Placing Databases @ Uber

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April, 2017
What do you mean by “placing databases”?

Why is it important where you place your databases?

Things we need to consider when deciding where to run a database:

- Does the host have enough resources to run the database?
- Should the host be avoided because of maintenance or some other issue?
- What other databases are already running on the host? Will using the host affect the cluster reliability?

Circles of the same color represent databases belonging to the same replication topology.
Overview

What I will cover today

● Motivation and Background
● Core Problem
● Architecture
● Constraint Modelling
● Placement Algorithm
● Relocation Algorithm
● Simulations
Motivation and Background

An overview of Schemaless and Opsless
Schemaless a NoSQL database

Overview and Database Topology

- Schemaless an in-house NoSQL key-value database with secondary indexes
- Simple API
  - Insert(datastore, row-key, column-key, ref-key, cell)
  - Get(datastore, row-key, column-key, ref-key)
  - Query(datastore, column-key, constraints)
- Topology of a Schemaless instance
- Schemaless is Ubers most popular storage technology
- Popularity means many databases to manage :(
Opsless for Managing Schemaless

Overview of how Opsless manages Schemaless

- Containerized databases using Docker
- Goalstate driven operations
- Operations performed through workflows that build upon idempotent basic REST operations
- Example: adding a database

- Example: splitting a cluster
Core Problem

How do we characterize good placement?
Core Problem

How do we characterize good placement?

When deciding to place a database we have some “hard” and some “soft” requirements:

- **Hard:**
  - Resource constraints: memory, disk, etc.
  - Host issues: bad disk, wrong OS version, etc.

- **Soft:**
  - Databases spread out to minimize harm from host, rack or datacenter failures
  - Limit same instance databases on a host
  - Limit databases on a host
Core Problem

How do we characterize good placement?

- When we have placed a database we need to keep a reservation of its placement

- As time goes on databases consume more disk, I/O operations, etc. so we probably want to relocate/move them
Architecture

The big picture of placing databases
Architecture

The big picture of placing databases

- **Opsless Agent** (Running on the database hosts)
  - Pull goal state
  - Push actual state

- **uOrchestrator** (Workflow engine)
  - Start workflows

- **uConfig** (Configuration store for goalstate)
  - Set goal states

- **Yggdrasil** (GraphCache for configuration)
  - Get actual states
  - Get placement and relocation suggestions

- **Overseer**
  - Get actual database allocations
  - Get database/host metrics

- **Graphite/M3** (Metrics systems)
  - Get database/host metrics
Architecture

The different components of Overseer

- Written in Go
- Exposes a HTTP-REST API
- Depends on the services
  - Yggdrasil - for finding datacenters, racks, hosts and databases that are currently in production
  - M3 & Graphite - for fetching metrics about hosts and databases used in the placement algorithms
- Keeps a cache of internal data models build using the data from the dependencies
- Keeps a set of reservations of databases placed on hosts until changes are visible in Yggdrasil
Architecture

The different components of Overseer

- The HTTP-REST API supporting
  - Suggest-Placement

```json
{
    "databases": [
        {
            "name": "somestore-us1-cluster5-db3",
            "creation_time": "2017-01-01T12:00:00Z",
            "relations": {...},
            "resource_requirements": [...],
            "placement_requirements": [...],
            "relation_requirements": [...]
        }
    ],
    "skip_reservations": false,
    "skip_transcripts": true
}
```
Architecture

The different components of Overseer

● The HTTP-REST API supporting
  ○ Suggest-Placement
  ○ Suggest-Relocation

```json
{
  "group_name": "dc1",
  "minimum_rank": 1,
  "minimum_age": "168h"
}
```
Placement Algorithm

How the placement of databases is done
Placement Algorithm

Filtering out PlacementGroups that pass the requirements

- Database
- ResourceRequirement
- RelationRequirement
- PlacementRequirement

Root

Datacenters

Racks

Hosts

- Host has a bad disk
- Has a same instance database
- Rack should be evacuated
- Host does not have enough memory
- Wrong datacenter
Placement Algorithm

Ordering the PlacementGroups that passed the requirements

- A PlacementOrdering is a ternary-relation:
  - PlacementGroup × PlacementGroup × Database →bool

  ```
  type PlacementOrdering interface {
    Less(pg1, pg2 *PlacementGroup, db *Database) bool
  }
  ```

- It must define a Strict Total Order:
  - Irreflexivity: a < a is always false
  - Transitivity: If a < b and b < c then a < c

Compare tuples for each group:
1. # Same cluster databases on rack
2. - Free disk space
3. - Used disk space
4. # Same instance databases on rack
5. # Databases on rack
6. - Free memory
7. - Used memory
Relocation Algorithm

How the relocation of databases is done
Relocation Algorithm
Filtering out PlacementGroups that pass the requirements

Database

× ResourceRequirement
× RelationRequirement
× PlacementRequirement

Host has a bad disk
Has a same instance database
Rack should be evacuated
Host does not have enough memory
Wrong datacenter

Root
Datacenters
Racks
Hosts
Relocation Algorithm

Ranking the current PlacementGroup against the others

- We again use the PlacementOrdering
  - PlacementGroup × PlacementGroup × Database → bool

- The relocation rank of the database is then $i$ as there are $i$ other groups that are better than the current.
Modelling

The central constraint concepts in Overseer
Modelling

Overview of the constraint types

PlacementGroup

represents a datacenter, rack, host or other physical entity which can potentially contain a hierarchy of other physical entities.

type PlacementGroup struct {
    Name      string
    Parent    *PlacementGroup
    Subgroups []*PlacementGroup
    Labels    *LabelSet
    Relations *LabelSet
    Resources *MetricSet
    Usage     *MetricSet
    Databases []*Database
}
Modelling

Overview of the constraint types

MetricType

represents a type of information, it can be cpu usage, memory usage, disk usage, etc.

```go
type MetricType struct {
    Name        string
    Unit        string
    Aggregation AggregationType
}
```

```json
{
    "aggregation": "sum",
    "unit": "bytes",
    "name": "disk_free"
}
```

```json
{
    "aggregation": "sum",
    "unit": "bytes",
    "name": "memory_free"
}
```
Database

represents a database which belongs to given
cluster in a given instance in a given pipeline, this is
captured by the relations field, which stores a set of
labels capturing the these relations.

database struct:

```
struct Database {
    Name string
    CreationTime time.Time
    PlacementRequirements [...] *PlacementRequirement
    RelationRequirements [...] *RelationRequirement
    ResourceRequirements [...] *ResourceRequirement
    Relations *LabelSet
    Usage *MetricSet
}
```

Example:

```
{
    "name": "somestore-us1-cluster5-dbbabel",
    "creation_time": "2017-01-01T12:00:00Z",
    "relations": {...},
    "resource_requirements": [...],
    "placement_requirements": [...],
    "relation_requirements": [...]
}
```
Modelling

Overview of the constraint types

**PlacementRequirement**

represents a requirement in relation to a specific PlacementGroup having a specific label, i.e. we want to be placed in a given datacenter or we do not want to be placed on a specific rack, etc.

```go
type PlacementRequirement struct {
    AppliesTo     *LabelSet
    ConditionType ConditionType
    Required      *LabelSet
}
```

```json
{
    "applies_to": {
        "set": [
            { "name": ["datacenter"]
        ]},
    "condition_type": "non_empty_intersection",
    "required": {
        "set": [
            { "name": ["dc2"]
        ]}
    }
}
```

```json
{
    "applies_to": {
        "set": [
            { "name": ["host"]
        ]},
    "condition_type": "empty_intersection",
    "required": {
        "set": [
            { "name": ["issue"]
        ]}
    }
}
```

```json
{
    "applies_to": {
        "set": [
            { "name": ["host"]
        ]},
    "condition_type": "empty_intersection",
    "required": {
        "set": [
            { "name": ["pools", "schemadock-testing"]
        ]}
    }
}
```
Modelling

Overview of the constraint types

RelationRequirement

represents a requirement in relation to a specific PlacementGroup having a specific relation, i.e. we want avoid a certain other type of databases.

```go
type RelationRequirement struct {
    AppliesTo   *LabelSet
    Label       *Label
    Comparison  ComparisonType
    Occurrences int
}
```
Modelling

Overview of the constraint types

ResourceRequirement represents a hard requirement for placing a Database in a given PlacementGroup which should have certain requirements for a specific metric.

```go
type ResourceRequirement struct {
    MetricType MetricType
    BoundType  BoundType
    Value      float64
}
```

```json
{
    "metric_type": {
        "aggregation": "sum",
        "unit": "bytes",
        "name": "disk_free"
    },
    "bound_type": "lower",
    "value": 841687164784
}
```

```json
{
    "metric_type": {
        "aggregation": "sum",
        "unit": "bytes",
        "name": "memory_free"
    },
    "bound_type": "lower",
    "value": 68719476736
}
```
Simulations

How to run simulations to answer questions about placements
Simulations
How to run simulations to answer questions about placements

We can run simulations on a snapshot of the hosts and databases in production. This is useful for:
- Deciding if we have enough capacity to create new instances
- Deciding if we have enough capacity to split instances
Simulations

How to run simulations to answer questions about placements

We can run simulations on a snapshot of the hosts and databases in production. This is useful for:

- Deciding if we have enough capacity to create new instances
- Deciding if we have enough capacity to split instances
- Experimenting with new placement orderings to see how it affects host utilization

```
{
  "operations": [
    {
      "type": "relocation",
      "relocation_request": {
        "group_name": "dc1",
        "minimum_rank": 1,
        "minimum_age": "0m"
      },
      "time": "2017-03-30T10:46:49.336639221-07:00",
      "relocations": 1000
    },
    {
      "type": "relocation",
      "relocation_request": {
        "group_name": "dc2",
        "minimum_rank": 1,
        "minimum_age": "0m"
      },
      "time": "2017-03-30T10:46:49.336639221-07:00",
      "relocations": 1000
    }
  ]
}
```
Thank you

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- Project Mezzanine: The Great Migration at Uber Engineering
  - http://eng.uber.com/mezzanine-migration/
- Designing Schemaless, Uber Engineering’s Scalable Datastore Using MySQL
  - https://eng.uber.com/schemaless-part-one/
- The Architecture of Schemaless, Uber Engineering’s Trip Datastore Using MySQL
  - https://eng.uber.com/schemaless-part-two/
- Using Triggers On Schemaless, Uber Engineering’s Datastore Using MySQL
  - https://eng.uber.com/schemaless-part-three/
- Dockerizing MySQL at Uber Engineering
  - https://eng.uber.com/dockerizing-mysql/