Execution of scientific workflows on hybrid infrastructure, a case study of AWS Elastic Container Service in combination with AWS Lambda

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Presentation plan

1. The idea
2. Introduction to scientific workflows
3. Workflow execution engine
4. Studied infrastructures
    a. containers
    b. cloud functions
5. Hybrid infrastructure support - implementation
6. Experiment
7. Conclusion
8. References

The idea

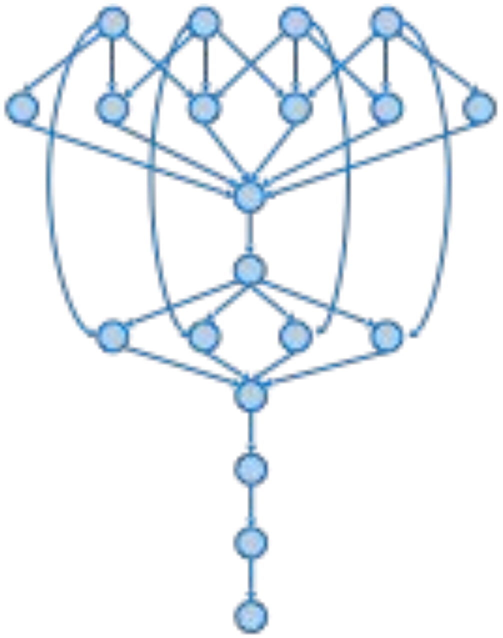
- Execution of scientific workflows on hybrid infrastructure...
- Some scientific workflows can benefit from being executed on *hybrid infrastructure*
  - In this case *Hybrid infrastructure* is achieved by combining two of *elastic* infrastructures containers with cloud functions

- The concept was implemented by extending an existing set of tools used to execute workflows [3] [4]
  - new Cloud Function component for Workflow Execution Engine
- Validate by experiment

Workflows

- high level description of the process
- graph representation
- dependency modeling

- decouple experiment from the infrastructure
- improved reusability/reproducibility
- supports parallelization



HyperFlow

- Simple, yet powerful, workflow execution engine [3]
    - aims to be an abstract workflow execution engine
- Written in JavaScript, uses Node.js runtime, some of the features:
    - lightweight
    - extensible
    - easy to understand and debug

- Doesn’t include support for execution on remote infrastructures
    - this can be achieved through extensions: *Functions* and *Executors*
        - function represents a given infrastructure on HyperFlow side
        - Executor is responsible for performing the operation

The elastic infrastructures

- Highly elastic cloud infrastructures:
    - on demand, almost instantaneous infrastructure provisioning
    - dynamic billing model
    - provide usable computing power
    - no/little system management
        - most of the management is automated or done through ‘infrastructure as a code’ concept

- Examples of such infrastructures: containerized environments, cloud functions

Containers

- Study of running workflows in containerized environment:
  M. Orzechowski, B. Baliś. "Container-Based Architecture for Resilient and Reproducible Scientific Workflows." CGW Workshop'17
  - targeted at container environments, namely: Kubernetes, AWS ECS etc.

- Promising approach, provides:
  - infrastructure as a code paradigm (by using Terraform)
  - easy infrastructure management
  - autoscaling
  - portability
- Some limitations:
  - Infrastructure indirectly operates on actual VMs
  - Adding new resources isn’t easy

Cloud functions

- Novel offering from cloud providers
- Developer prepares application or application components in form of source code for a given runtime
  - node.js, java, python etc.
  - implements a single *handler* function
- Cloud provider is responsible for infrastructure/resource provisioning
  - only one configurable parameter: memory size, also impacts available performance
- Function (application) instances are created on demand
  - so called *cold start* of a function is around 1 second

- callable through: REST API, messaging (AWS SQS), other events

Cloud functions cont.

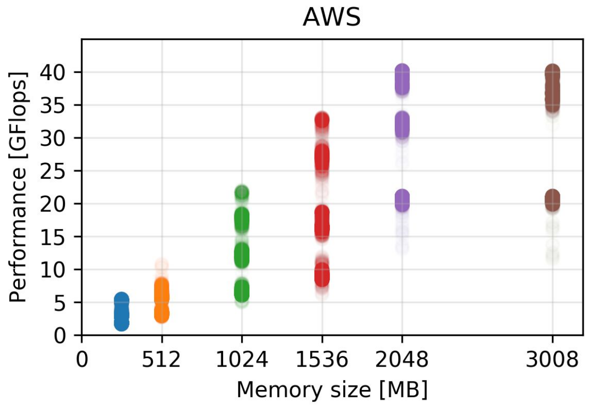
- a step further when it comes to elasticity, than containers or PaaS

- Functions provide:
    - Almost instant provisioning of new resources
    - 100ms billing granularity, function’s start overhead is not billed
    - massive parallelism, AWS allows up to 1000 simultaneous executions

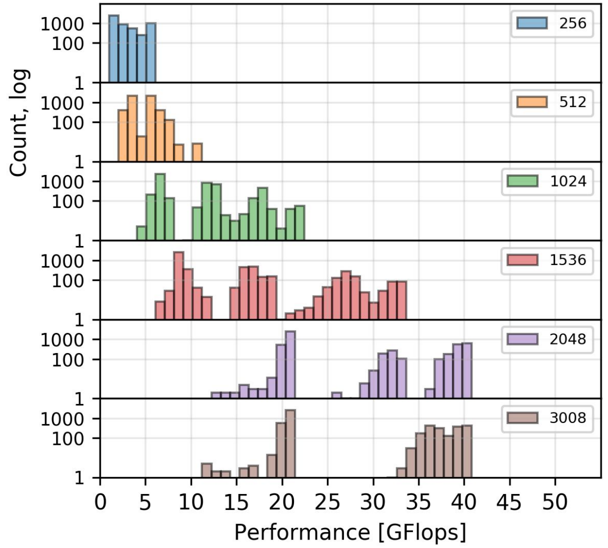
- Limitations (compared to containers):
    - limits on run time and memory (15 mins and 3GB at this point)
    - although miniscule, there is still an aspect of ‘cold start’
    - reliability
    - lack of environment reusability

Cloud function benchmarking

- Performance changes in relation to memory size
- In most cases there is one dominant value
- More information in [6] [7] [8]



- Ongoing work studying other aspects like:
  - provisioning speed
  - reliability
  - limits of parallelism

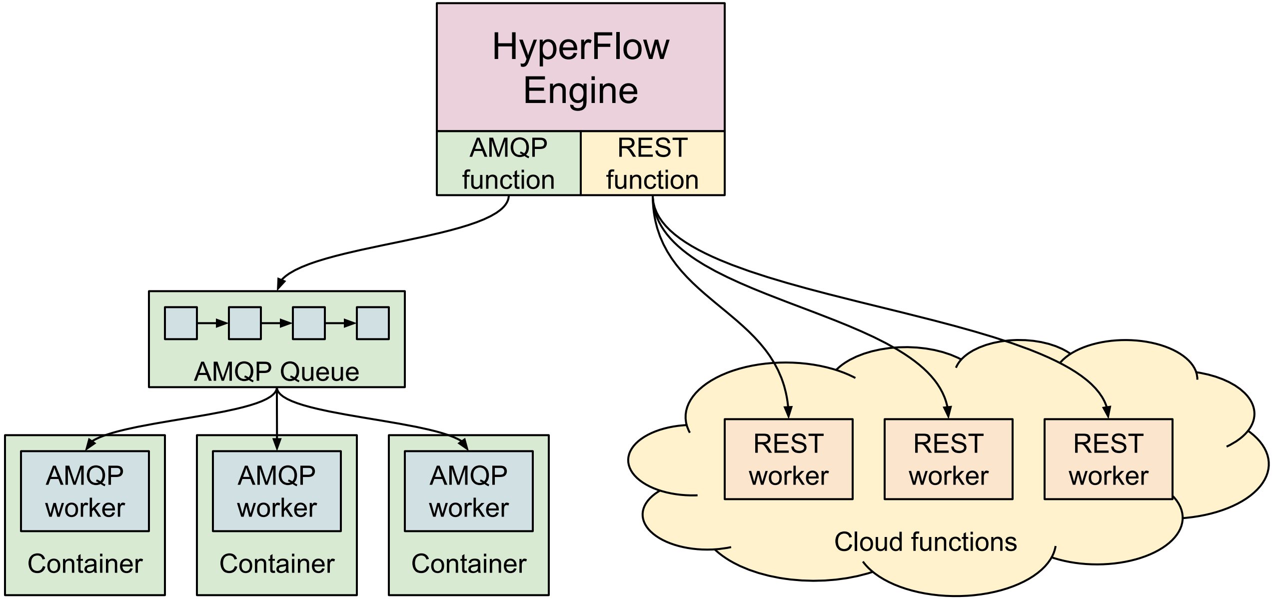


Implementation details

- Container execution uses existing “AMQP Command” Function
- Cloud functions use new “REST Service Command” function
  - HTTP used as a transport layer
  - compatible with multiple executors (exposing a proper API)
- Target infrastructure for each task is chosen before the start
  - Instrumentation is part of workflow graph

- Infrastructure as a code paradigm was implemented by using Terraform

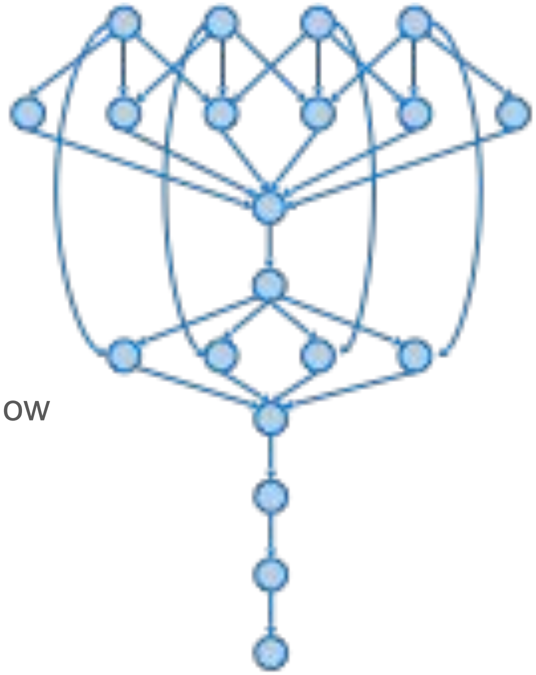
Architecture



Experiment setup

- Test two infrastructure models:
  - Container based
  - Hybrid (containers + cloud functions)

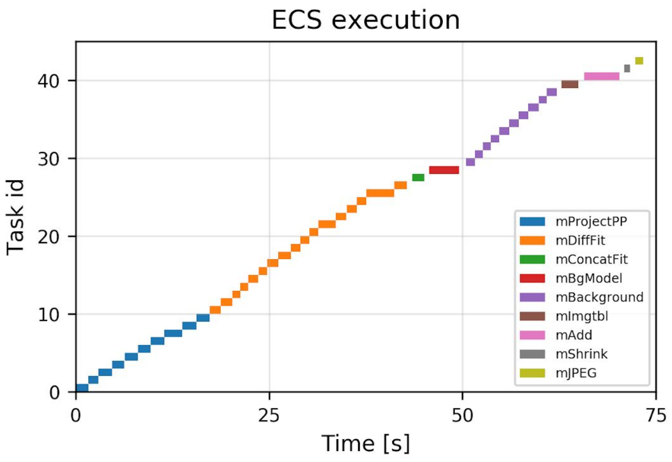
- Testing workload:
  - Montage (Image Mosaic Software), a popular example of workflow
  - 0.5 degree workflow
  - over 40 tasks
    - parallelizable

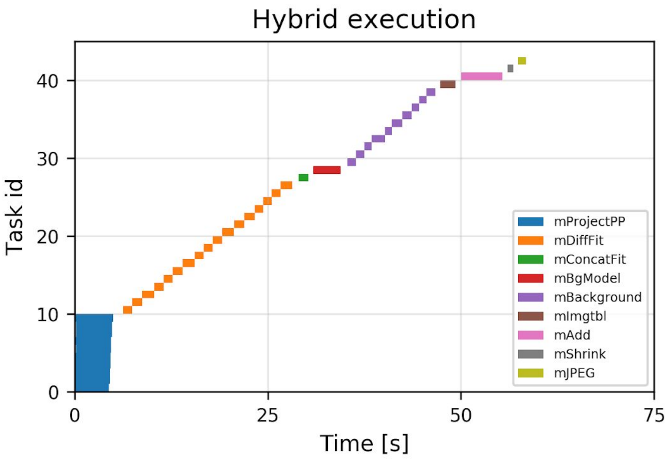


Experiment results (preliminary)

- Left chart: single Instance of container-worker hosted by t2.micro managed through ECS
- right chart: above infrastructure was extended with 256 MB Lambda

- Overall timespan was reduced, but at a slightly higher cost of execution





Hybrid Infrastructure scheduling

- Build on a basis of “Cloud function optimizer” [8]
  - workflow preprocessor
  - builds an execution plan, determines target infrastructure and its configuration based on certain criteria
- Prepare execution plan based with constraints like:
  - cost
  - timespan/deadline
  - data access overheads

Conclusions

- Using hybrid infrastructure can be beneficial for certain type of workflows
- Cloud functions can't be treated as universal replacement for containers, rather a supplement
- Overall hybrid infrastructure allows for covering a wider space of possible workflow execution constraints

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