ceph

Ceph



- Open source project
- Software Defined Storage
- Runs on commodity hardware
- Commodity servers
- IP networks
- HDDs, SSDs, NVMe, NV-DIMMs, …
- A single cluster can serve object, block, and file
- Highly Available and resiliency with self healing
- Scalable

Ceph Architecture


OBJECT
BLOCK
FILE
RGW
S3 compatible Object storage gateway
RBD
Virtual Block device
CEPHFS
Distributed network file system
LIBRADOS
Low-level storage API
RADOS
Reliable, elastic, distributed storage layer with replication and erasure coding

Ceph Rados Components

ceph-mon

Monitor

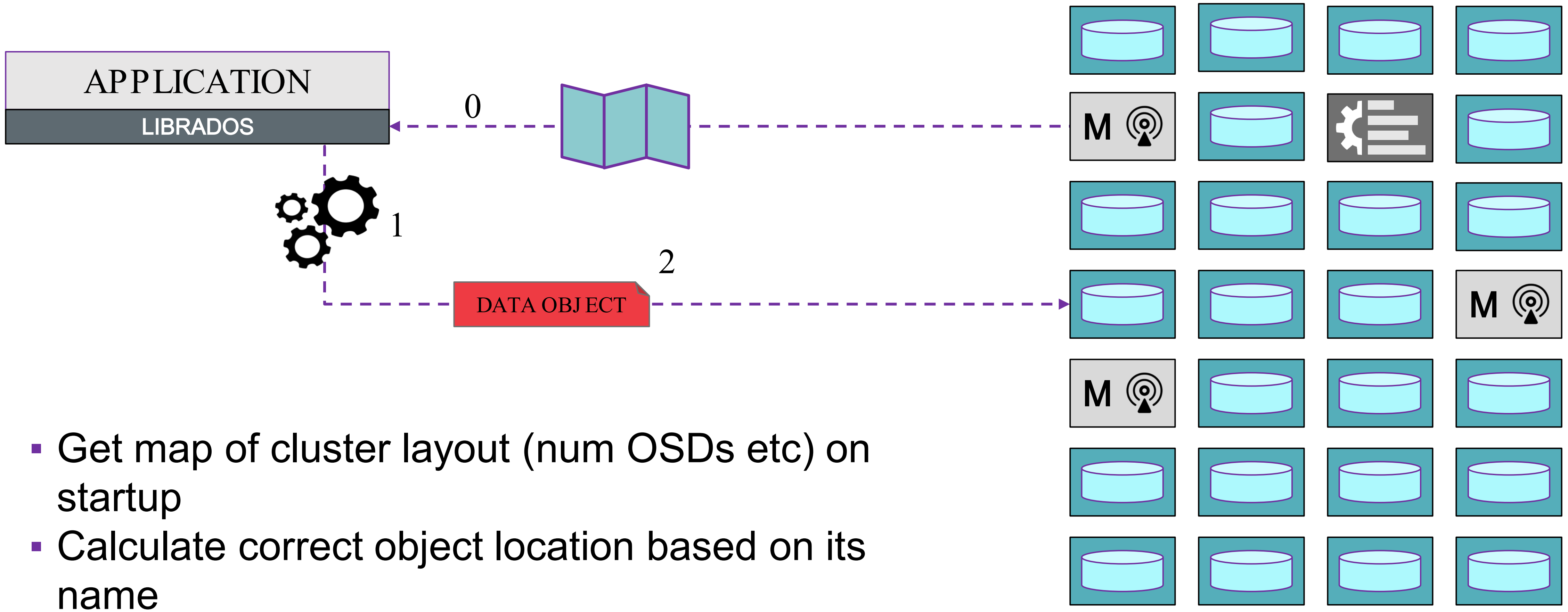
- Central authority for authentication, data placement, policy
- Coordination point for all other cluster components
- Protect critical cluster state with Paxos
- 3, 5 or 7 per cluster

ceph-osd

OSD (Object Storage Daemon)

- Stores data on an HDD or SSD
- Services client IO requests
- Cooperatively peers, replicates, rebalances data
- 10s-1000s per cluster

CRUSH: Calculated Placement



- Get map of cluster layout (num OSDs etc) on startup
- Calculate correct object location based on its name
- Read from or write to appropriate OSD

Why symmetry is important in Software Defined Storage?

Some math and physics ideas, and how they apply to Software Defined Storage

Symmetry in Software Defined Storage (SDS) Architecture

- Why limit to SDS?
  - Technically asymmetry is not limited to SDS
  - SDS have a variety of possible configuration, hardware and components they support
  - In the long run after several expansions they become asymmetric
  - The use cases we are focusing on are mainly applicable for SDS systems
    - Closed storage systems and appliances use similar ideas but refer to them differently

Device Symmetry

- Performance
  - IOPS/Throughput and latency
- Technology
  - Media (HDD vs SSD)
  - Protocol (SATA vs NVMe)
- Load
- Size
- Fill rate
  - The devices should be full in the same percentage (all devices should be X% full at any given time), when a single device is 100% full the system becomes 100% full

Weakest Link in the Chain Effect

- Take a system with N devices, each with M IOPS
  - Total max performance: NxM IOPS
  - A system with 100 devices with 200 IOPs will produce 20,000 IOPS
- Under some circumstances
  - Many simultaneous clients (more than devices)
  - Each work in sync mode (request, wait for response, request, etc)
  - As a result: system is fully loaded
- If one device has less performance (O < M IOPS)
  - The system performance after some time will reduce to NxO IOPS
    - As if all the devices had O IOPs
    - A system with 99 devices of 200 IOPS and one device of 100 IOPS will produce 10,000 IOPS

Advantages of Symmetry

- Easier to manage capacity
- Easier to manage performance
- Simpler to configure
- Easier to validate

Symmetrical Software Defined Storage

- So we want symmetrical system!
- Not always…

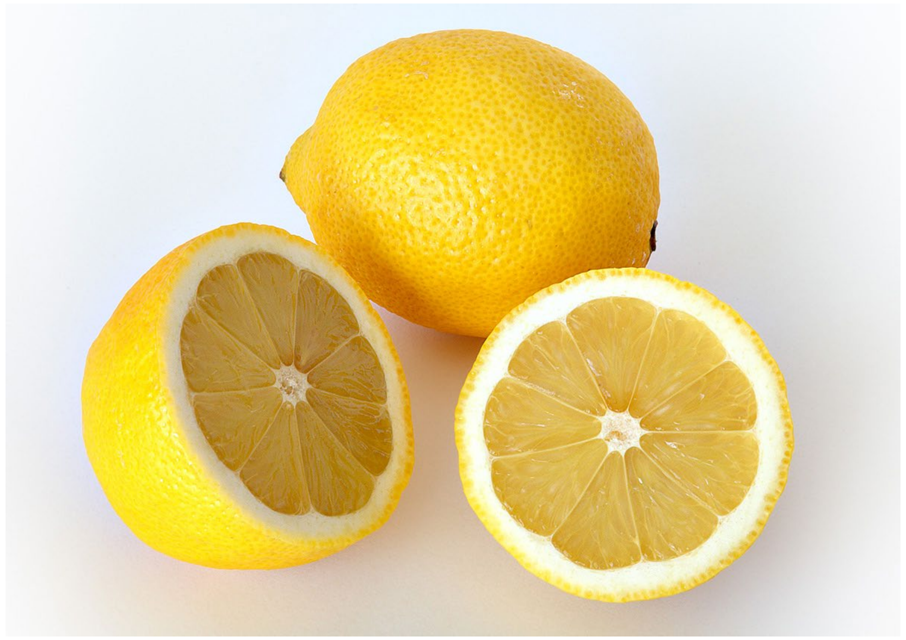
- Can we break the assumptions is such a way that we can gain from breaking the symmetry?

- **Yes!!!**

Asymmetrical Software Defined Storage Systems

So Why Consider Asymmetry?

- Follow the money...
  - Cloud economics
  - When life gives you lemons, make lemonade...
- Reality
  - Gradual upgrade/migration


By André Karwath aka Aka - Own work, CC BY-SA 2.5,

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Breaking the Symmetry

- Is it worth it?
  - Reducing cost
  - Increase reliability
- Functional break
  - Get the most out of it

Cost Analysis (AWS - Aug 2021)

- Comparing m5 and i3en instances - not apples to apples!

Type	vCPU	Memory	Network BW	Storage	15 TB $/month	IOPs / max BW	Price / month
m5.8xlarge	32	128 GiB	10 Gb/s	EBS only	**$1200** - $1875+	45 K / 1.5 GBs[1]	$1,106
i3en.6xlarge	24	192 GiB	25 Gb/s	2x7500 NVMe SSD	0 (included)	500 K / 4 GBs[1]	$1,953

[1] - Note the network bandwidth may be the bottleneck here

- Cost comparison
  - For similar bandwidth we need 2 m5.8xl instances for every i3en.6xl instance
    - $3,412 / month (2 instances + 15TB EBS gp2) relative to $1,953 / month
  - For a similar price EBS based system has much lower bandwidth.
- Can we combine options and gain price and performance together?

Performance Analysis (AWS - Aug 2021)

- Fact summary
  - Local storage has 10x 4KB IOPs and ~3x the bandwidth
  - Local storage is cheaper (for consistent high load system)
  - Local storage reliability may not be in our control
  - EBS storage is much more reliable than a local storage.
- Replicated storage facts
  - Read is served by a single device
  - Write is served by multiple devices

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- Replicated storage facts
  - Read is served by a single device
  - Write is served by multiple devices
- Let the cheaper, faster but less reliable devices serve all the reads

What is the Gain

- Reads are faster
  - Faster latency and bandwidth for most workloads
- Write bandwidth is higher
  - Bandwidth of the slower storage devices is not used for read IOs
  - No change to the latency
- Points to watch
  - Network bandwidth
  - Workload Read/Write distribution (%)

More Options

- Replica count
  - Very reliable slower device (99.999%)
    - We may use 2 replications, one on the local storage and one on cloud storage
  - Protection from AZ failure
    - We may replicate to 2 instances of cloud storage in 2 AZs + one local storage replication on a third zone
  - Consider the data importance
    - Not all data is equal - in some cases we may compromise durability over cost
    - Especially if we can reconstruct the data easily
- We have many options to balance cost, performance and reliability

Implementing Asymmetry in Ceph

- Primary affinity - not good enough
  - The primary will always be a local device, but not guarantee that the others will never be local devices
- Custom CRUSH rule (based on device class)
  - A bit more complex, but effective

Sample Asymmetric CRUSH Rule

```
rule local_with_EBS {
  id 3
  type replicated
  min_size 1
  max_size 10
  step take default class local
  step chooseleaf firstn 1 type host
  step emit
  step take default class EBS
  step chooseleaf firstn 0 type host
  step emit
}
```

A Different View

- So what do we have here
  - For <u>every</u> piece of data we have
  - One copy on a fast storage, used by all read IOs
    - One or more copies on a slower storage used mainly for write IOs
  - So it looks just like ...

A Different View

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- Full size read NVMe flash cache for the entire storage pool

Other use cases

- Phased upgrade of the system
  - Assuming you have a large system and you want to add capacity
    - What if you can't get the same devices as in your current system?
    - What if you want to upgrade technology (from older SSD to NVMe-SSD) but not at once?

Conclusions

- In some cases symmetrical storage systems are optimal
- In some cases requiring full symmetry is not feasible
- When symmetry can't be forced, we can still make the best of the configuration we have
  - Split the system into symmetrical pools
  - Combine different devices into the same pool, but route more load (reads/writes) to the faster devices and less load (writes only) to the slower devices
  - Some middle solution that plays with the load between the devices but is not all or nothing for reads

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