Cluster-Wide Context Switch of Virtualized Jobs

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INRIA

Agenda

Motivation

Global Design

- Architecture
- Implementation

Proof of concept

- A sample scheduler
- Experiment on a cluster

Conclusion

Agenda

Motivation

Clusters

- large infrastructures to execute various jobs

Resource Management System (RMS)

- manage the execution of jobs
- resources are allocated to jobs according to their description
- scheduling: which jobs to execute, and where ?

Jobs schedulers

Usually

A corse-grain exploitation of resources :

- static allocation of resources
- execution to completion

Dynamic schedulers exist

Based on mechanisms that manipulate the jobs dynamically (migration, preemption, dynamic allocation of resources, ...). BUT

- mechanisms are complex to implement
- mechanisms are complex to use efficiently

Motivation

Virtual Machines (VMs) as a backend for dynamic schedulers

- each component is embedded into its VM
- VMMs provide migration, preemption
- still complex to use efficiently

A cutting-edge building block

dynamic consolidation, *best-effort jobs* , . . .

- various policies, but common concepts to perform the changes
- each provides an ad-hoc solution to handle several common issues:
  - dependencies between actions
  - correctness
  - reactivity

Proposition

Performing the changes should not be a primary concern for developers

- a generic cluster-wide context switch based on VMs
- developers only focus on the algorithm to select the jobs to run
- the cluster-wide context switch takes care of the rest
  - detects the changes to perform
  - ensures the correctness of the transition
  - computes the fastest possible transition

The implementation leverages the consolidation manager Entropy

Agenda

From jobs to *virtualized Jobs*

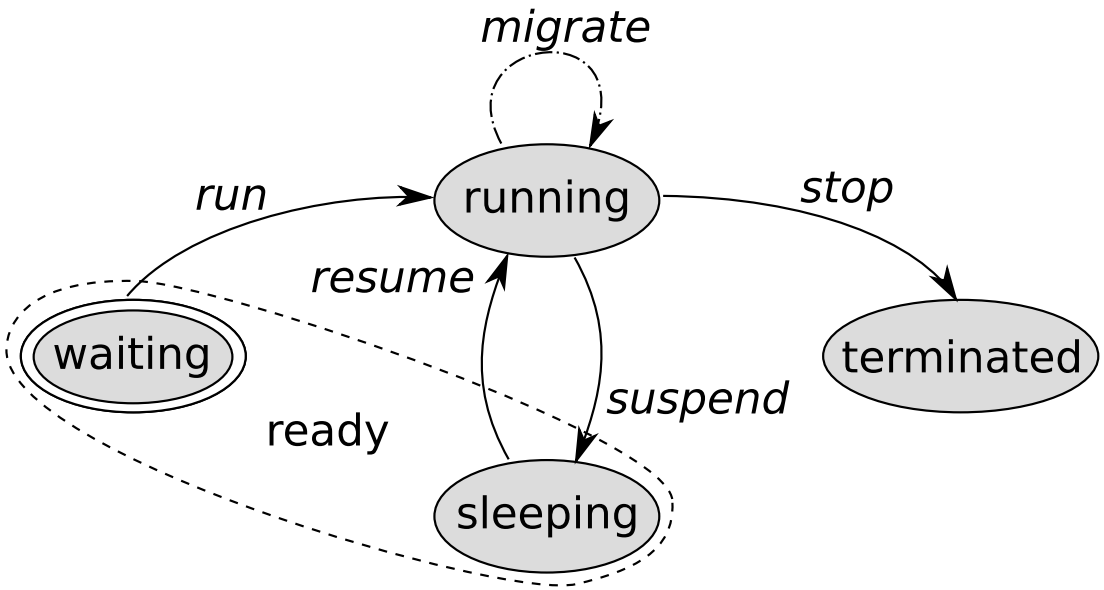
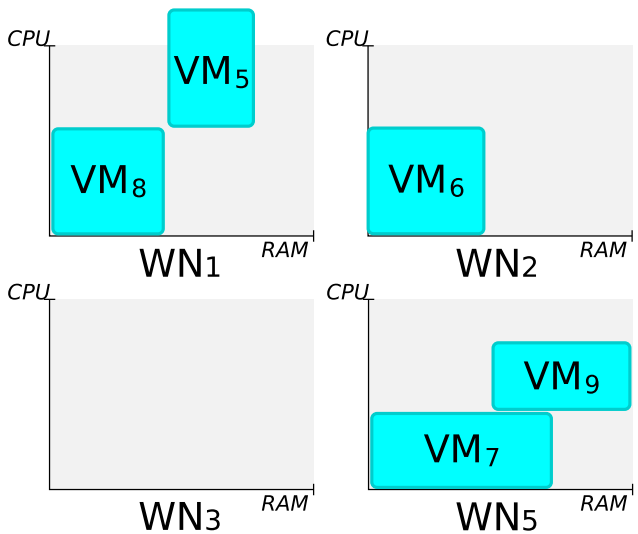


Figure: The life cycle of a vjob

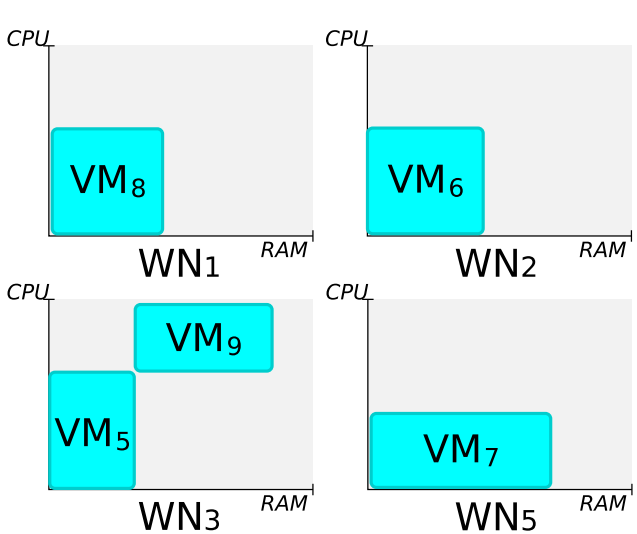
- a vjob encapsulates one or several VMs
- to change the state of a vjob,
  actions (except migrate) are executed on each VMs

Configuration

- describes the assignment of the running VMs to working nodes
- nodes provide CPU and memory resources
- running VMs require CPU and memory resources to run at peak level

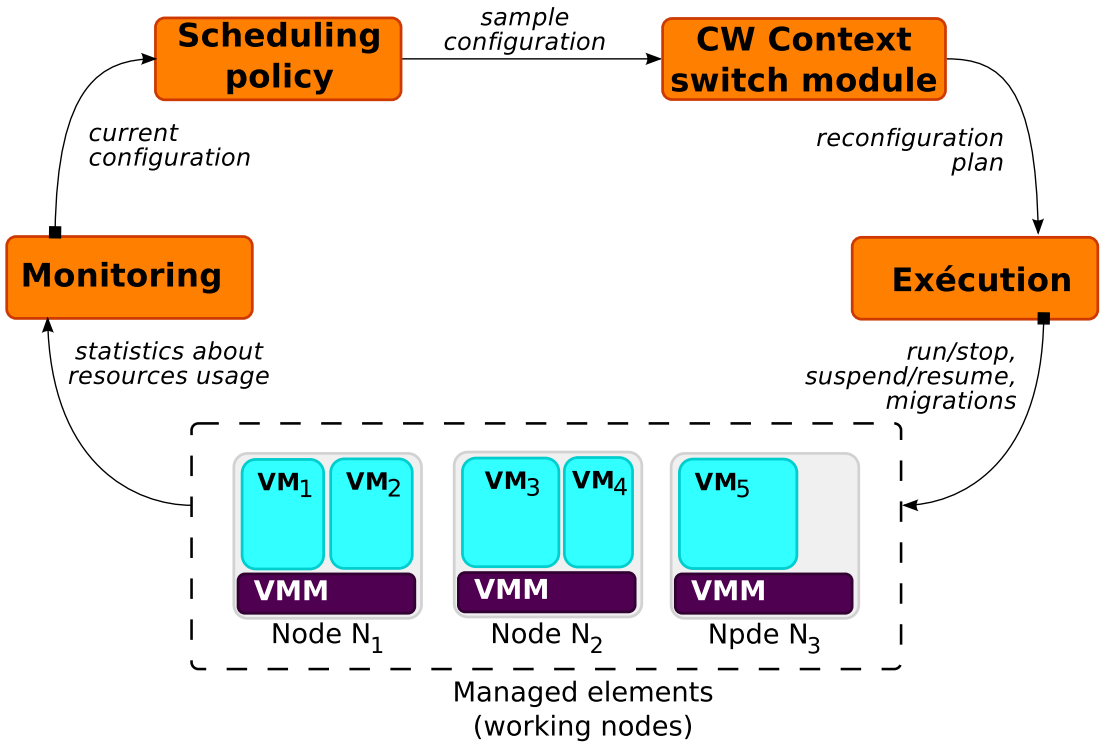


(a) Non-viable configuration



(b) Viable configuration

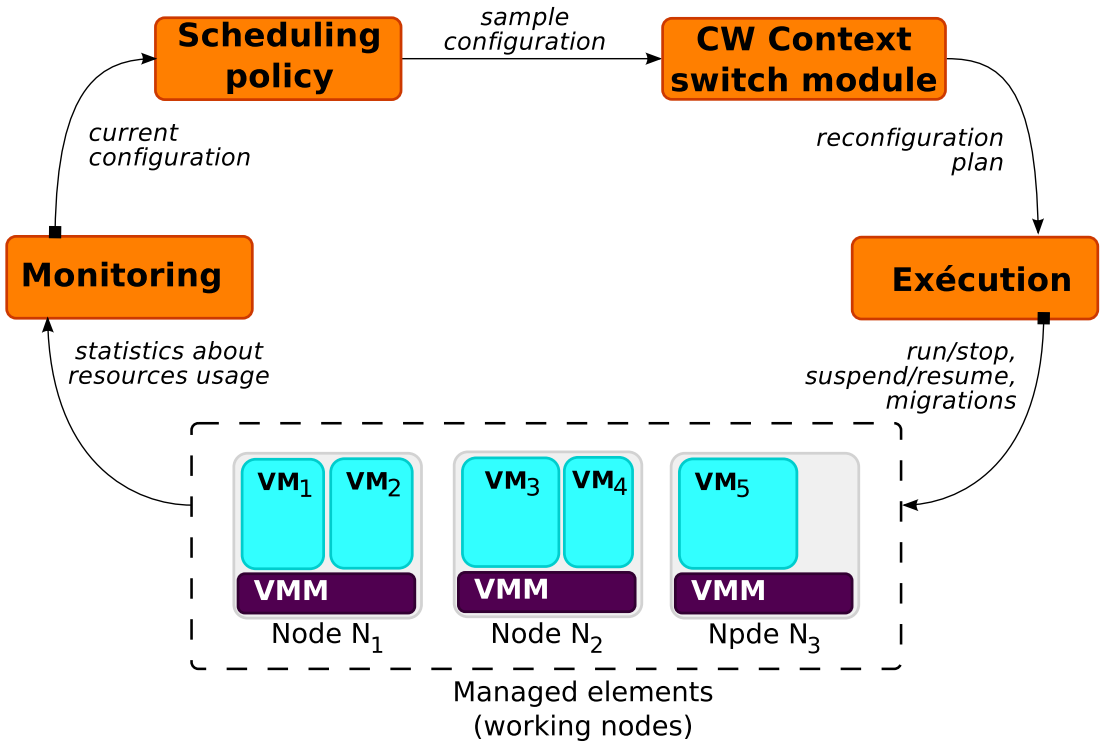
The control loop of Entropy



Monitor

- extract the current configuration:
  VM position, CPU/memory consumption
- adaptable to a specific monitoring system (currently Ganglia)

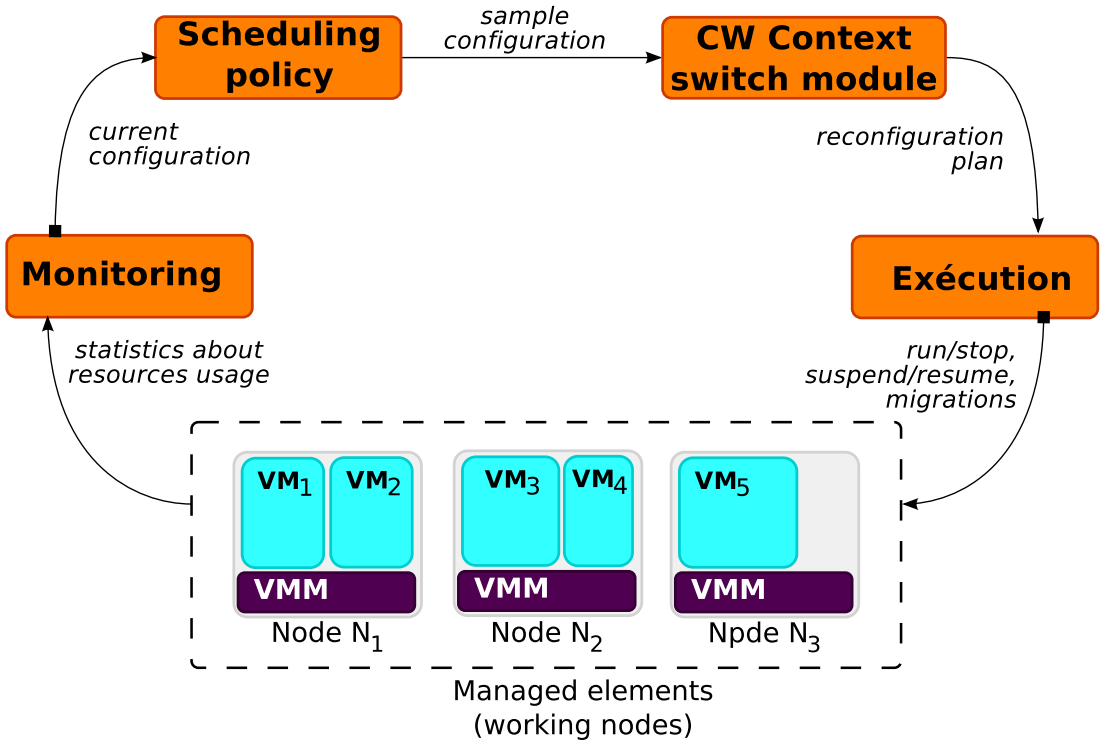
The control loop of Entropy



Scheduling policy

- an algorithm to select the vjobs to run wrt. the current configuration
- provided by a developer

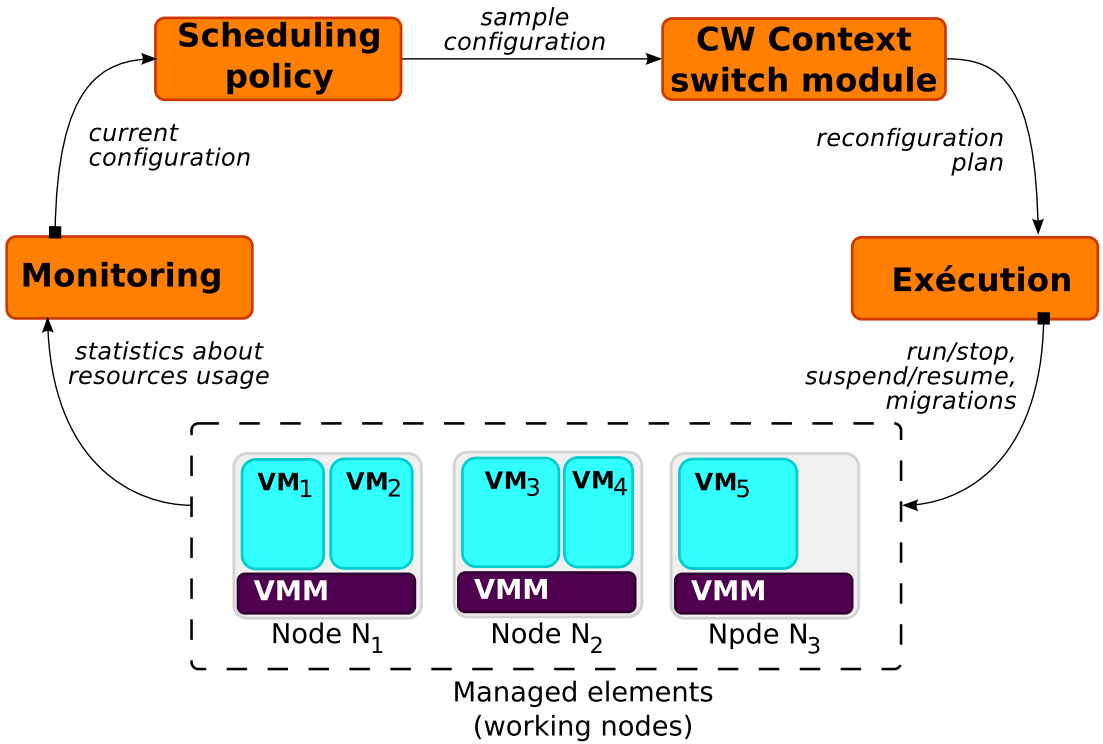
The control loop of Entropy



The cluster-wide context switch module

- selects a position for each VM to run
- infers the actions that make the transition w. the current configuration
- computes the fastest plan that ensure the correctness of the process

The control loop of Entropy



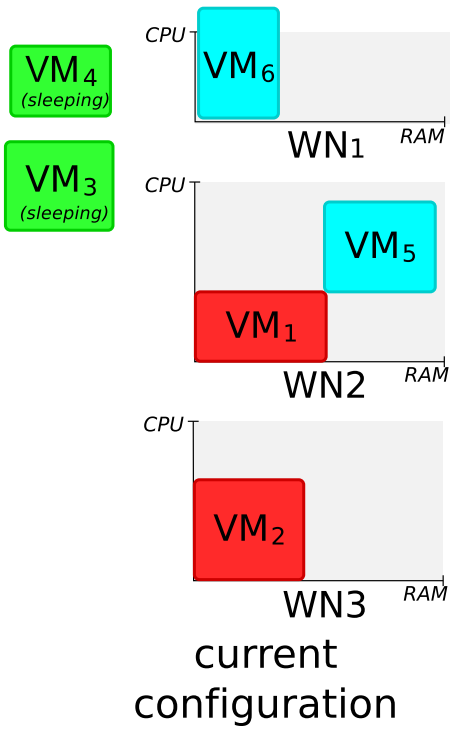
Execution

- associate each action of the plan with a driver that performs the action
- adaptable to specific environments.
  Currently support Xen VMM (XML-RPC) or shell command

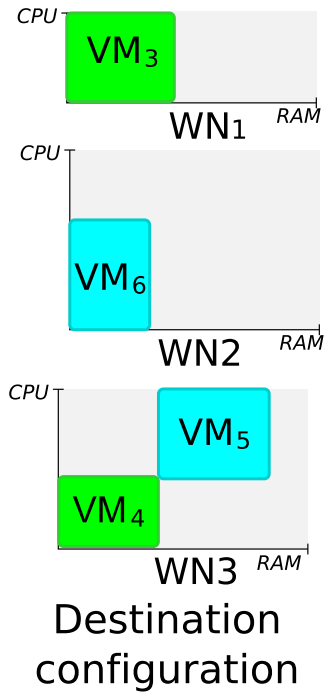
Role of the CW context switch

- detects the actions to perform
- selects a position for each VM to run
- plans the actions to guarantee the correctness of the process
- computes the fastest possible plan

Plan the actions

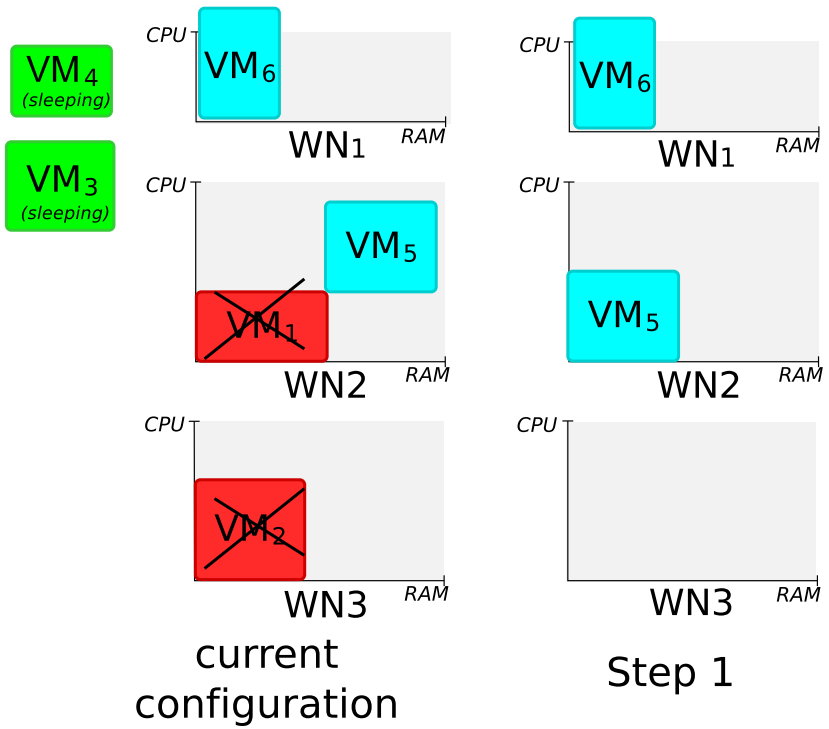


current configuration



Destination configuration

Plan the actions



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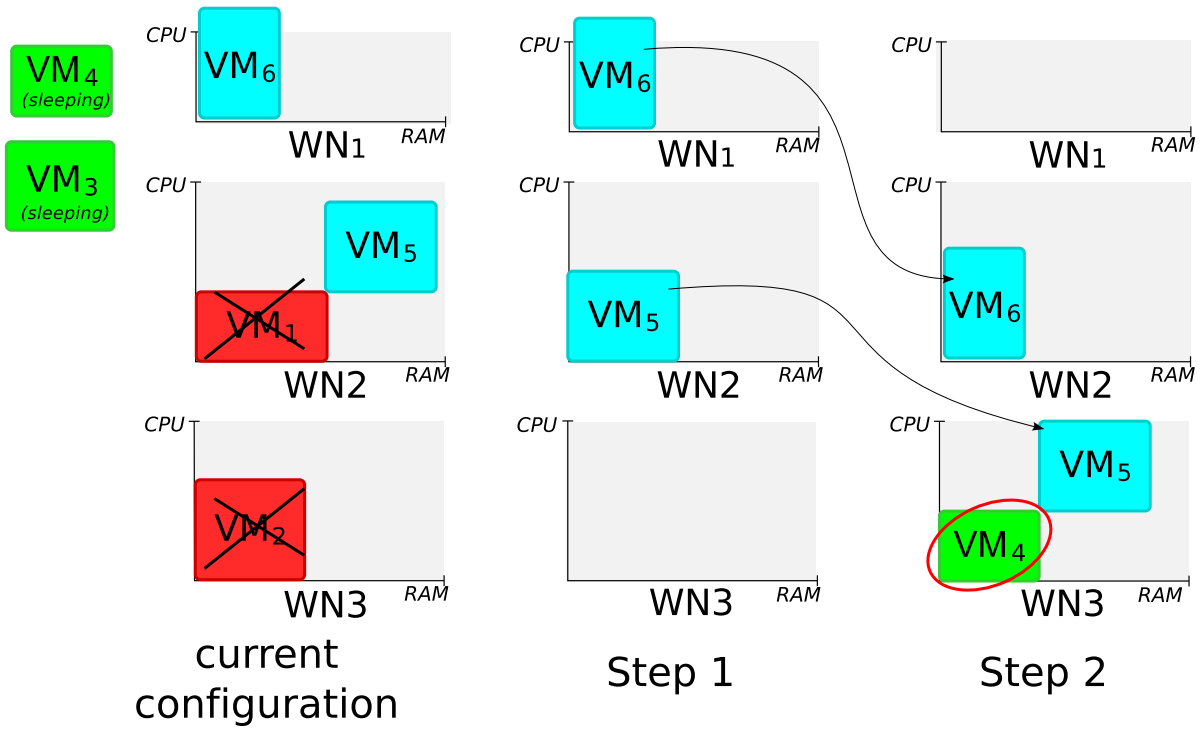

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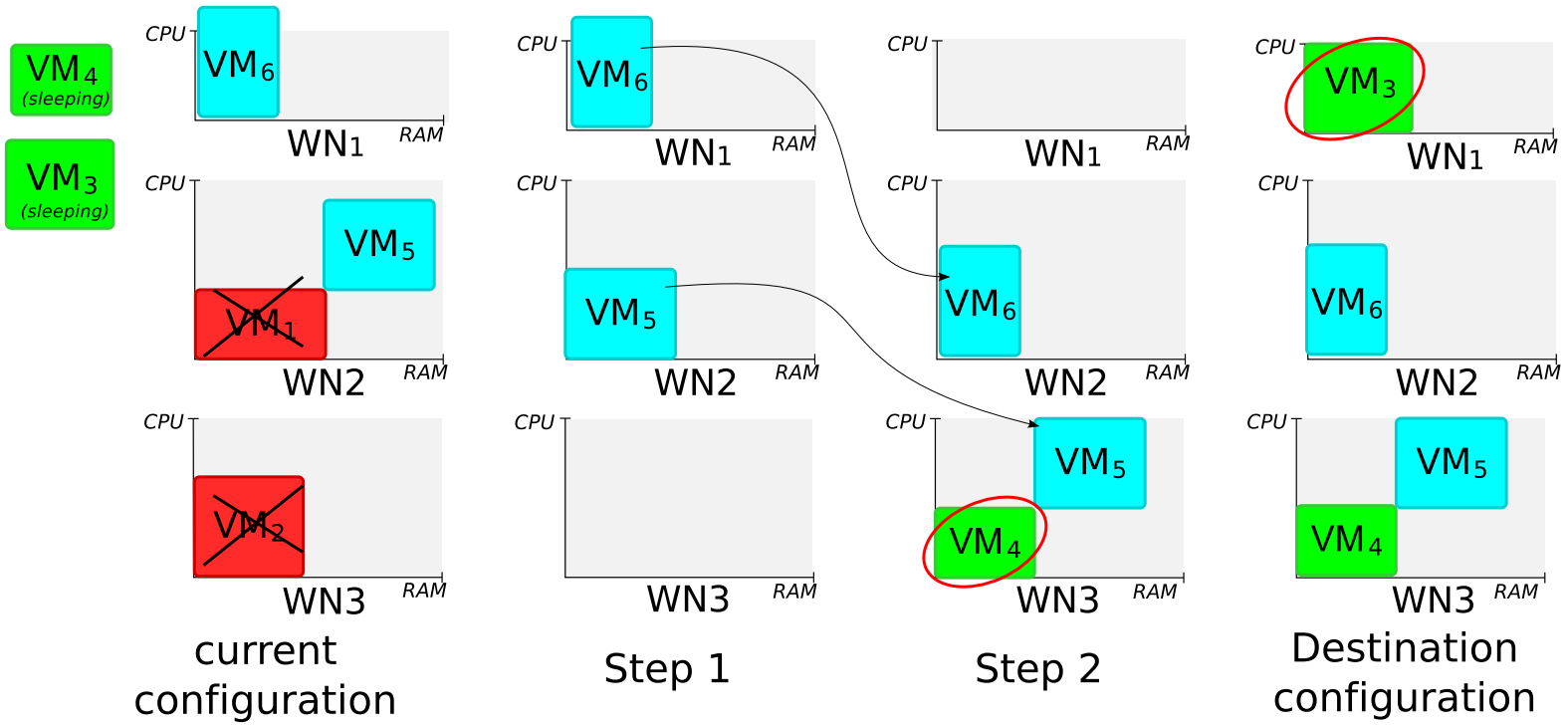
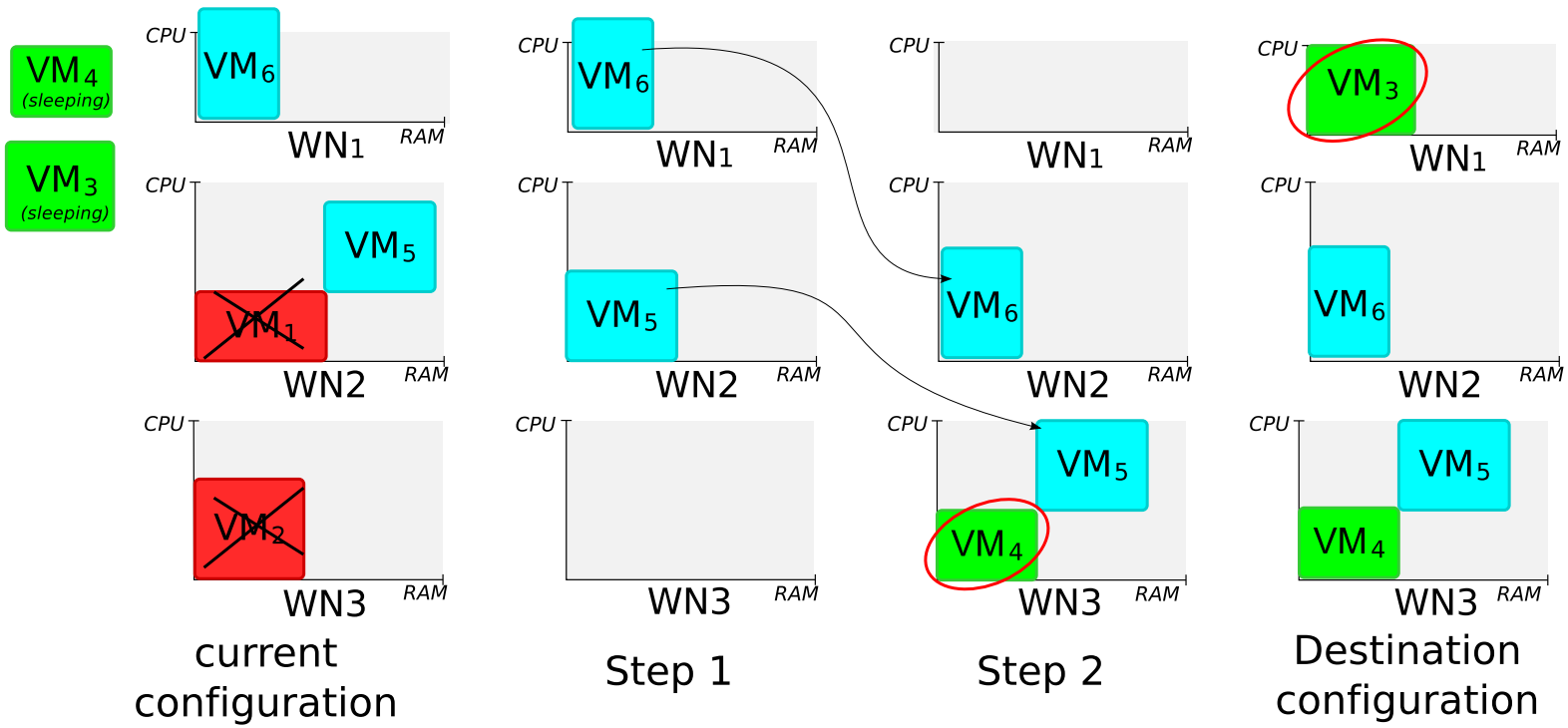


The reconfiguration plan

- a protocol to execute actions
- actions feasible in parallel are grouped into a same step
- steps are executed sequentially

Suspending/Resuming a vjob

- inter-connected VMs should be continuously in the same state
- coordination to ensure that distributed applications will not fail



Suspending/Resuming a vjob

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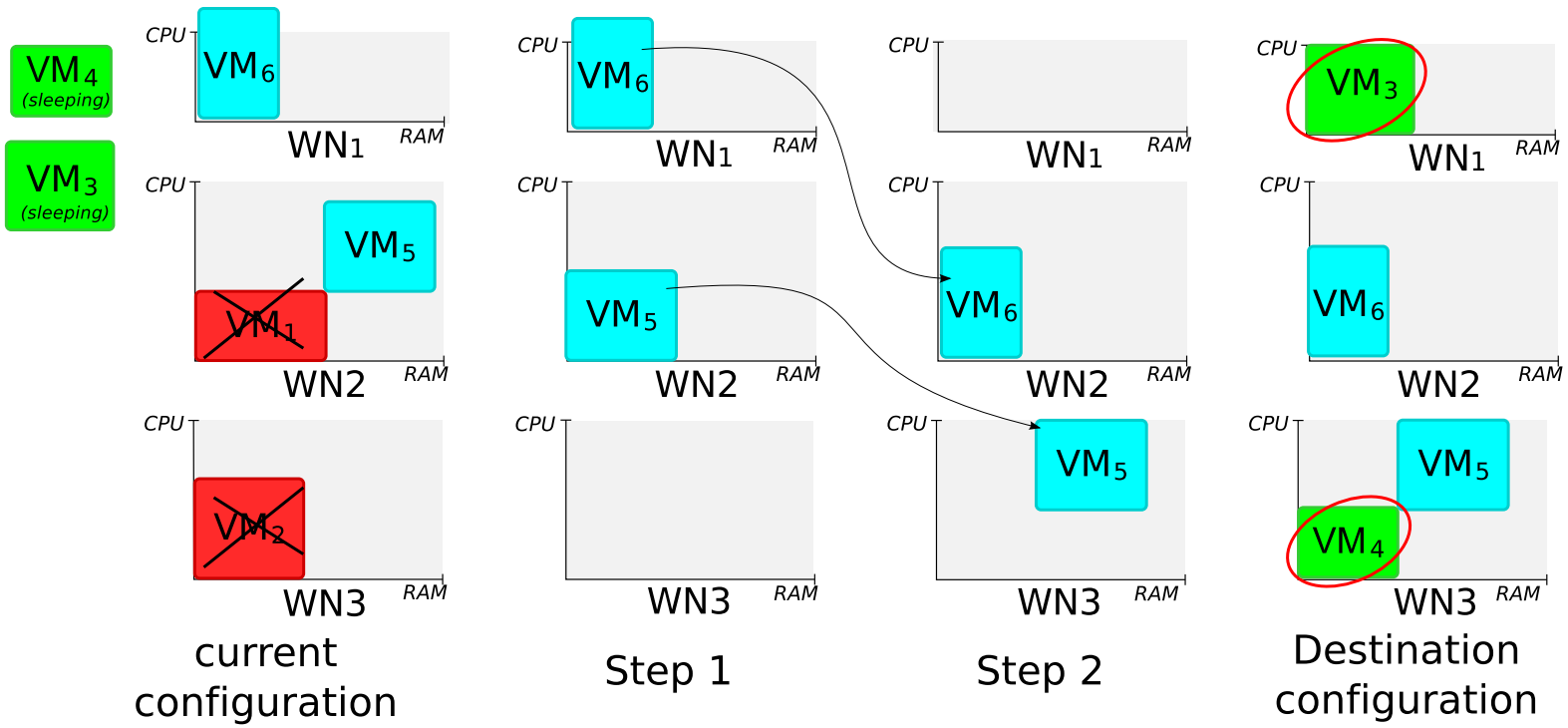
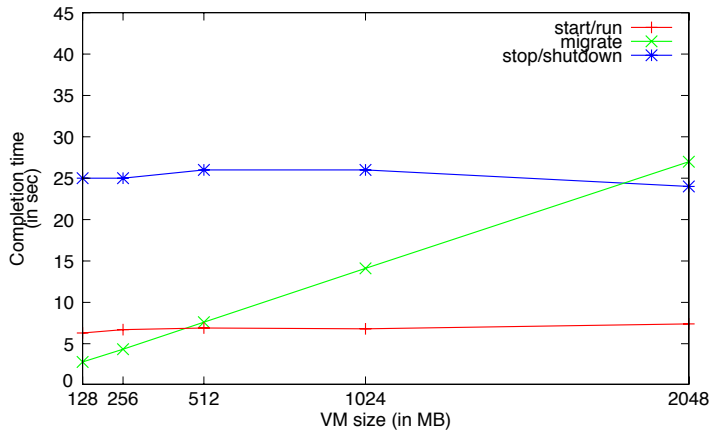
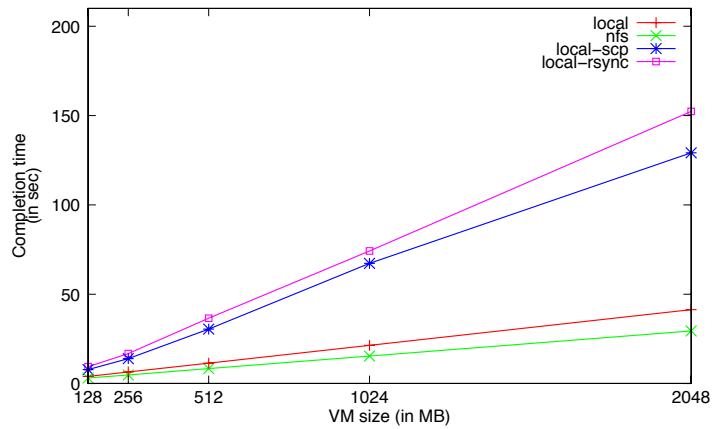


- actions are grouped into a same step
- synchronization between the pause/unpause actions

Reducing the duration of a cluster-wide context switch





- the duration of an action depends on its context
- a function estimates the cost of a whole CW context switch

Reducing the duration of a CW context switch

An approach based on constraint programing

Entropy computes a new configuration that

- is viable
- respects the scheduling policy
- implies the minimal cost

In practice

- actions are performed asap.
- prefer moving VMs will small memory requirements
- avoid migrations and remote resumes

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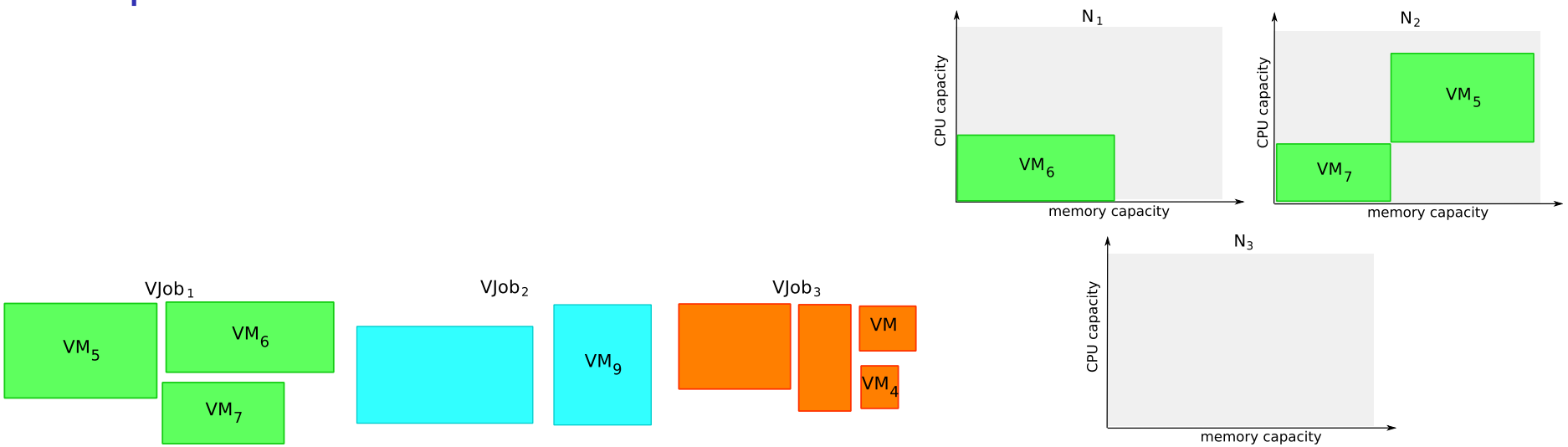
A sample scheduler

Principle

- a FIFO queue
- VMs are assigned to nodes using a First Fit Decrease heuristic
- priority between jobs to prevent starvation

Example



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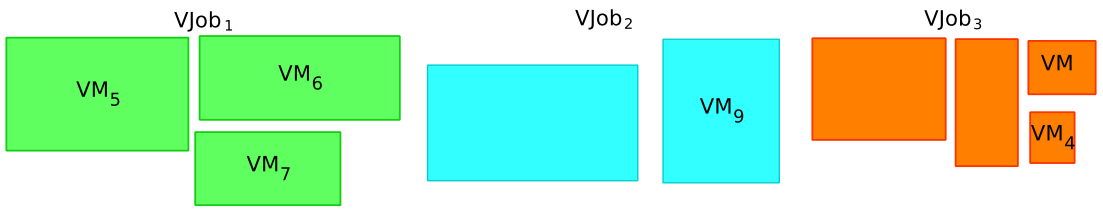

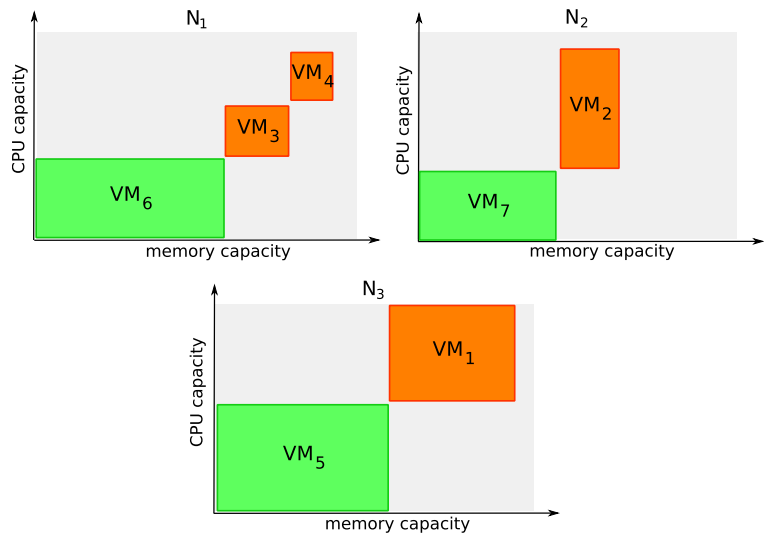

A sample scheduler

Principle

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- VMs are assigned to nodes using a First Fit Decrease heuristic
- priority between jobs to prevent starvation

Benefits using CW context switch

- dynamic allocation of resources
- preemption
- migration of VMs

Environment

Hardware

- 11 working nodes
- 3 storage nodes share VM images
- 1 service node is running Entropy

Protocol

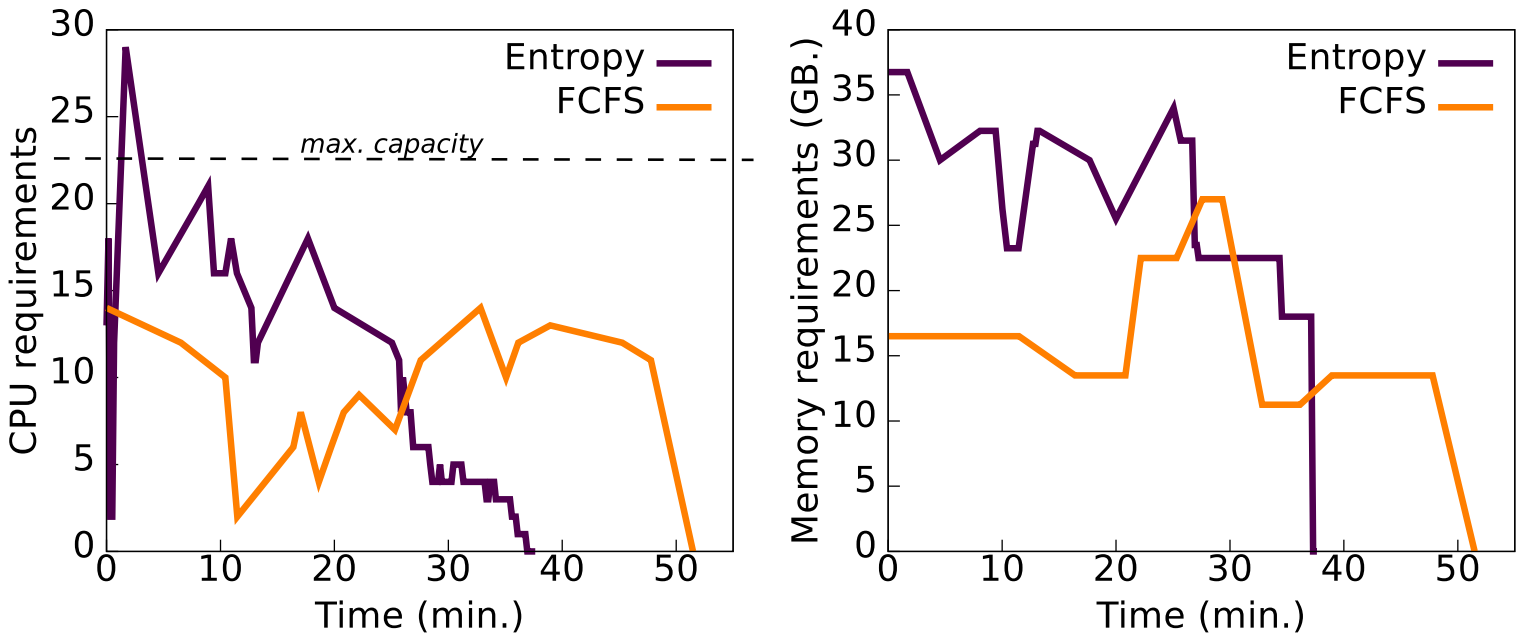
- a queue of 8 vjobs (NASGrid benchmarks)
- each vjob uses 9 VMs
- comparison with regards to FCFS
  - resources usage
  - completion time

Experiment on a cluster

Benefits

- improve resource usage
- suspend/resume transparent for the developer

Resources usage



Experiment on a cluster

Benefits

- improve resource usage
- suspend/resume transparent for the developer
- reduce the completion time

Cumulated execution time

- FCFS: 250 minutes
- Entropy: 150 minutes

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Conclusion

RMSs start to manage VMs instead of process

- VMMs provide mechanisms to implement dynamic schedulers
- manipulate VMs is tedious and may be non cost-effective
- various scheduling policies but common concepts to perform the context switch

A generic cluster-wide context switch

- make the implementation of dynamic schedulers easier
- the context switch is outside the scheduling algorithm
- an implementation in Entropy with a sample algorithm

`http://entropy.gforge.inria.fr`
version 1.2 (LGPL)

I'm looking for a postdoc position

- fond of - virtualization, distributed systems, autonomic computing, ...
- dislike - tomatoes