Containerized Workflow Scheduling

Research Project 1
Project #71

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July 5, 2018

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Introduction - Workflows

- Nodes represent tasks
- Edges represent dependencies

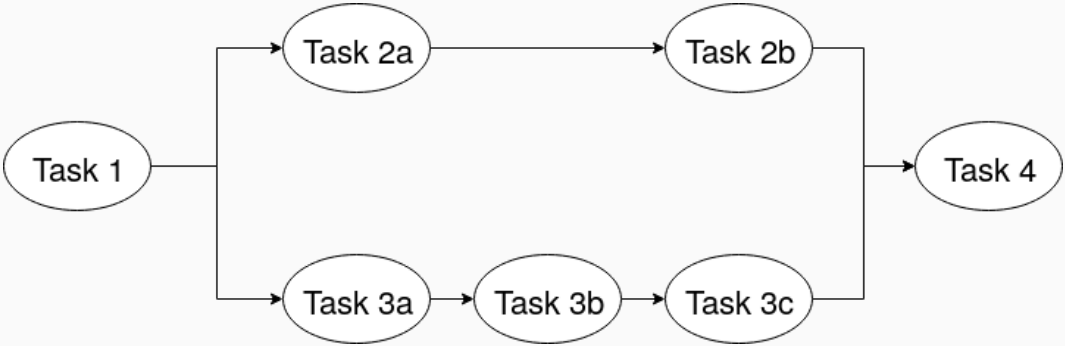


Figure 1: Example workflow

Introduction - Workflow Management Systems

- Used to manage/execute workflows
- Automation
- Failure recovery
- Map tasks to resources
- Examples:
  - Pegasus [1]
  - Taverna [2]

Introduction - Tasks as Containers

- OS-level Virtualization
- Lightweight
- Stand-alone

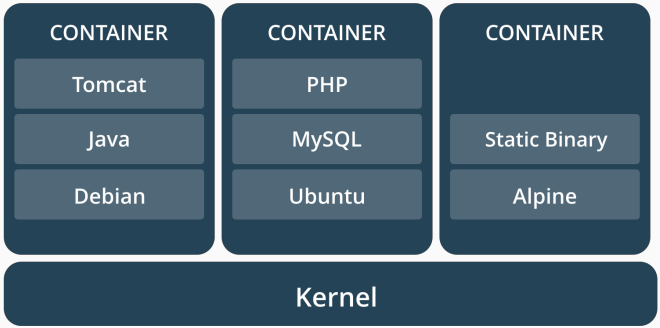


Figure 2: Example of binaries packaged with their dependencies in a container [3]

Introduction - Container Orchestration

- Containers at scale
- Cluster of multiple nodes
- Automates scheduling, deployment and management of containers
- Examples:
  - Docker Swarm [4]
  - Kubernetes [5]

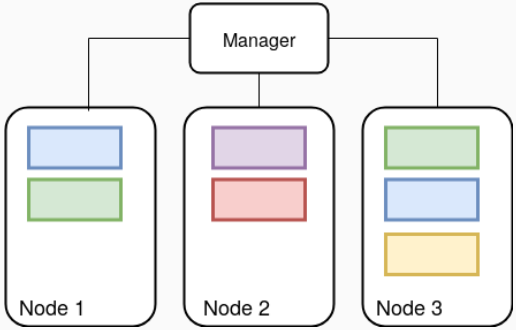


Figure 3: Example of a cluster with 3 worker nodes.

Problem statement - Combining Workflows and Container Scheduling

- Find node for container
- Queue is FIFO
- Context of task is lost
- No dependencies
- Ordering/Dependencies on higher level

Research Question

How can we order the execution
of a containerized workflow on a container scheduler?

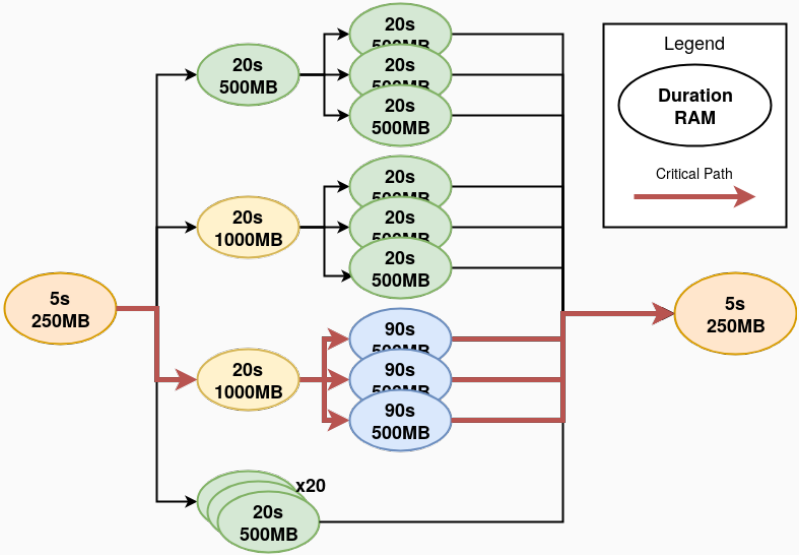
Related Work

- Argo - Container-native workflow engine for Kubernetes [6]
- Apache Airflow - Plugin for Kubernetes (in development) [7]
- Makeflow on Mesos by Zheng et al. [8]

Method

1. Design a workflow with a critical path
2. Run workflow on container schedulers
    - Two container scheduling algorithms: Docker Swarm and Kubernetes
    - Two workflow scheduling algorithms: Critical path and Batch
3. Measure total execution time

Method - The Workflow



Method

- Infinite resources: 5+20+90+5=120 seconds
- Constrained resources:
  - Swarm: 5 nodes x 1 GB RAM
  - Kubernetes: 4 nodes x 1 GB RAM
- Assuming no overhead:
- Depending on the ordering of tasks

Table 1: Lowest/Highest possible total execution times assuming no overhead

Scheduler	Lowest	Highest
Swarm	120s	160s
Kubernetes	130s	180s

Method - Order the Execution

- Submit containers in order
  - Scheduler queue is not FIFO
  - Seemingly random
- Kubernetes:
  - Priority flag
- Swarm:
  - No priority flag
  - Hold back part of tasks

Results - Swarm

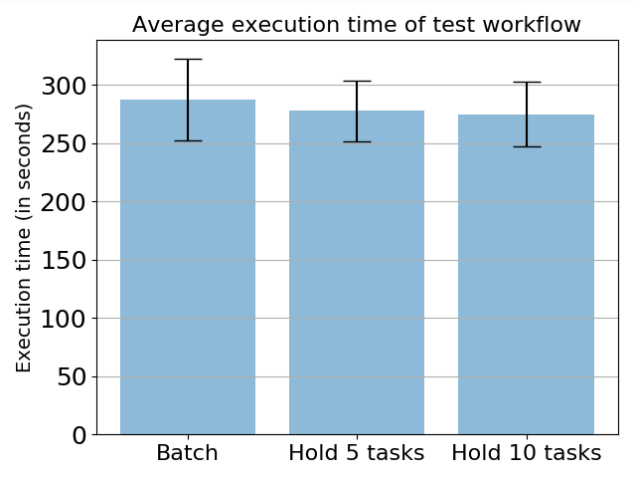


Figure 5: Average execution time of the Workflow on Swarm

Results - Kubernetes

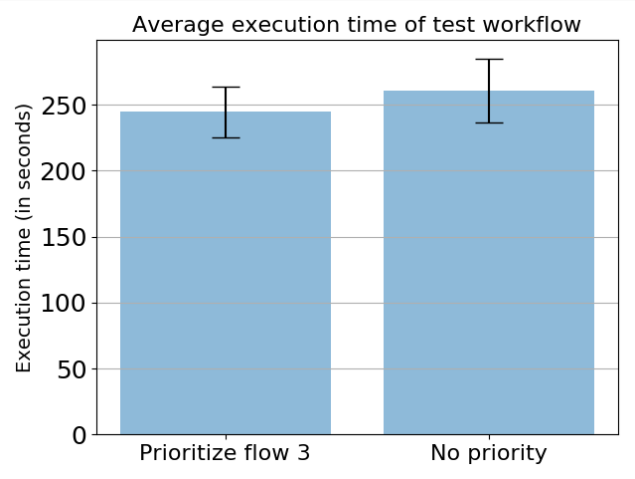


Figure 6: Average execution time of the Workflow on Kubernetes

Conclusion

- Scheduling queue is not FIFO
- Execution time is erratic
- Critical path slightly lower execution times

Discussion

- Container schedulers lack features
- Kubernetes priority flag does pre-emption
- Interface between Workflow Management System and Container Scheduler
  - Monitoring
  - Active re-ordering
- More scheduling algorithms

Questions?

Questions?

References i

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