THE STORAGE CRASHCOURSE

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You will see the asterisk a lot

I will generalize and simplify some concepts. Things will be technically wrong, but still useful to understand the rough concept

K8S STORAGE RESOURCE MODEL

Kubernetes does not contain a baked in solution for storage, only interfaces to integrate with external storage providers

instead it allows you to bring your own via the *Container Storage Interface*

PERSISTENT VOLUME CLAIM

- Namespaced
- Contains a volume “request”
- Attached to pod
- The resource you will be working with most

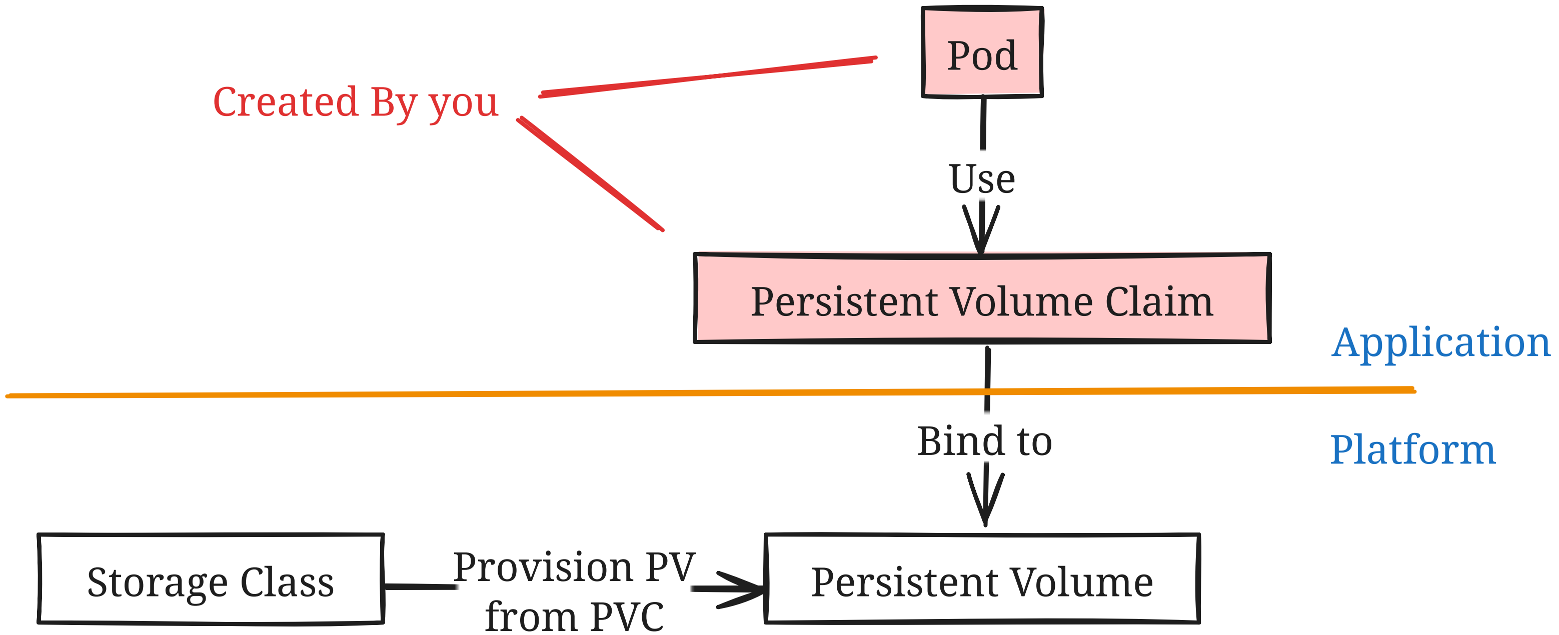
PERSISTENT VOLUME

- Reference to the real volume on the storage platform
- Contains implementation details for the used storage driver

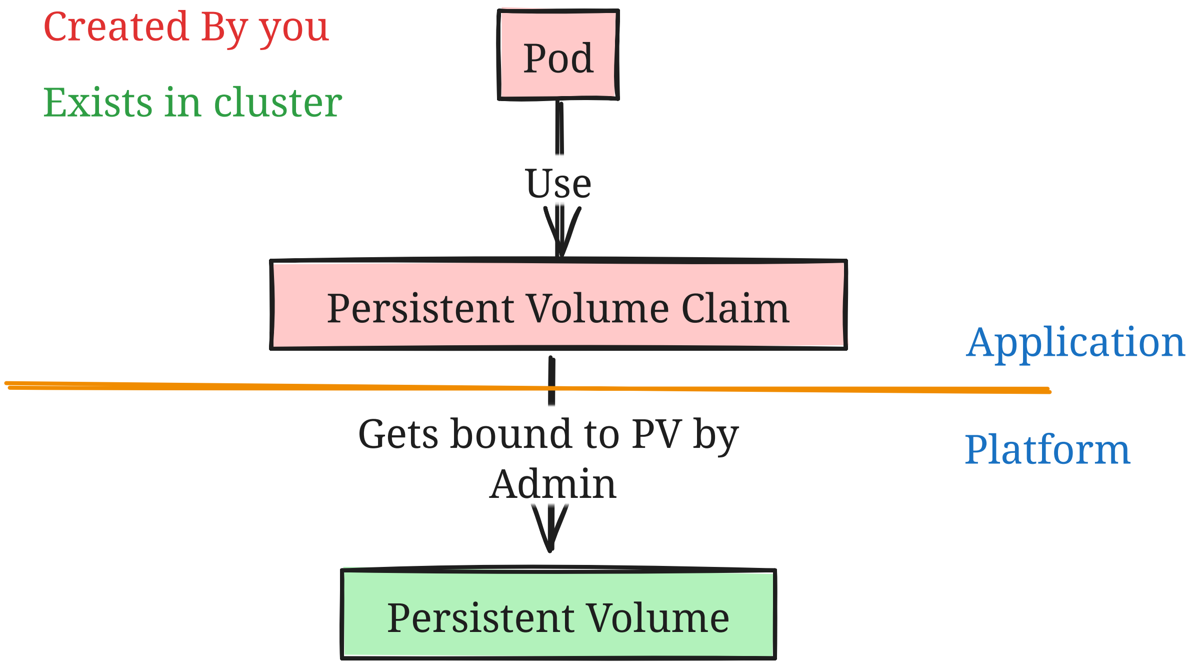
STORAGE CLASS (SC):

- Settings for dynamically provisioning a PV from a PVC

DYNAMIC PROVISIONING



STATIC PROVISIONING



ATTACHMENT SEMANTICS

- ReadWriteOnce / RWO - Attached only at one Node at a time
- ReadWriteMany / RWX - Attached to multiple Nodes at a time
- ReadOnlyMany / ROX - Attached to multiple Nodes at a time (ReadOnly)
- ReadWriteOncePod / RWOP - Attached only at one **Pod** at a time

TYPES OF STORAGE PROVIDERS

- Cloud Provider Integrations
  - AWS EBS+EFS, Azure Files
- Connection to external storage solutions
  - Pure Storage, SMB, VSphere, JuiceFS
- Storage Operators
  - Rook Ceph, Longhorn
- Special use case
  - Local Path, Secrets CSI Driver

List of known ones: https://kubernetes-csi.github.io/docs/drivers.html

WHAT IS CSI?

CSI DRIVERS?

- Maps storage solution to Kubernetes
- Handles volume lifecycle
    - Provisioning, Attachment, Mounting, Deleting
- Maintained by storage solution provider*
- Run as Pods in Kubernetes*
- Installed via Helm Charts/K8s manifests or comes with your cluster

VERY SHORT HISTORY OF KUBERNETES STORAGE

- In the beginning: in-tree Storage Providers
- Since 1.2: FlexVolume for out-of-tree providers
- Since 1.9: Container Storage Interface introduced
- 1.13: CSI is GA
- Since around 1.21: in-tree Storage Providers deprecation
- Since 1.23: FlexVolume deprecated

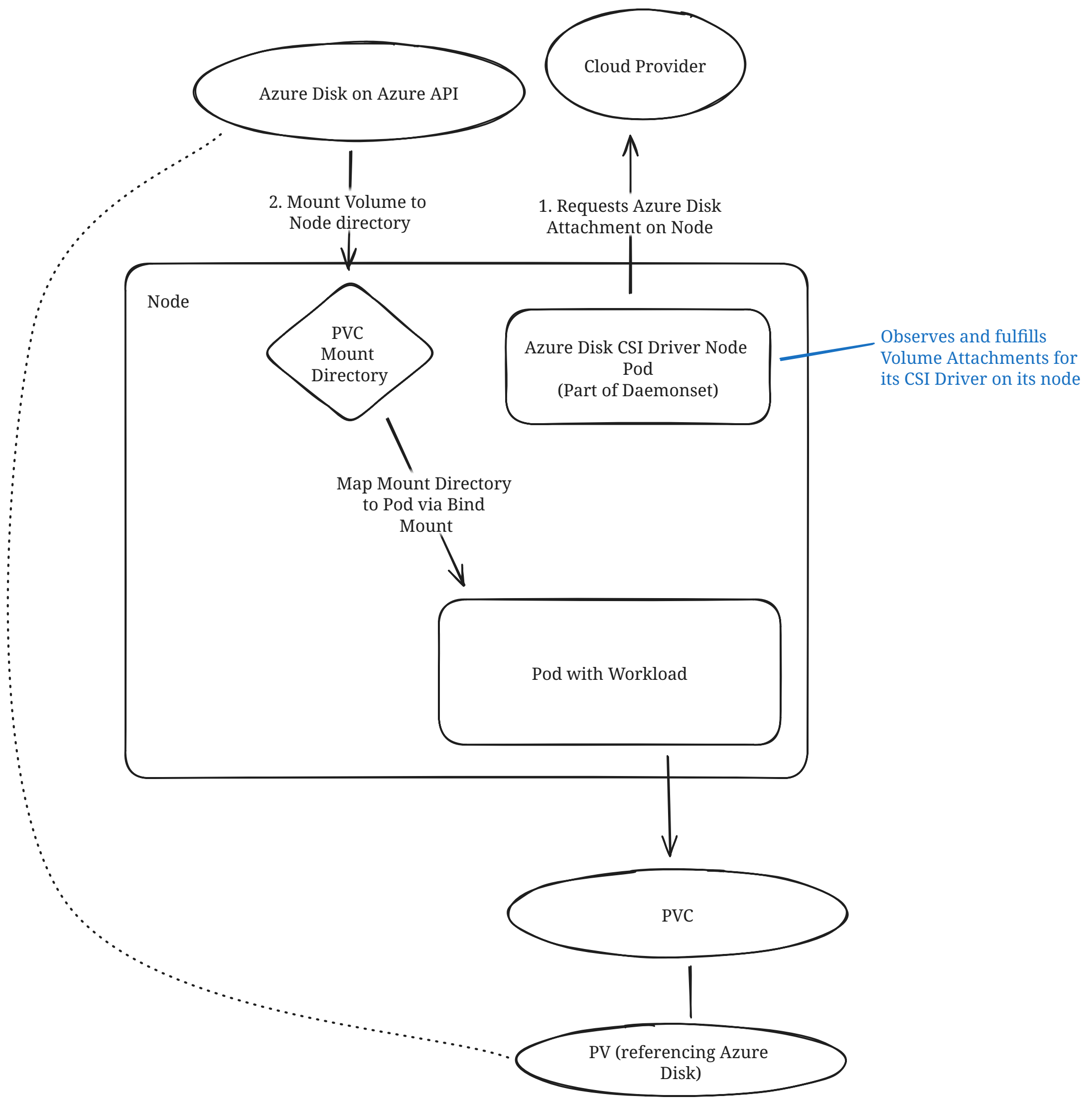
-> CSI **is** K8s Storage today*

OPTIONAL FEATURES

- Online Volume Expansion
- Volume Cloning/Snapshotting
- Raw Block Volumes

HOW CSI MOUNTING WORKS?

EXAMPLE: ATTACHING AN AZURE DISK VOLUME


Azure Disk on Azure API
Cloud Provider
2. Mount Volume to Node directory
1. Requests Azure Disk Attachment on Node
Node
PVC Mount Directory
Azure Disk CSI Driver Node Pod (Part of Daemonset)
Observes and fulfills Volume Attachments for its CSI Driver on its node
Map Mount Directory to Pod via Bind Mount
Pod with Workload
PVC
PV (referencing Azure Disk)

HOW TO SELECT THE RIGHT PROVIDER FOR YOU?

Everybody gangsta until the storage cluster stops clustering

-They

- the easiest problems are the ones you do not solve yourself
- Explore available options
- Use a cloud provider integration, if you can
- Most SANs have a CSI Provider (PureStorage, NetApp, etc.)
- Use well established solution with a high degree of automation, like Rook Ceph if you have to do it yourself

BACKUPS

Snapshots are not Backups

Replicas are not Backups

One Backup is no Backup

Untested Backups do not exist

If you can delete it using the credentials used to create it, it does not exist

A GOOD BACKUP IS

- Immutable
- Tested
- Replicated
- Infrastructure independent

=> Object Storage

HOW TO SETUP?

- Create Bucket outside of regular infrastructure permission system
- Create Credentials without delete permissions, only hiding for deployment into infrastructure
- Use a Lifecycle Rule to delete backups after they have been hidden for a while (90 days - x Years)

VELERO

- Backups K8s resources as well
  - Please use GitOps for that
- Difficult to integrate with anything else than plain PVCs*
- Can do a CSI Snapshot and extract data to an object store
- Does its operations using a `DaemonSet`

K8UP

- Back up all PVCs into an Object Store using Restic
- Manages helper pods for Application Level Backups
- No cluster level configuration necessary
- Does backups using `Jobs` -> only allocating resources during operations
- One `Backup` Custom Resource per namespace

```yaml
apiVersion: k8up.io/v1
kind: Schedule
metadata:
  name: confluence
spec:
  backup:
    schedule: "@daily-random"
    podSecurityContext:
      runAsUser: 0
  check:
    schedule: "@weekly-random"
  prune:
    schedule: "@weekly-random"
    retention:
      keepDaily: 30
      keepMonthly: 6
      keepWeekly: 8
  backend:
    s3:
      endpoint: https://s3.eu-central-003.backblazeb2.com
      bucket: "backupbucket/apps-confluence"
      accessKeyIDSecretRef:
        name: k8up-credentials
        key: username
      secretAccessKeySecretRef:
```

```yaml
apiVersion: k8up.io/v1
kind: PreBackupPod
metadata:
  name: confluence-db-backup
spec:
  backupCommand: pg_dump
  fileExtension: .sql
  pod:
    spec:
      containers:
      - name: confluence-db-dump
        image: postgres:latest
        env:
          - name: PGDATABASE
            value: confluence
          - name: PGHOST
            value: acid-confluence
          - name: PGPASSWORD
            valueFrom:
              secretKeyRef:
                key: password
                name: confluence.acid-confluence.credentials.postgresql.ac
          - name: PGUSER
            valueFrom:
              secretKeyRef:
```

ALTERNATIVES TO PVCS

S3 STYLE OBJECT STORES

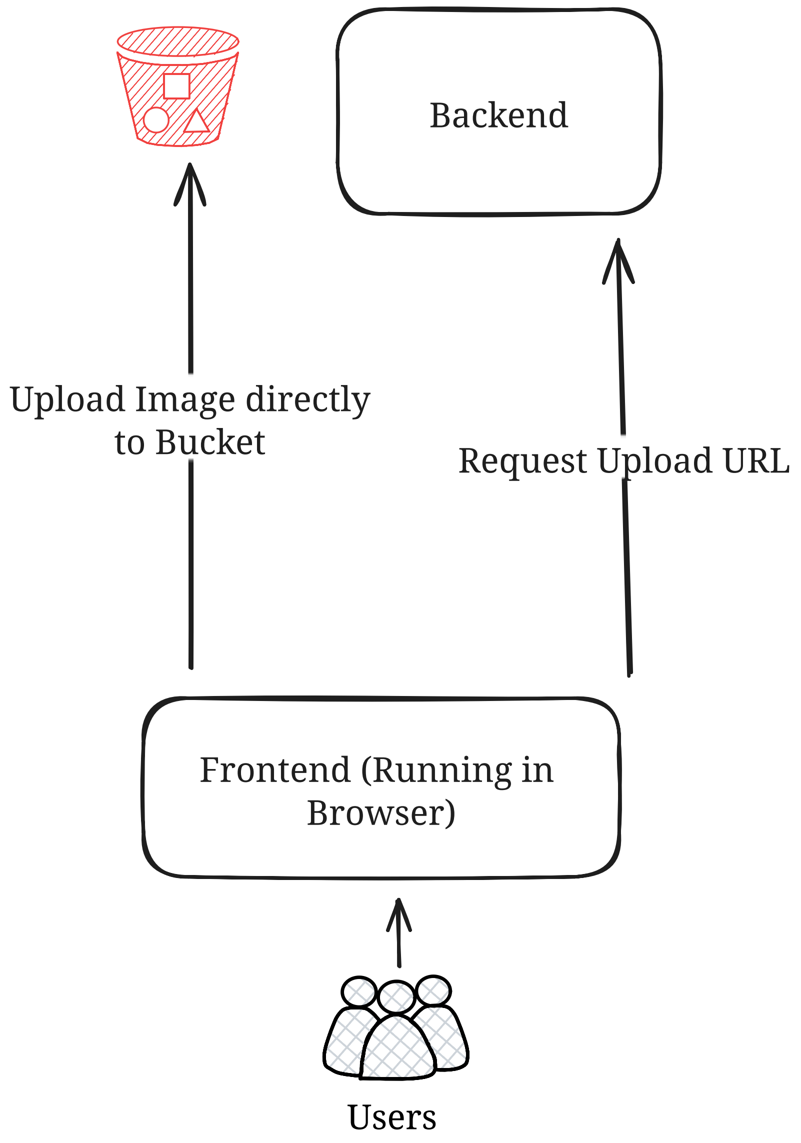
- Read-After-Write consistent*
- High Time-To-First-Byte Latency (100ms+)*
- Partial Downloads
- Per-Request Performance limit instead of Per-Bucket limit
- Big Limitation: NO PARTIAL OBJECT UPDATES
- Cheaper than block storage*

PRESIGNED URLS IN S3

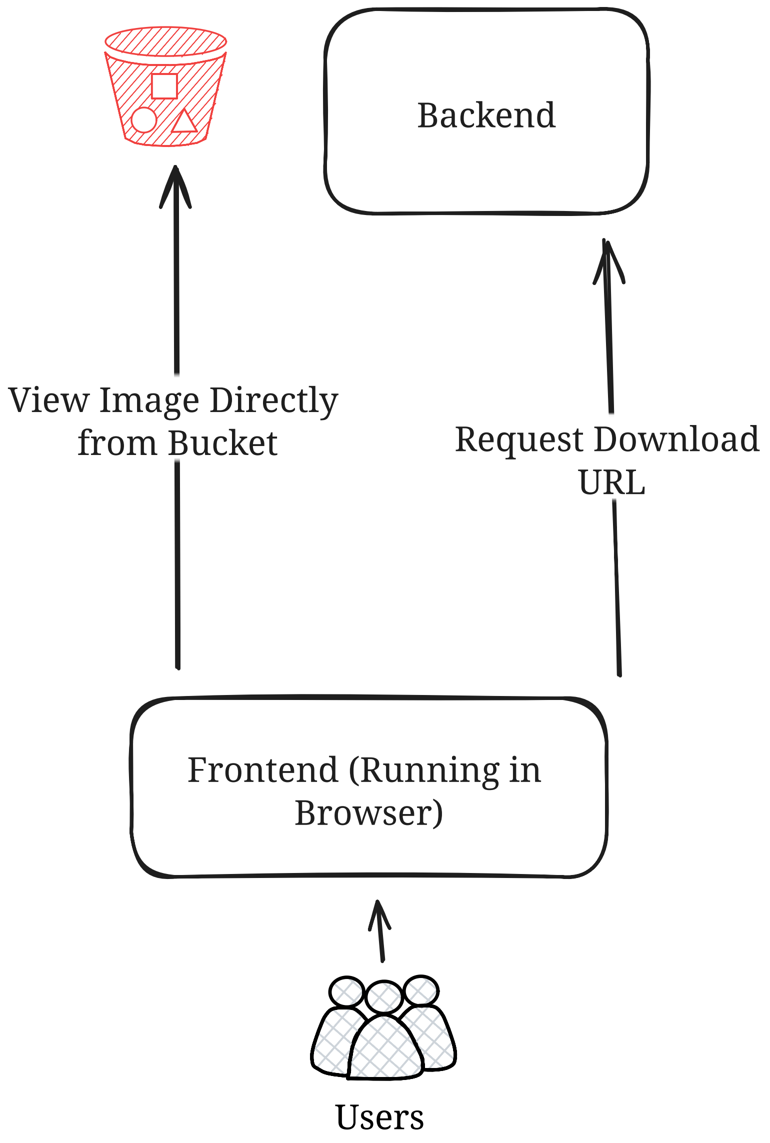
Delegate temporary S3 Permissions directly to the end-user client

Allows you to move data without passing through your own application/infrastructure

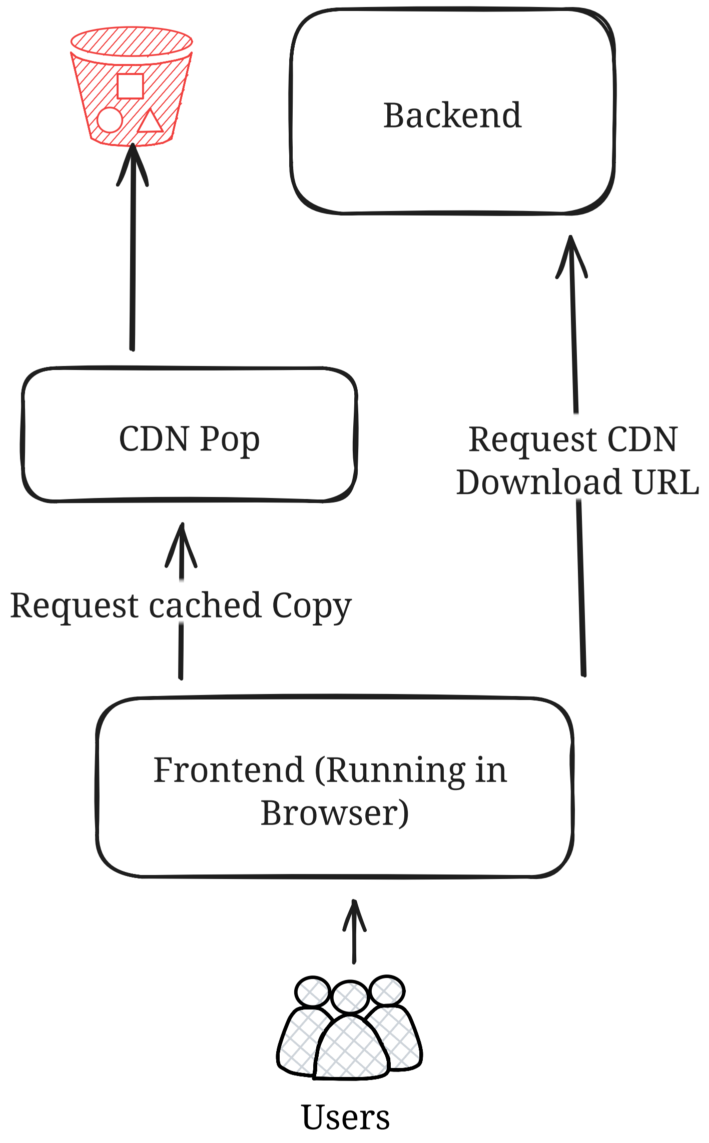
UPLOAD


Backend
Upload Image directly to Bucket
Request Upload URL
Frontend (Running in Browser)
Users

DOWNLOAD


Backend
View Image Directly from Bucket
Request Download URL
Frontend (Running in Browser)
Users

USING A CDN


Backend
CDN Pop
Request CDN Download URL
Request cached Copy
Frontend (Running in Browser)
Users

RUNNING DATABASES IN-CLUSTER

WHY?

WHY?

Managed Databases are fine, but

- Poor integration with Kubernetes CD
- Expensive
- Different features across cloud vendors
- Latency
- Separate Database Teams add communication overhead

GENERAL ADVICE (REGARDLESS OF DB)

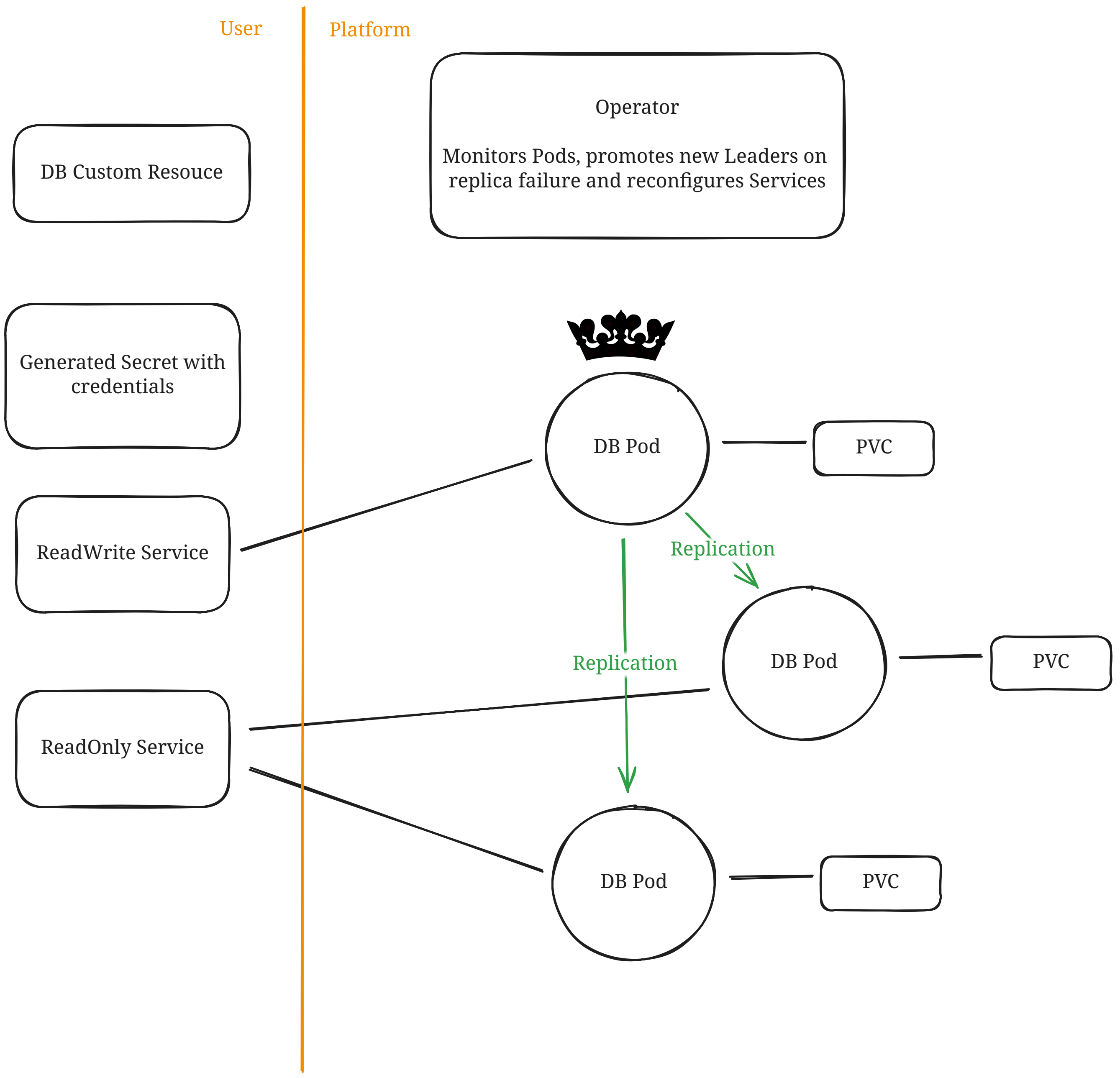
- Run a DB cluster, please
- Use an operator if you need persistence
- Test your application to handle DB reconnection
- Use monitoring and backups

ACID DATABASES

Postgres, MySQL, MariaDB

ACID DATABASES CONSIDERATIONS

- Use a fast, low latency PVC
- Run your DB in the same K8s cluster as the application


User
Platform
DB Custom Resouce
Operator
Monitors Pods, promotes new Leaders on replica failure and reconfigures Services
Generated Secret with credentials
DB Pod
PVC
ReadWrite Service
Replication
DB Pod
PVC
Replication
ReadOnly Service
DB Pod
PVC

CLOUDNATIVE PG

CNCF Project

Does all the things

WAL Streaming, Automatic Backups, Replication, Upgrades, Point-In-Time Restore

https://cloudnative-pg.io/

ZALANDO POSTGRES OPERATOR

A bit older, based on a project called Patroni for Docker

Similar to CNPG, but some features hard to use outside of AWS (e.g. WAL Streaming)

Use the more modern CNPG

https://github.com/zalando/postgres-operator

MYSQL OPERATOR

Built by Oracle

Tried to use it, but had issues all around in the beginning of 2023

Might be better now

¯_(ツ)_/¯

VITESS

- MySQL Compatible
- Kubernetes Native design
- Supports data sharding
- Some compatibility limitations: https://vitess.io/docs/19.0/reference/compatibility/mysql-compatibility/

ORACLEDB OPERATOR

https://github.com/oracle/oracle-database-operator

BACKUPS

- WAL Archiving
- Regular Dumps, if size allows for it

FUN TIMES WITH NETWORK ATTACHED STORAGE

RUNNING STORAGE CLUSTERS INSIDE KUBERNETES

Long: Failover on the protocol level is a must

Short: Yes, if it is Rook Ceph

LATENCY

- Using networked filesystems introduces significant IO latency >0.5ms
- Limits your sequential throughput to 2000 ops/s
- Leads to high commit/flush latency

Solution:

Agressively parallelize your IO - Your throughput will scale pretty well*

THANK YOU