Modeling Scheduling Policies for Serverless Computing

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August 30, 2021

Research project performed at LIG, Datamove INRIA Team

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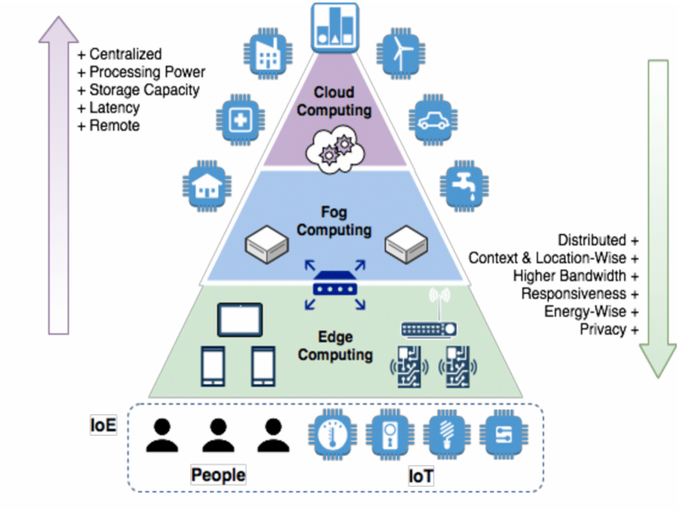
Related Work

- There are works presenting Serverless in cloud applications using bin-packing algorithms [14, 5], or knapsacks [3].
- I. Baldini et al. survey existing serverless platforms used in industry, academia and opensource projects [7].
- W. Shi et al. define the concept of Edge computing [24].
- D. Shmoys and E. Tardos developed an approximation algorithm [25] to assign independent tasks to unrelated machines.

Summary

Edge Computing ?



Edge Computing Overview
[Source : DOI:10.1109/CONIITI.2018.8587095]

Serverless Computing

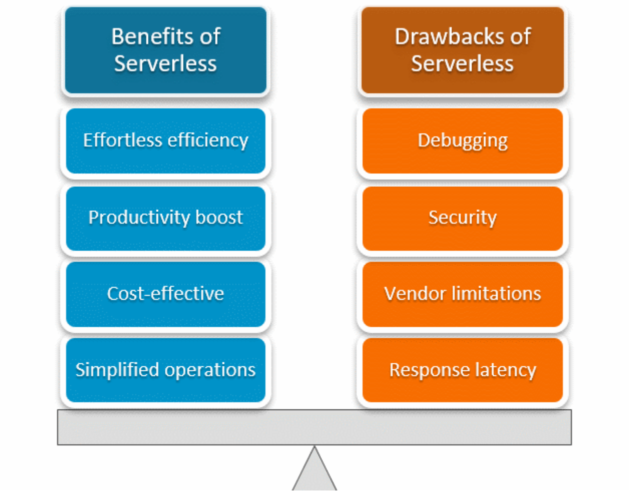
- AWS Lambda, a serverless computing platform by Amazon
- AWS popularized the Function as a Service (FaaS) definition, which became Serverless later

Change of Responsibility

The service provider takes care of:

- capacity planning,
- configuration,
- management,
- maintenance,
- fault tolerance,
- scaling of containers,
- physical servers

Benefits and Drawbacks of Serverless



Benefits and Drawbacks of Serverless
[Source : bmc.com/blogs/serverless-computing/]

Serverless example

An example of Serverless application

Source : martinfowler.com/articles/serverless.html

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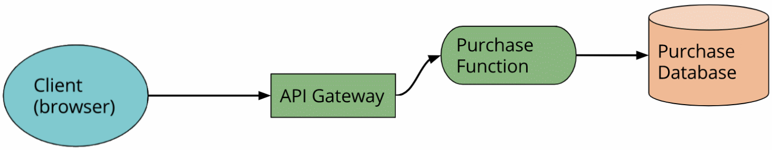
Serverless example



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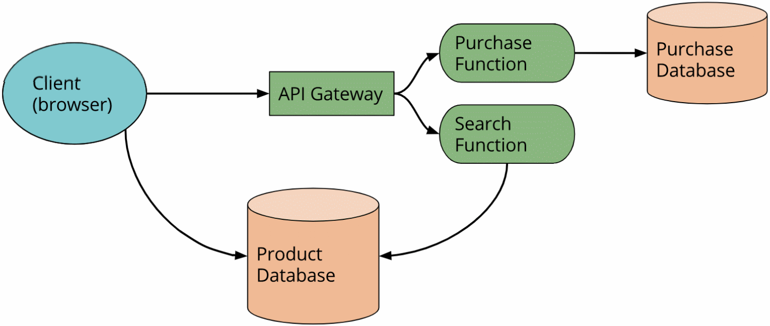
Serverless example



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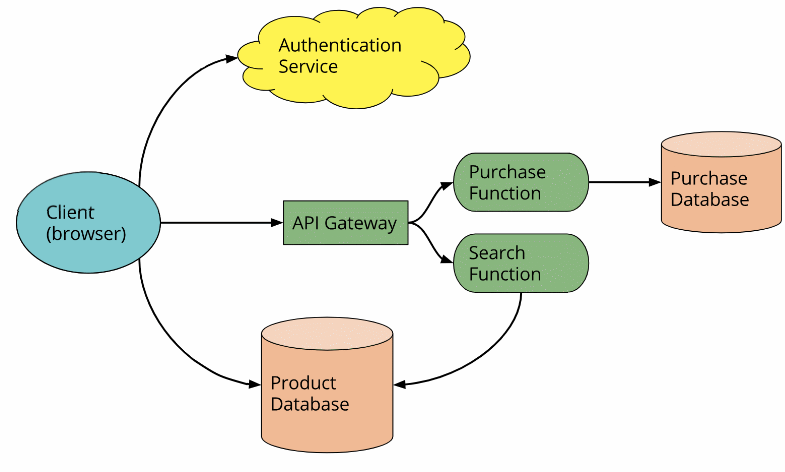
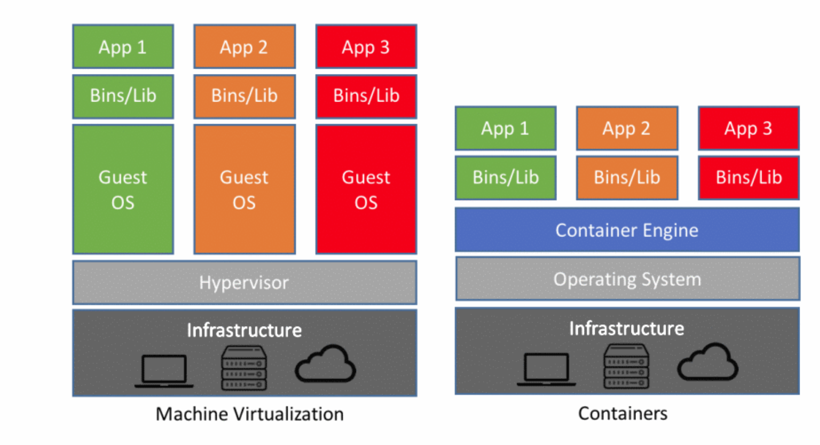
Serverless example



An example of Serverless application

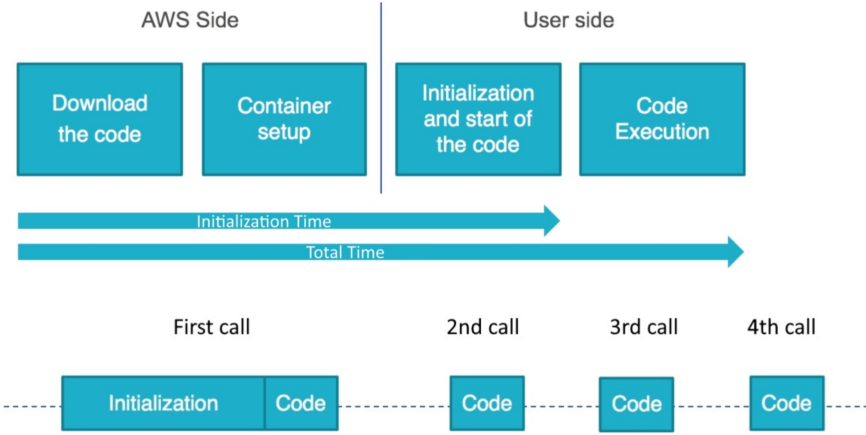
Source : martinfowler.com/articles/serverless.html

Containers vs Virtual Machines



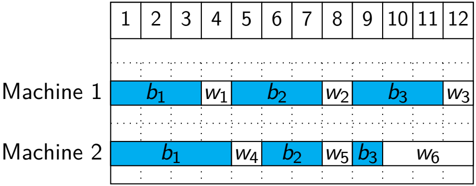
Source : netapp.com/blog/containers-vs-vms/

A model of containers

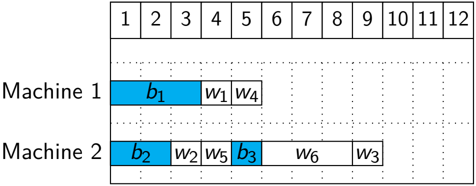


Source : AWS re:Invent 2017 – Become a serverless Black Belt

A model of containers



If every function boots its environment

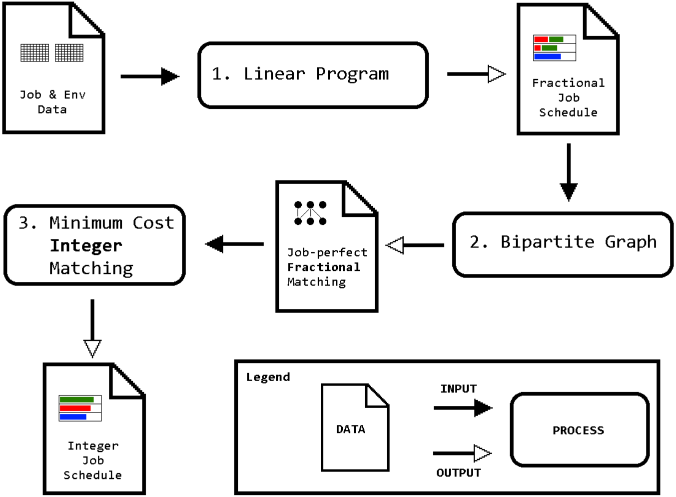


If environments are considered separately

Assumptions

- Tasks and environments are independent and known in advance
- Their cost and processing time on a machine is known
- The dependency between tasks and environments is known
- Communication time and cost are ignored

Algorithm


Job & Env
Data
1. Linear Program
Fractional
Job
Schedule
2. Bipartite Graph
Job-perfect
Fractional
Matching
3. Minimum Cost
Integer
Matching
Integer
Job
Schedule
Legend
DATA
INPUT
OUTPUT
PROCESS

Linear Program : Variables

```
int M;                          //Nb of Machines
int N;                          //Nb of Jobs
int c[0..M][0..N];              //Cost of a Job on a Machine
int p[0..M][0..N];              //Time of a Job on a Machine

int K;                          //Nb of Environments
int d[0..M][0..K];              //Cost of a Env on a Machine
int b[0..M][0..K];              //Time of a Env on a Machine
int env[0..N];                  //Job i needs Env env[i]

dvar float x[0..M][0..N];       //Job placement on Machines
dvar float e[0..M][0..K];       //Env placement on Machines
```

Linear Program : Constraints

$$\sum_{i=1}^{M} \sum_{j=1}^{N} c_{ij} * x_{ij} + \sum_{i=1}^{M} \sum_{k=1}^{K} d_{ik} * e_{ik} \leq C \tag{1}$$

$$\sum_{i=1}^{M} x_{ij} = 1 \qquad \forall j \leq N \tag{2}$$

$$\sum_{j=1}^{N} p_{ij} * x_{ij} + \sum_{k=1}^{K} b_{ik} * e_{ik} \leq T \qquad \forall i \leq M \tag{3}$$

$$x_{ij} \geq 0 \qquad \forall i \leq M, \forall j \leq N \tag{4}$$

$$x_{ij} = 0 \text{ if } p_{ij} + b_{i,env[j]} > T \qquad \forall i \leq M, \forall j \leq N \tag{5}$$

$$x_{ij} \leq e_{i,env[j]} \qquad \forall i \leq M, \forall j \leq N \tag{6}$$

$$e_{ik} \leq 1 \qquad \forall i \leq M, \forall k \leq K \tag{7}$$

$$e_{ik} \geq 0 \qquad \forall i \leq M, \forall k \leq K \tag{8}$$

Bipartite Graph

For a bipartite graph $G = (X + Y, E)$, the following properties are equivalent :

- G admits an X-perfect fractional matching
- G admits an X-perfect integral matching
- G satisfies Hall's marriage theorem's condition

Bipartite Graph

- $m = 3$
- $n = m(m-1) + 1 = 7$
- $p_{i1} = m, i = 1, ..., m$
- $p_{ij} = 1, i = 1, ..., m, j = 2, ..., n$
- $c_{ij} = 0, i = 1, ..., m, j = 1, ..., n$
- $C = 0$
- $T = 3$

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

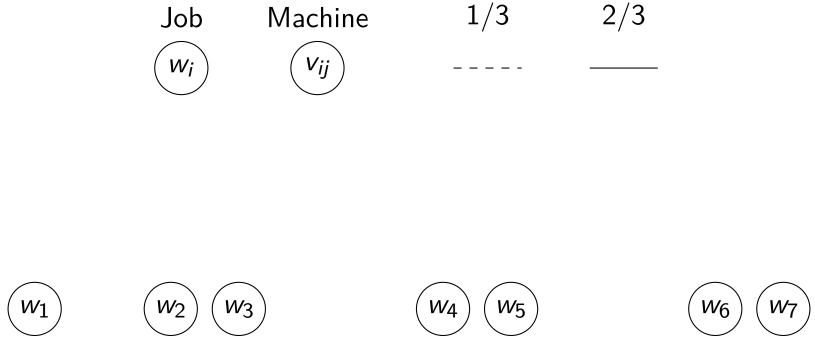
Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

Job	Machine	1/3	2/3
w_i	v_{ij}		

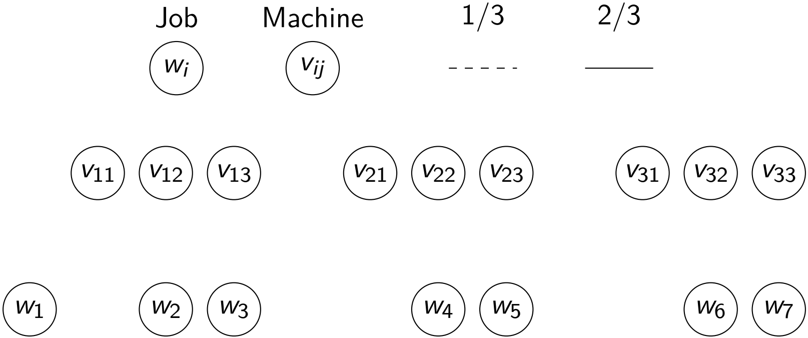
Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$



Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$



Bipartite Graph

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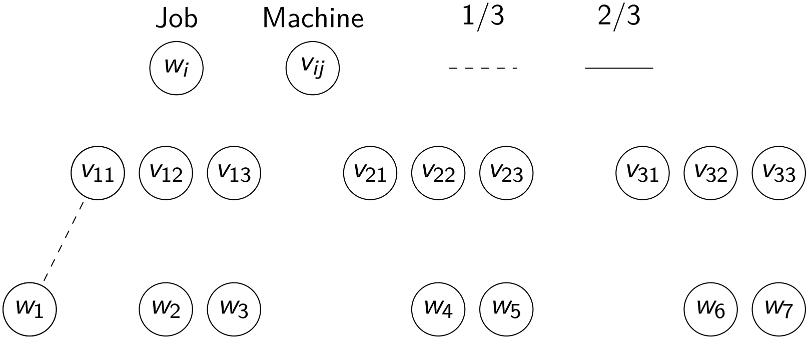
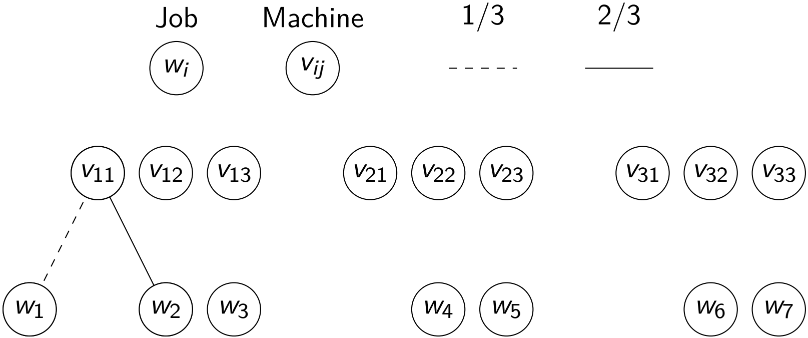


Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$



Bipartite Graph

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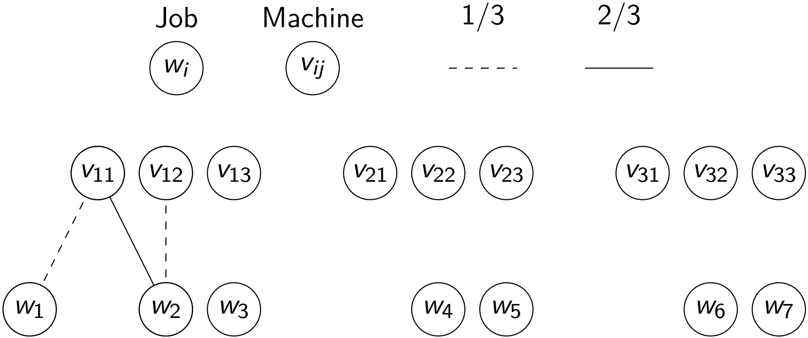
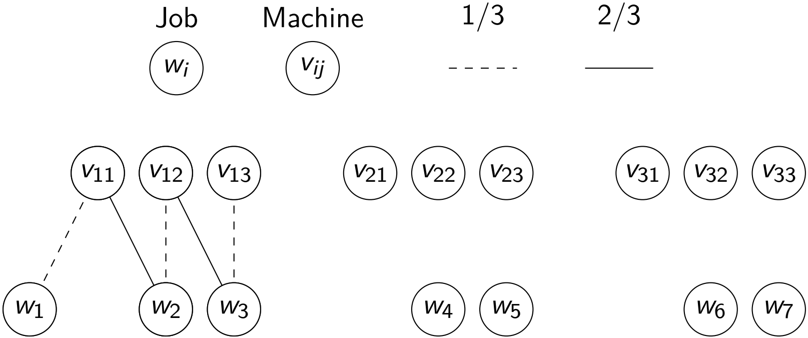


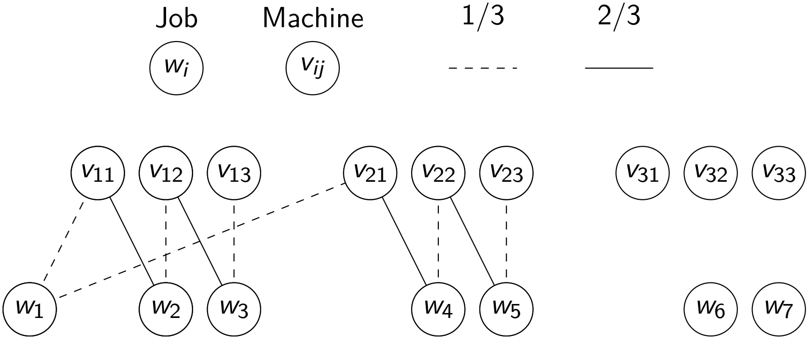
Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$



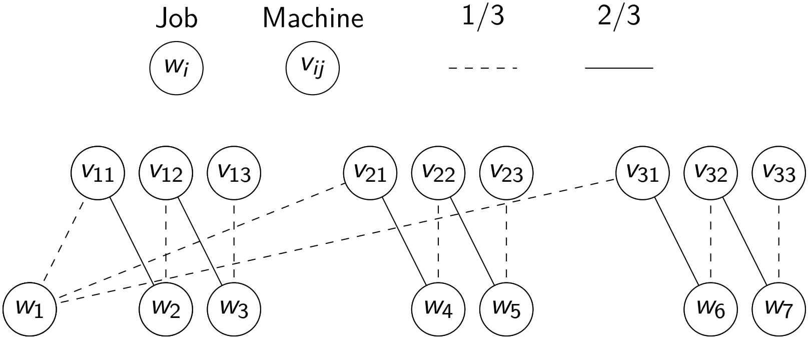
Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

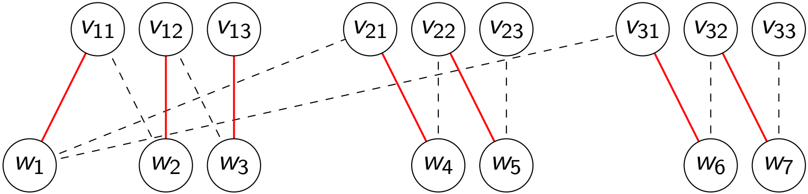


Bipartite Graph

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

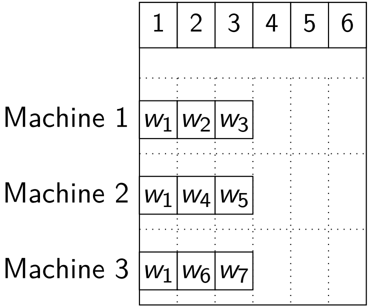


Solutions

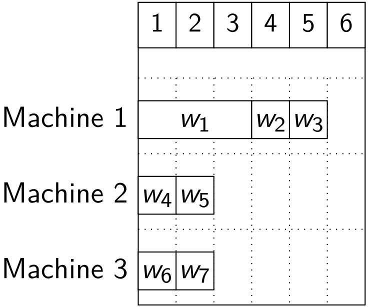


$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix} \qquad X' = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

$$X = \begin{bmatrix} 1/3 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1/3 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1/3 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

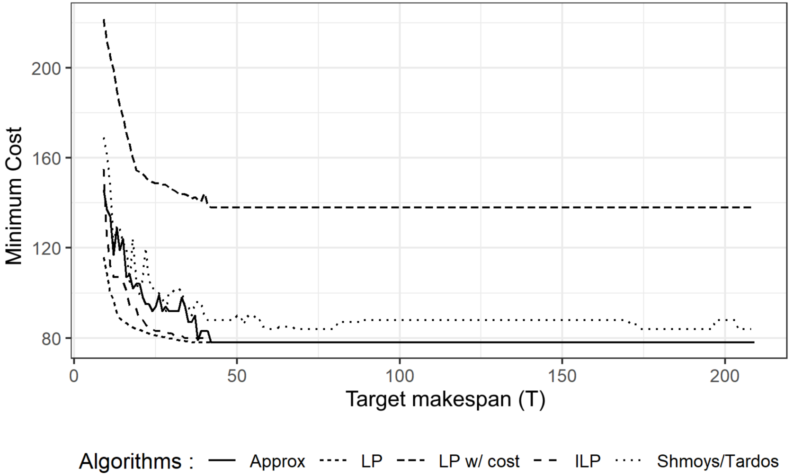


$$X' = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

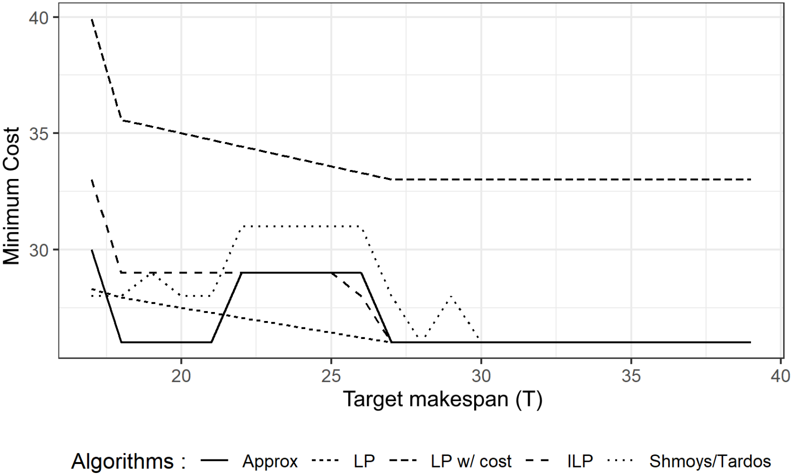


Experimental setup

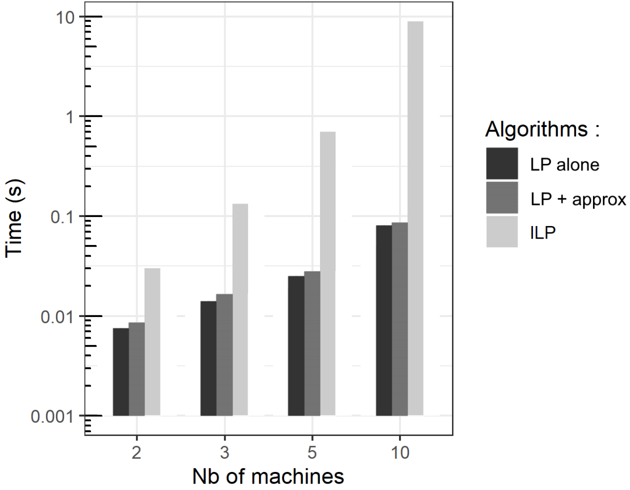
Using python with the library python-MIP and the CBC solver.
For each algorithm, for each T, we find the minimum C that gives a result.



10 machines, 21 tasks, 4 environments



2 machines, 4 tasks, 2 environments



Time to run the algorithms depending on the number of machines

Contributions

- A model of containers
- An algorithm to schedule containers on unrelated machines
- An analysis of parameters for the algorithm

Future Works

- Testing in simulation
- Finding a heuristic to replace the linear program
- Finding a better model for edge platforms

The End

Thanks for listening!

Any questions?

Documentation of the Python-MIP library.
https://python-mip.readthedocs.io/en/latest/.

Marcelo Amaral, Jordà Polo, David Carrera, Iqbal Mohomed, Merve Unuvar, and Malgorzata Steinder.
Performance evaluation of microservices architectures using containers.
In *2015 IEEE 14th International Symposium on Network Computing and Applications*, pages 27–34, 2015.

Silvio Roberto Martins Amarante, Filipe Maciel Roberto, André Ribeiro Cardoso, and Joaquim Celestino.
Using the multiple knapsack problem to model the problem of virtual machine allocation in cloud computing.
In *2013 IEEE 16th International Conference on Computational Science and Engineering*, pages 476–483, 2013.

Mohammad S. Aslanpour, Adel N. Toosi, Claudio Cicconetti, Bahman Javadi, Peter Sbarski, Davide Taibi, Marcos