TRAINING THE NEXT GENERATION OF EUROPEAN FOG COMPUTING EXPERTS

mck8s: A container orchestration platform for geo-distributed multi-cluster environments

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About me and FogGuru

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- Funded by EU
- 6 European organizations
- 8 PhD students
- +20 publications

http://www.fogguru.eu/

FogGuru

@thefogguru

Outline

1. Evolution of cloud deployments
2. Challenges in multi-cluster management
3. Kubernetes Federation
4. Mck8s architecture
5. Mck8s controllers
6. Demonstration

Evolution of cloud deployments

- Cloud environments are increasingly geographically distributed
- Geo-distributed deployments
  - Hybrid-cloud
  - Multi-cloud
  - Fog computing
- Non-functional requirements to address:
  - Performance (low latency)
  - High bandwidth and reliable connectivity
  - HA and disaster recovery
  - Scalability
  - Security
  - Compliance

Hybrid cloud

Combine resources from private and public clouds (Eg. Enterprise applications)

Why?: Low latency, high availability, scalability, data locality, security, privacy, legal restrictions

Multi-cloud

Combine resources from multiple public clouds (Eg. Consumer applications)

Why?: Low latency, high availability, scalability, best-of-breed services, cost, vendor neutrality

Fog computing

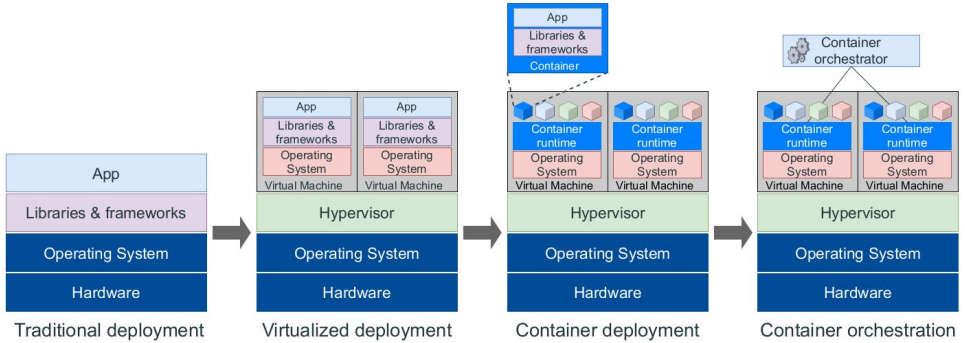
Combine resources from private and public clouds as well as micro data centers with vast geographical distribution (Eg. Telco clouds, IoT)

Why?: Low latency, high bandwidth, reliable connectivity

Challenges in multi-cluster management

- Potentially 100's or 1000's of clusters → automate deployment of applications & resource management
- Several challenges
  - Resilience
  - Placement
  - Autoscaling
  - User traffic routing and load balancing

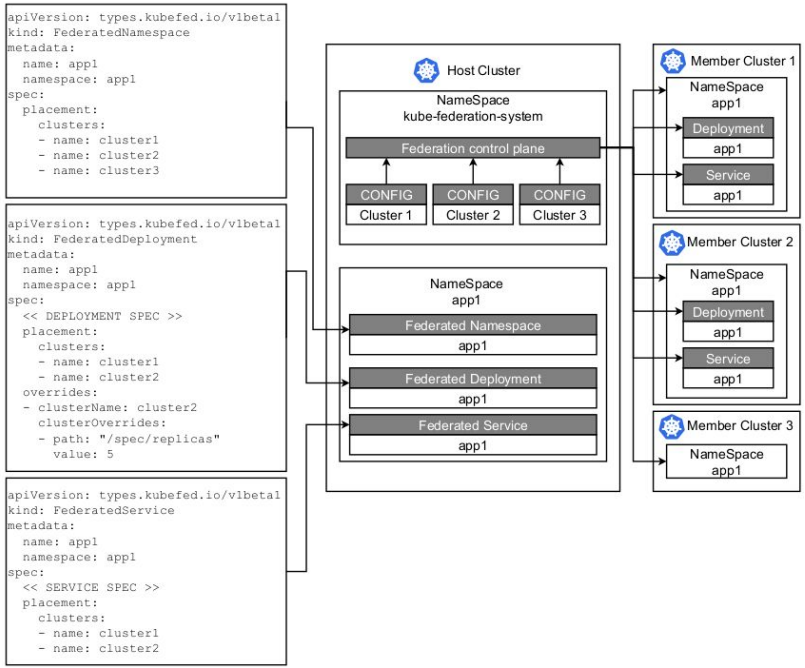
- Container orchestrators are basic foundation for building orchestrators for geo-distributed environments
  - Portable
  - Inter-operable
  - Extensible



Evolution of application deployment from VMs to container orchestration.

Kubernetes Federation (KubeFed)

- Sub-project of Kubernetes SIG Multicluster
- Provides control plane, concepts and abstraction for managing multiple Kubernetes clusters
- Provides manual placement
- Provides fully load-balanced or weight-based placement (Replica Scheduling Preferences)
- More automated policies needed in geo-distributed environments

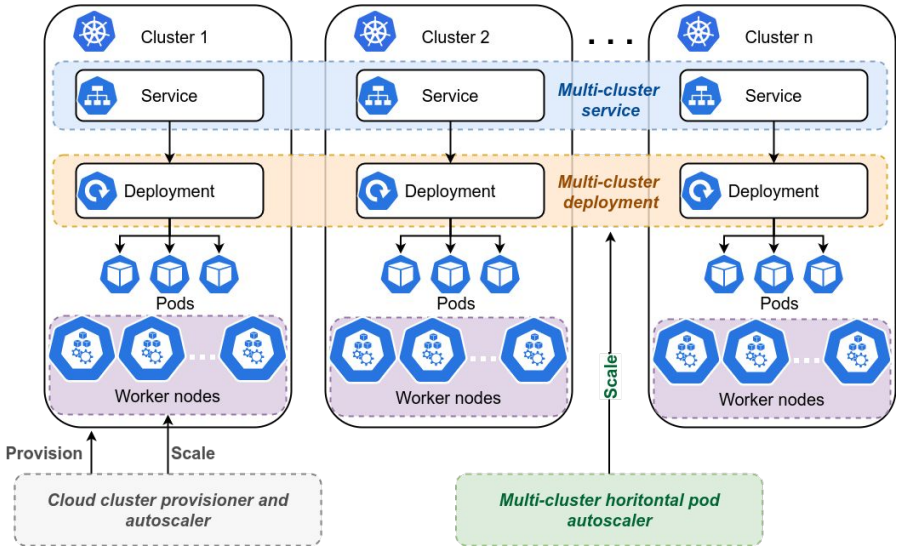


High-level KubeFed architecture with manifest files.

Multi-cluster Kubernetes (*mck8s*)

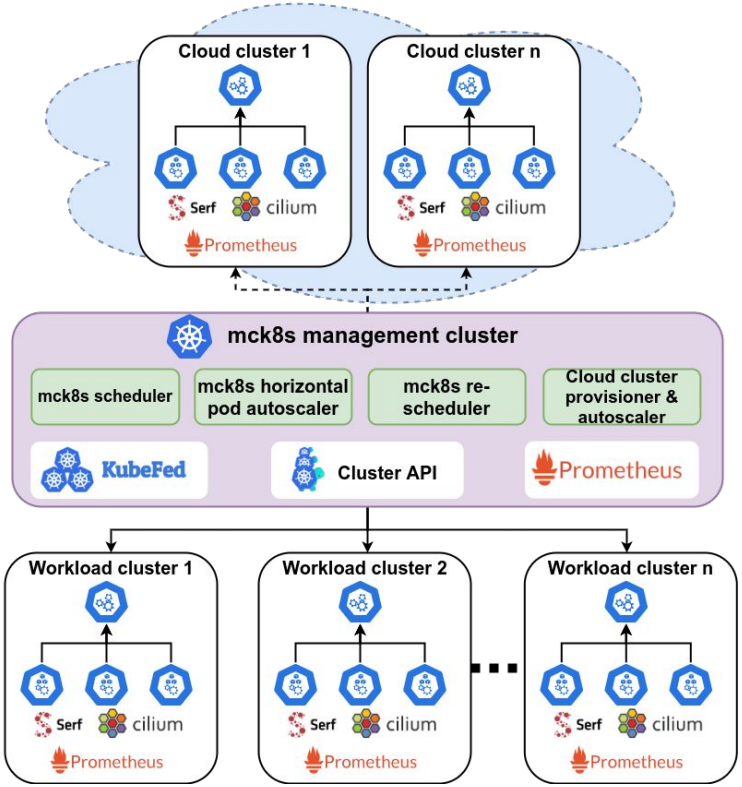
Goal:

- Provide automated placement, offloading and bursting
- Autoscaling at three levels:
  - Multi-cluster (federation)
  - Cluster (worker nodes)
  - Pods
- Inter-cluster network routing and load balancing



mck8s architecture

- One management cluster where applications are deployed
- Multiple workload clusters (potentially from different providers) that run applications
- Builds upon KubeFed, Cluster API, Prometheus, Serf and Cilium
- Four new controllers:
  - Multi-cluster scheduler
  - Multi-cluster horizontal pod autoscaler
  - Mck8s de-scheduler
  - Cloud cluster provisioner and autoscaler



mck8s custom resources

- Multi-cluster deployment (MCD)
- Multi-cluster job (MCJ)
- Multi-cluster service (MCS)
- Multi-cluster horizontal pod autoscaler (MCHPA)
- Cloud cluster provisioner and autoscaler
- Multi-cluster re-scheduler

```yaml
apiVersion: apiextensions.k8s.io/v1
kind: CustomResourceDefinition
metadata:
  name: multiclusterdeployments.fogguru.eu
spec:
  scope: Namespaced
  group: fogguru.eu
  versions:
    - name: v1
      served: true
      storage: true
  names:
    kind: MultiClusterDeployment
    plural: multiclusterdeployments
    singular: multiclusterdeployment
    shortNames:
      - mcd
      - mcds
  versions:
    - name: v1
      served: true
      storage: true
      schema:
        openAPIV3Schema:
          type: object
          properties:
            spec:
              type: object
              x-kubernetes-preserve-unknown-fields: true
            status:
              type: object
              x-kubernetes-preserve-unknown-fields: true
```

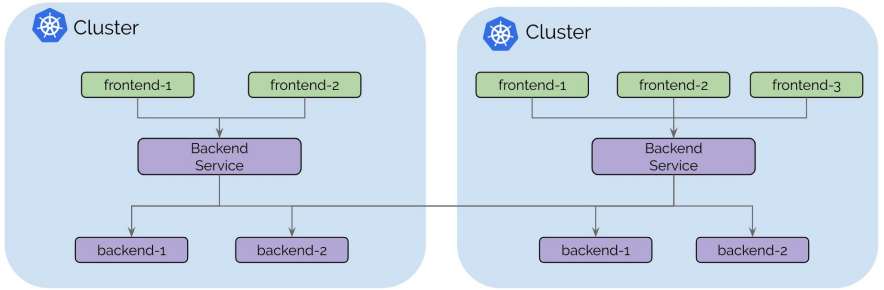
Multi-cluster scheduler

- Responsible for the lifecycle the following resources
  - MCD
  - MCS
  - MCJ
- Manual and policy-based automated scheduling / placement
  - Cluster-affinity: on selected clusters
  - Resource-based: worst-fit, best-fit
  - Network traffic-based: traffic-aware
- Horizontal offloading to neighboring clusters
- Bursting to neighboring clusters

```yaml
apiVersion: fogguru.eu/v1
kind: MultiClusterDeployment
metadata:
  name: hello
spec:
  numberOfLocations: 2
  placementPolicy: traffic-aware
  selector:
    matchLabels:
      app: hello
      tier: backend
      track: stable
  replicas: 2
  template:
    metadata:
      labels:
        app: hello
        tier: backend
        track: stable
    spec:
      containers:
        - name: hello
          image: "gcr.io/google-samples/hello-go-gke:1.0"
          resources:
            requests:
              memory: 1024Mi
              cpu: 1000m
            limits:
              memory: 1024Mi
              cpu: 1000m
          ports:
            - name: http
              containerPort: 80
```

Multi-cluster service and inter-cluster network routing

- Multi-cluster service creates services on the clusters containing the corresponding deployments
- Relies on Cilium cluster-mesh for inter-cluster network routing and load balancing




```yaml
apiVersion: fogguru.eu/v1
kind: MultiClusterService
metadata:
  name: hello
  annotations:
    io.cilium/global-service: "true"
spec:
  selector:
    app: hello
    tier: backend
  ports:
  - protocol: TCP
    port: 80
    targetPort: http
```

Multi-cluster horizontal pod autoscaler

- Control the scaling of MCDs from the management cluster
- Compute the number of desired replicas based on resource utilization
- Pass to the multi-cluster scheduler

```yaml
apiVersion: fogguru.eu/v1
kind: MultiClusterHorizontalPodAutoscaler
metadata:
  name: hello
spec:
  scaleTargetRef:
    apiVersion: fogguru.eu/v1
    kind: MultiClusterDeployment
    name: hello
  minReplicas: 2
  maxReplicas: 10
  metrics:
  - type: Resource
    resource:
      name: cpu
      target:
        type: Utilization
        averageUtilization: 50
```

Cloud cluster provisioner and autoscaler

- Periodically checks of status of MCDs
- Provision a K8S cluster in the cloud provider of choice via Cluster API
- Join to the federation
- Scale-out or -in the cluster nodes as necessary
- Remove the cloud cluster is not needed anymore

```
apiVersion: fogguru.eu/v1
kind: CloudProvisioner
metadata:
  name: cp1
spec:
  cloudClusterName: cloud1
  gatewayIP: 10.16.91.27
  floatingIP: 10.16.92.1
  extNetworkID: c95efff4-fd35-46f1-af1d-d65459fcebef
  securityGroupID: 9cc0b5b7-222f-41bb-8960-98f5cce14
  cloudsYaml:
Y2xvdWRzOgogIG9wZW5zdGFjazoKICAgIGF1dGg6CiAgICAgIGF1
  certText:
W0dsb2JhbF0KYXV0aC11cmw9aHR0cDovLzEwLjE2LjYxLjI1NTo1
```

Implementation

- Implemented in Python
- Using Kopf (Kubernetes Operators Framework)

multiclusterscheduler.py

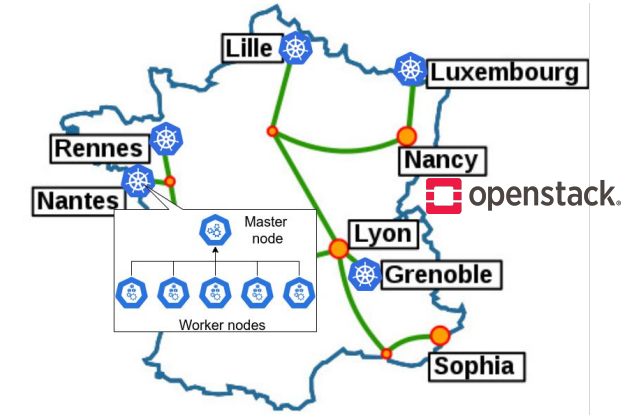
multi-cluster-scheduler > multiclusterscheduler.py > ...

```python
import kopf
import yaml, pandas as pd
from utils import findPossibleClusters, getFogAppLocations,  getCloudCluster, \
    createDeployment, createService, deleteDeployment, deleteService, patchDeployment, patchService, createJob, \
    deleteJob, patchJob, getMaximumReplicas, findNearestClusters, getAllocatableCapacity, getFogAppClusters, getServiceClusters
import json
import time

# Create multi-cluster deployment
@kopf.on.create('fogguru.eu', 'v1', 'multiclusterdeployments')
def create_fn(body, spec, patch, **kwargs):
    # Get info from multiclusterdeployments object
    fogapp_name = body['metadata']['name']
    fogapp_image = spec['template']['spec']['containers'][0]['image']
    fogapp_replicas = spec['replicas']
    fogapp_cpu_request = int(spec['template']['spec']['containers'][0]['resources']['requests']['cpu'][:-1])
    #fogapp_cpu_limit = spec['template']['spec']['containers']['resources']['limits']['cpu']
    fogapp_memory_request = int(spec['template']['spec']['containers'][0]['resources']['requests']['memory'][:-2])
    #fogapp_memory_limit = spec['template']['spec']['containers']['resources']['limits']['memory']
    #fogapp_type = spec['appType']
    #fogapp_type = body['kind']
    spec_text = str(spec)

    # Make sure image is provided
    if not fogapp_image:
        raise kopf.HandlerFatalError(f"Image must be set. Got {fogapp_image}.")

    if not fogapp_replicas:
        raise kopf.HandlerFatalError(f"Number of replicas must be set. Got {fogapp_replicas}.")

    # Get namespace
    if 'namespace' in body['metadata']:
        fogpapp_namespace = body['metadata']['namespace']
    else:
        fogpapp_namespace = "default"
```

Demo

Pre-requisites

- A management cluster and few workload clusters (K8S)
- KubeFed, Prometheus, Cluster API on management cluster
- Workload clusters with Cilium and Cilium cluster mesh, Serf, Prometheus
- Credentials for a cloud provider (OpenStack, AWS, GCP, etc.)
- Physical / virtual network between clusters (eg. VPN)



Testbed containing a management cluster (Rennes) and 5 workload clusters (Rennes, Nantes, Lille, Grenoble, Luxembourg). OpenStack cloud cluster in Nancy.

Each of the five clusters has a master node and 5 worker nodes

Clusters 1 & 5
- 4 CPU cores
- 16 GB RAM

Clusters 2, 3, 4
- 2 CPU cores
- 4 GB RAM

	Rennes	Nantes	Lille	Luxembourg	Nancy	Grenoble
Rennes	-	2.16	23.26	27.41	25.18	17.45
Nantes	2.16	-	22.21	26.29	24.16	16.38
Lille	23.26	22.21	-	11.88	9.70	12.06
Luxembourg	27.41	26.29	11.88	-	2.90	15.33
Nancy	25.18	24.16	9.70	2.90	-	13.14
Grenoble	17.45	16.38	12.06	15.33	13.14	-

Inter-site network latency (RTT) in milliseconds

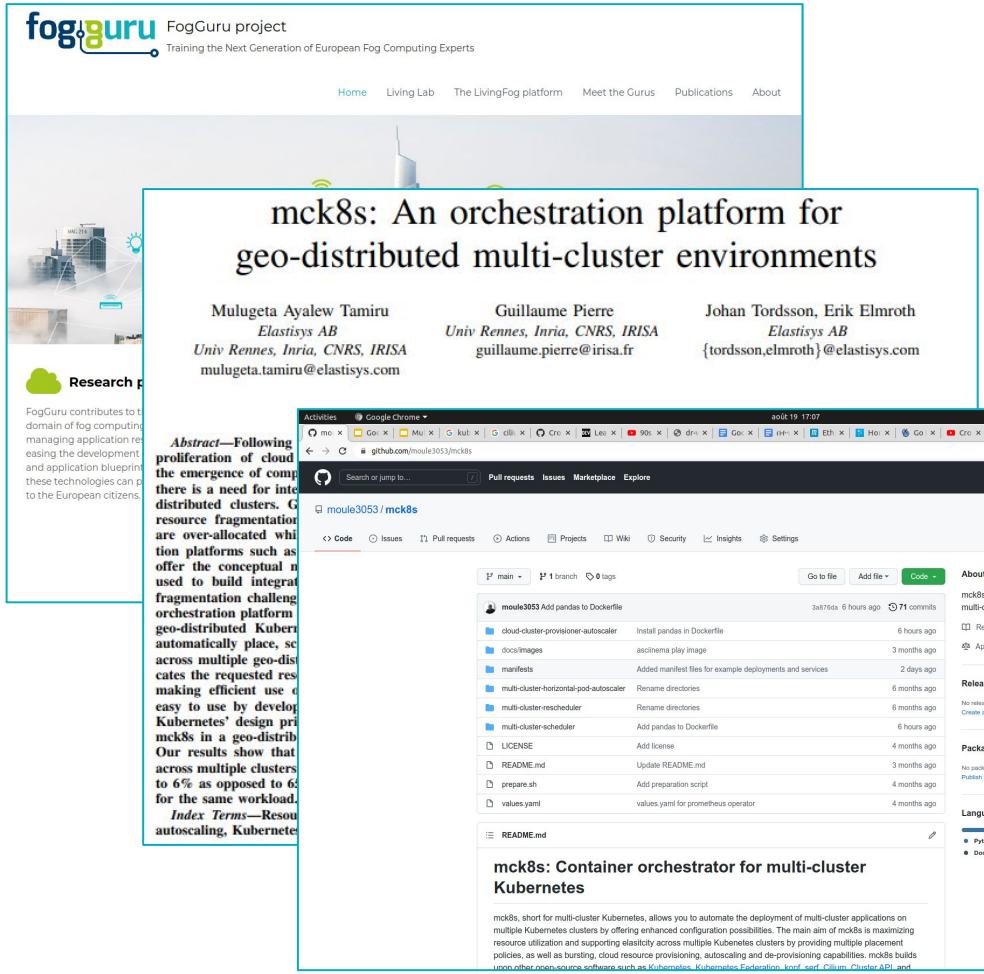
Demo

Learn more & contribute

FogGuru project website:
http://www.fogguru.eu

Related paper (accepted at 30th International Conference on Computer Communications and Networks (ICCCN 2021)):
https://hal.inria.fr/hal-03205743

Github:
https://github.com/moule3053/mck8s



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