Toward efficient and safe deployment and reconfiguration of distributed software

68NQRT seminar - IRISA

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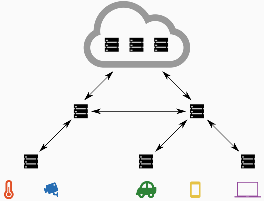
Introduction

Distributed infrastructure

Distributed infrastructure

- Set of distributed interconnected machines
- e.g. HPC clusters, Local servers, Grid (Grid'5000, EGI), private/public Cloud (Amazon), Fog and Edge
- Properties: heterogeneous, large scale



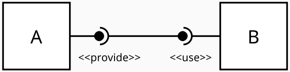
Distributed software

Distributed software

- Software composed of multiple modules
- Dependencies between these modules

Component models

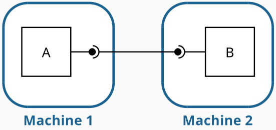
- Set of modules ≈ set of components
- Black box of code
- Explicit *interfaces* through *ports* (e.g. functional dependencies: use-provide)
- *Assembly languages* to define an application
  - instances of components
  - connections between ports
- Separation of concerns, maintainability etc.



What is the deployment?

Deployment

- Placement (mapping modules / resources)
- **Software commissioning**
  - Allocation of resources
  - Creation and configuration of the components
  - Connection of the components
  - etc.



Problem statement

Soft. and infrastructures evolution

- bigger distributed software
  - *e.g.*, OpenStack, Spark, smart-* apps etc.
- massively geo-distributed heterogeneous infrastructures
  - *e.g.*, Fog, Edge, IoT

Problem statement

- deployment automation
- generic deployment
- easy deployment
- efficient deployment
- safe deployment

Deployment

Deployment

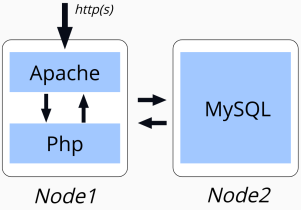
Automated deployment

Automated deployment - Scripts

Installing LAMP (Linux Apache MySQL Php) on a (bare metal) server

Steps

- install an operating system (Linux)
- install (`apt-get install`)
- configuration of Apache, MySQL
- network configuration
- check installation, add plugins etc.

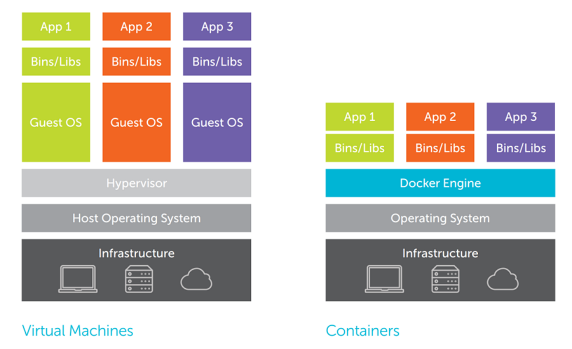


Portability issues and errors

- commands are not portable from one OS to another
- libraries may have different versions on different OSs
- OS specific configurations may be needed
- error prone

Automated deployment - Virtualization

Enhances portability of deployment



Virtual images

- images are needed both for VM and containers
- user can build her/his own images (bootstrap installation)
- user can use existing images (Docker registry, VM templates)

Automated deployment - Virtualization

Installing Apache using Docker and centos basic image

Docker container virtualization

- understand Docker commands
- write or customiza Docker files
- bootstrap problem for IT administrators

Cloud providers

- understand the provisioning API of Cloud providers (AWS Cloud formation, Heat orchestration Template etc.)
- system commands may still be needed to configure or customize the VM
- worse bootstrap problem for Cloud administrators (*e.g.*, OpenStack deployment)

Automated deployment - Tools and models

Ansible, Puppet, Chef

- abstractions above SSH and bash scripts (*e.g.*, yaml, python)
- generic deployment tools (*e.g.*, bare metal, containers or VMs)
- deployment procedure splited in different parts
    - hierarchical view
    - *e.g.*, roles, playbooks, tasks
- data communication between parts
    - *e.g.*, handled by Jinja2
- same set of operations can be applied on multiple hosts
- strict sequential order between different parts (roles, playbooks and tasks)
- bootstrap problem is very limited (ssh, python on nodes)

LAMP deployment in Ansible

LAMP deployment in Puppet

Deployment

State of the art

Classification metrics

Very complex deployment ecosystem: scripts, virtualization, ansible, puppet, chef, kubernetes, juju, etc.

State of the art limited to deployment models and tools

Deployment and components

- 1 module $\approx$ 1 component (*e.g.*, role in Ansible)
- each component has a deployment life-cycle (*e.g.*, stoped, configured, installed etc., plabooks and tasks in Ansible)
- life-cycle management automation is needed

Properties

- Programmable life-cycle (expressivity, safety)
- Life-cycle coordination (automation and safety)
- Parallelism (operations on multiple hosts, inter-component, intra-component)

State of the art

Production tools

Model	Programmable life-cycle	Life-cycles coordination	Parallelism
Ansible/Puppet/Chef	Yes	Yes (sequential)	Same component multiple hosts
Kubernetes	No	No	inter-component
Juju	No	Yes (fixed)	inter-component

Academic research

Model	Programmable life-cycle	Life-cycles coordination	Parallelism
CCM/L2C/Deployware	No	Yes (fixed)	inter-component
Fractal/GCM	Yes	No	inter-component
TOSCA	Yes	No	inter-component
Blender/Aeolus	Yes	Yes	inter-component+

- Madeus is a new component-based deployment model
- Madeus is inpired from Aeolus
- Madeus enhances the efficiency of deployements

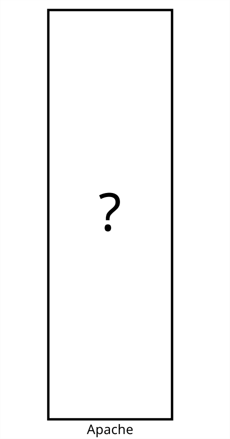
Deployment

Madeus

Madeus - Definitions

Component

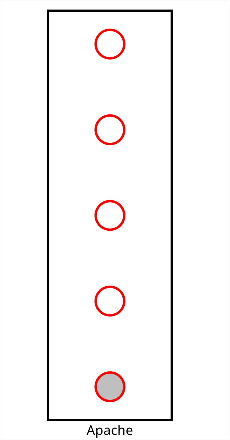
- Usually corresponds to a module of a distributed application
- Has its own life-cycle



Madeus - Definitions

Place

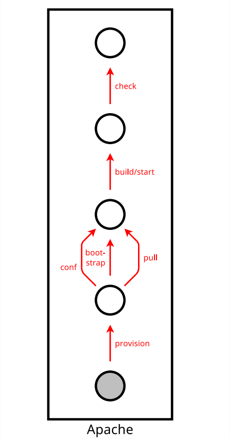
- A “milestone” in the component life-cycle
- Acts as a synchronization mark if multiple actions are performed in parallel



Madeus - Definitions

Transition

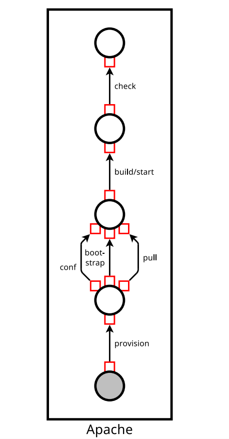
- Bound to an action (i.e. a function)
- From one place to another



Madeus - Definitions

Dock

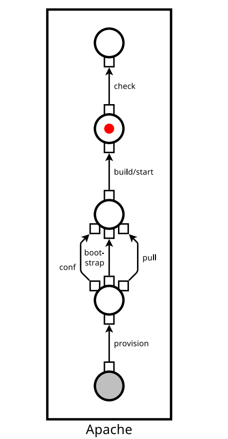
- Allows to handle synchronization of parallel actions with a graphical object
- Attached to places
- Two kinds of docks: input and output
- Connection points for transitions



Madeus - Definitions

Token

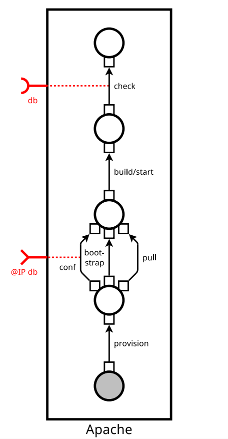
- Represents the state in the life-cycle of the component
- Either present on or absent of each place, dock and transition



Madeus - Definitions

Input port

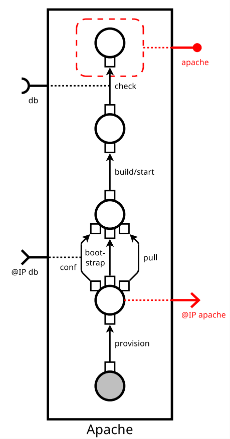
- Bound to transitions that require some data/service
- These transitions can only be triggered when the port is connected



Madeus - Definitions

Output port

- Data output ports: provide data (e.g. IP address)
- Service output ports: indicates that a service is provided by the component



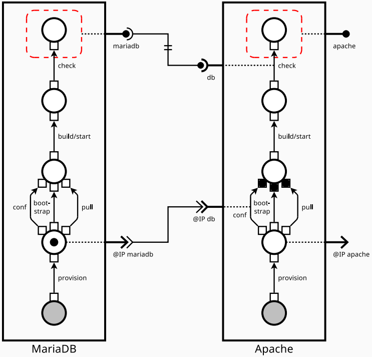
Madeus - Definitions

Assembly

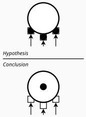
- Set of instances of components
- Connections between their ports
- Similar to a *main* function

Configuration $\langle mk, ebl, val \rangle$

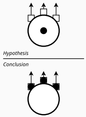
- *mk*: marking = location of tokens
- *ebl*: enabled = whether or not connections are enabled
- *val*: values = values stored in the data output ports



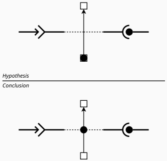
Madeus - Operational Semantics



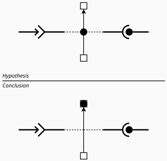
input docks to place



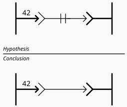
place to output docks



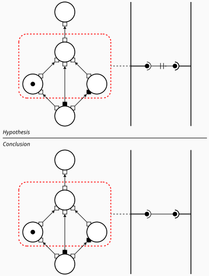
fire transition



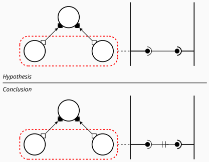
end transition



enable data connection

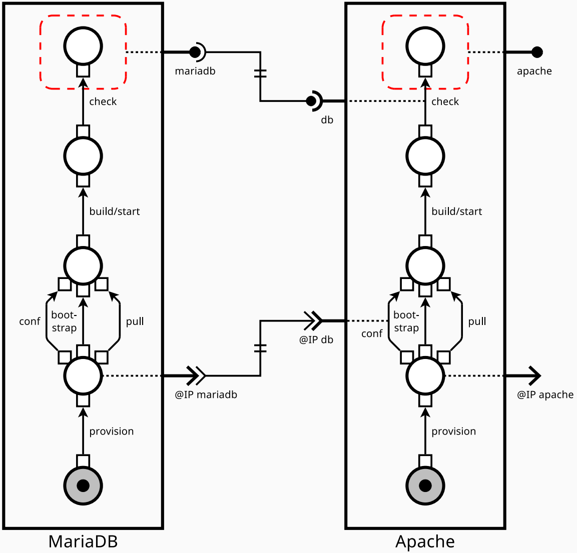


enable service connection



disable service connection

Madeus - LAMP example



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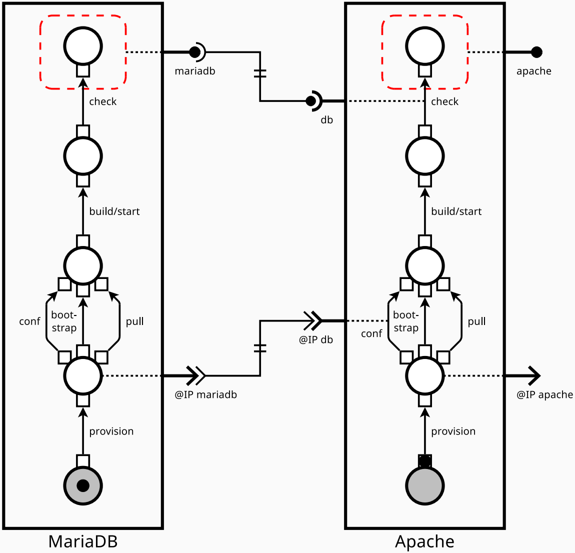

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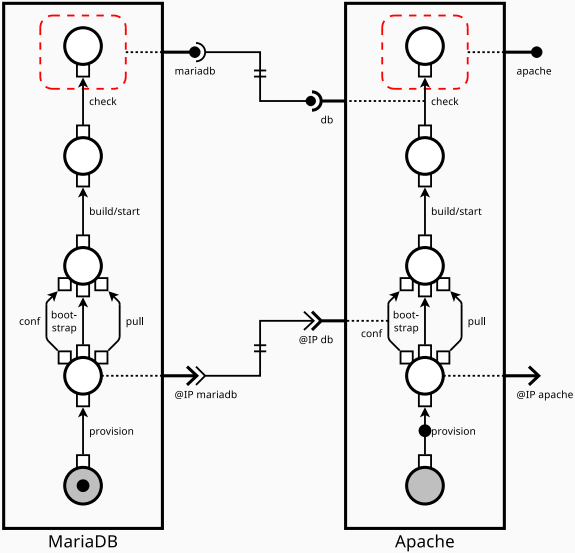

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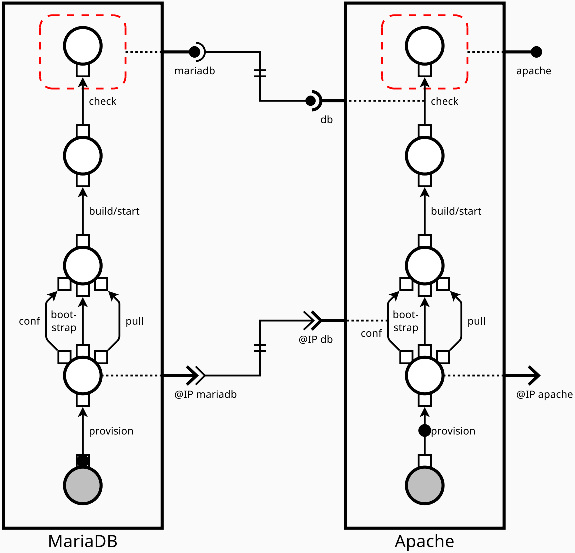

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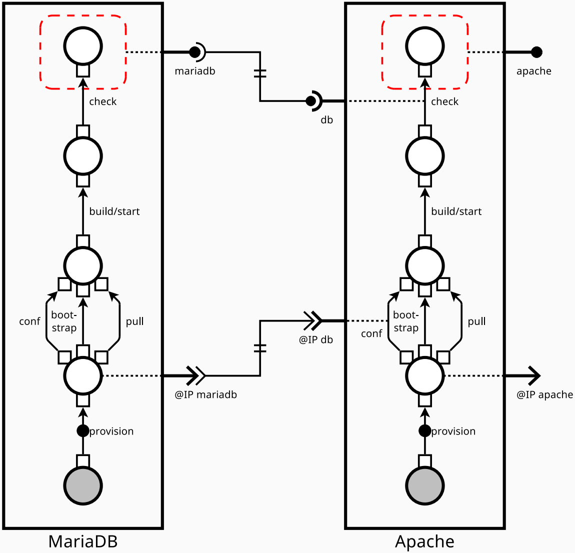

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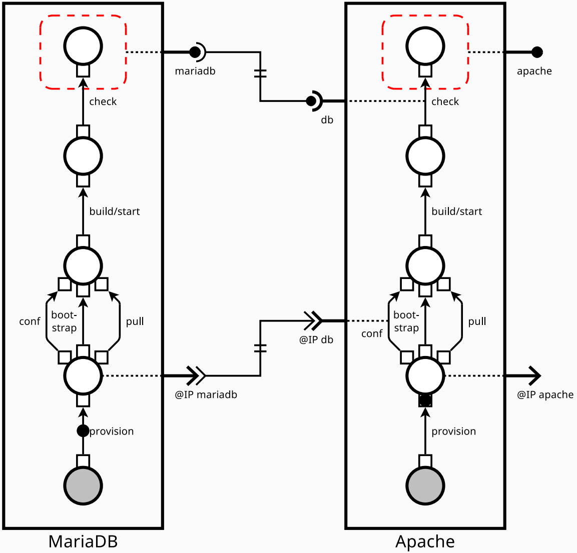

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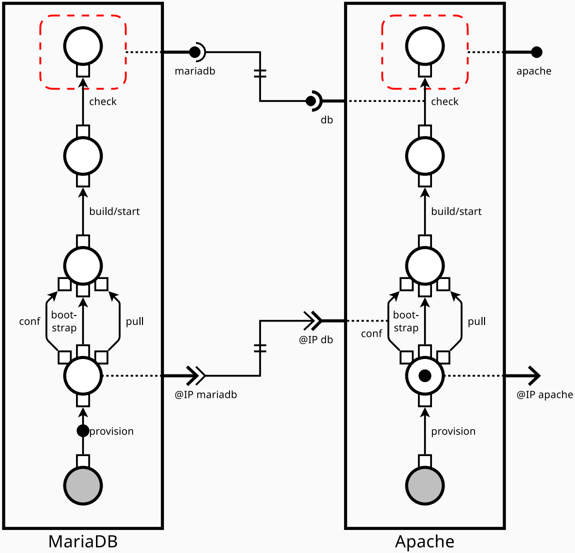

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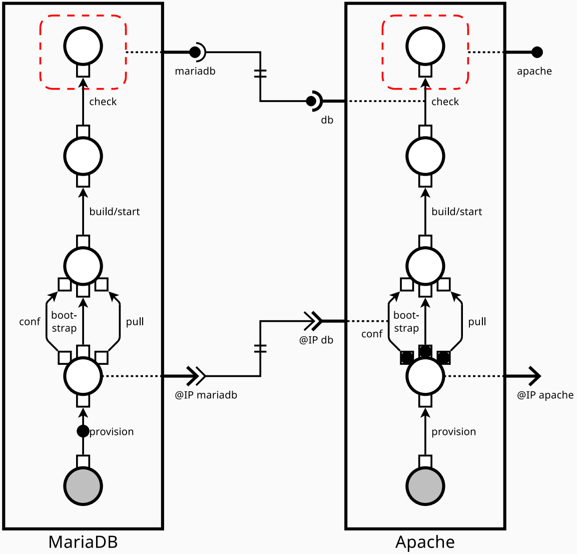

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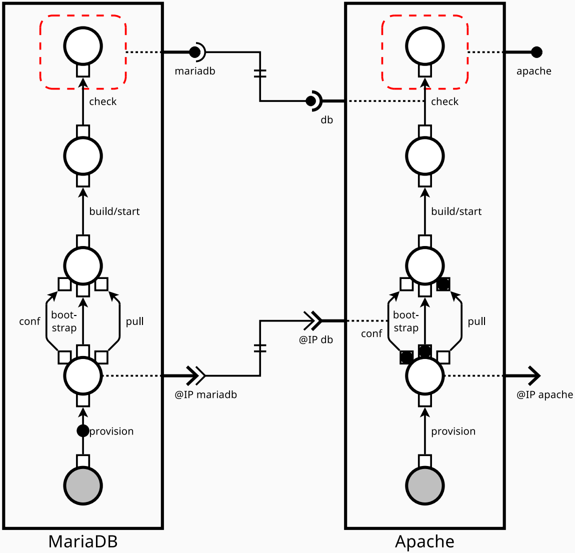

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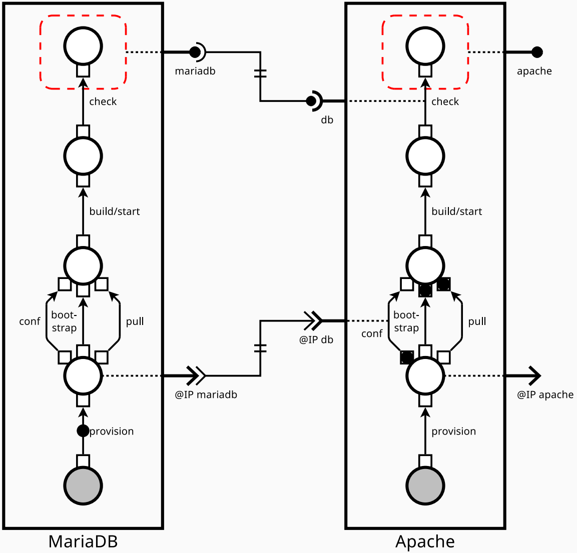

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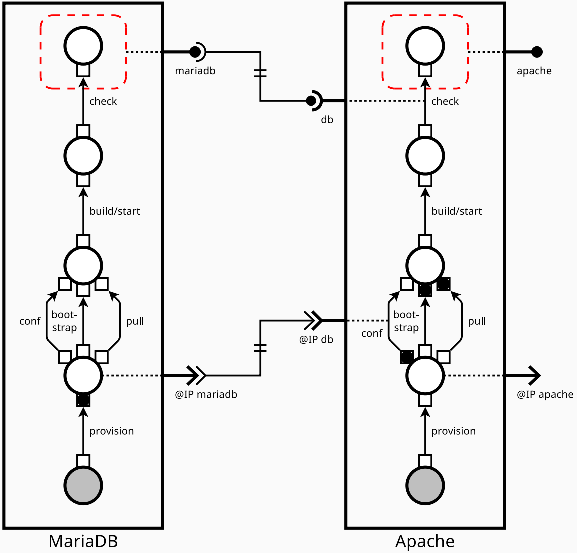

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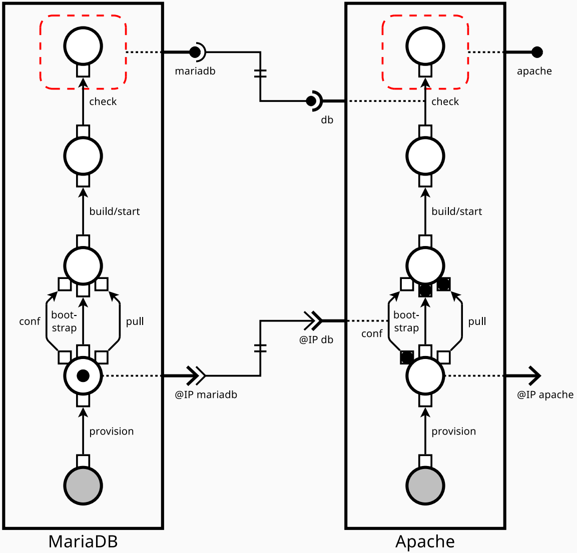

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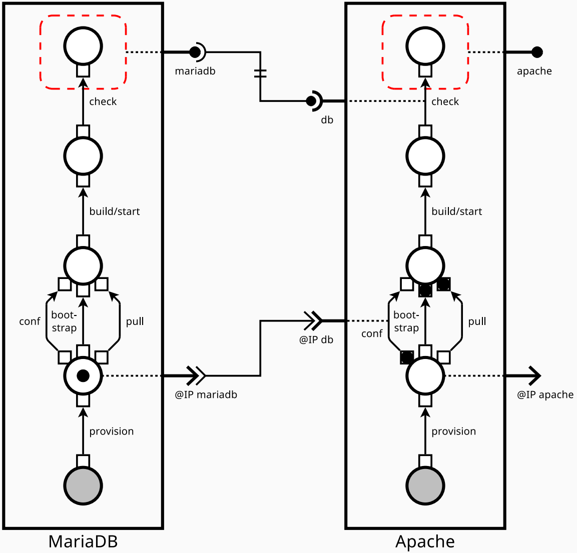

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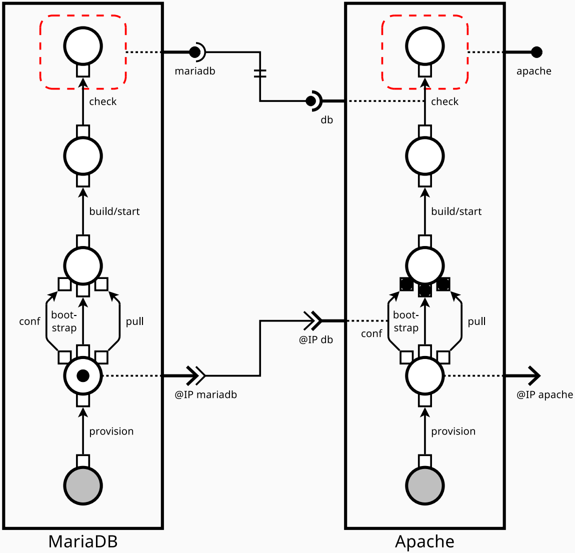

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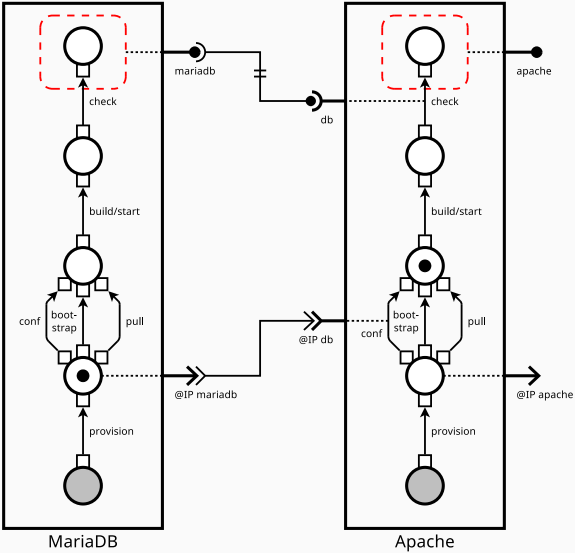

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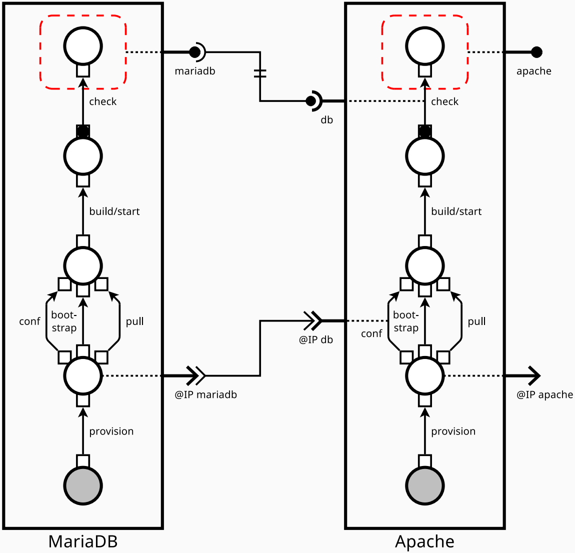

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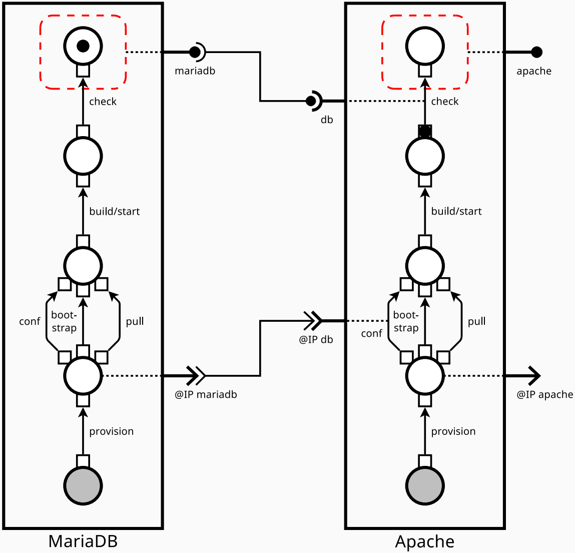

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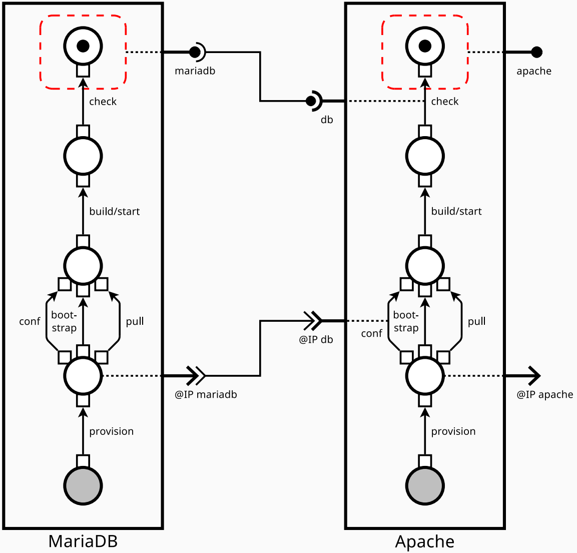


Madeus - Evaluation

OpenStack (bootstrap)

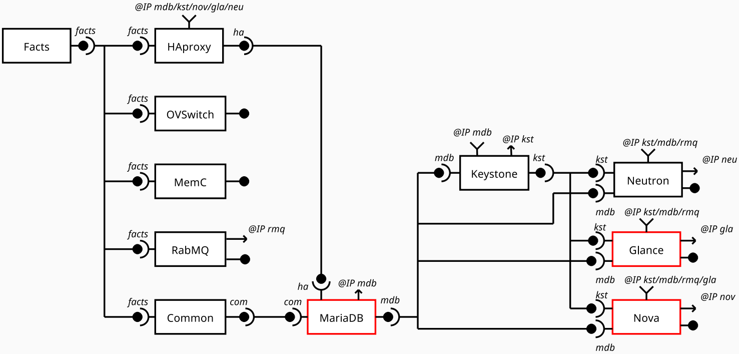
- open source operating system of the Cloud
- large distributed software
- modular architecture composed of more than 30 projects
- more than 150 services

Kolla-Ansible OpenStack Deployment

- our deployment reference is the Kolla project
- production tool to deploy OpenStack ONLY
- deploy a containerized minimal OpenStack by using **Ansible**
- 11 projects, 36 services
- deployment on three nodes: controller (16 services), network (11 services), compute (9 services)

Madeus - Evaluation

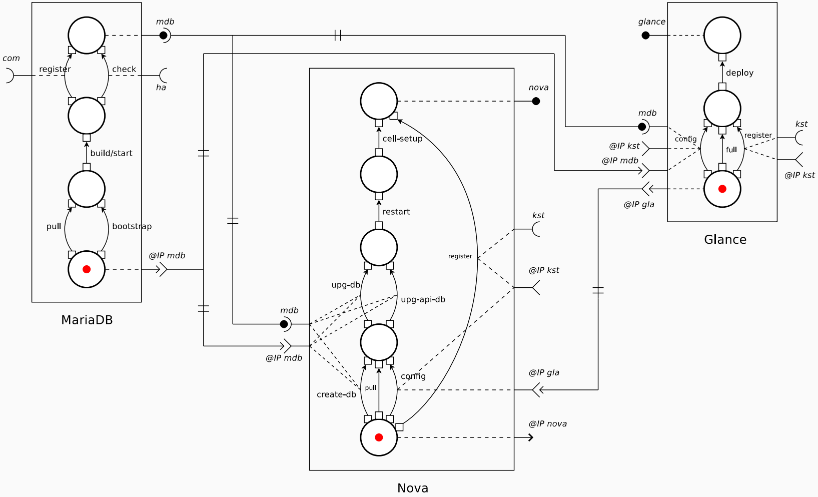
Full coarse-grain view of the Madeus deployment



Places	Transitions	Ports
32	30	47

Madeus - Evaluation

Detailed Madeus components (MariaDB, Nova, Glance)



Madeus - Evaluation

Deployment versions

- spmd-1t = Kolla-ansible
- dag-2t = Aeolus (simulated with Madeus, no parallel transitions)
- dag-nt = Madeus

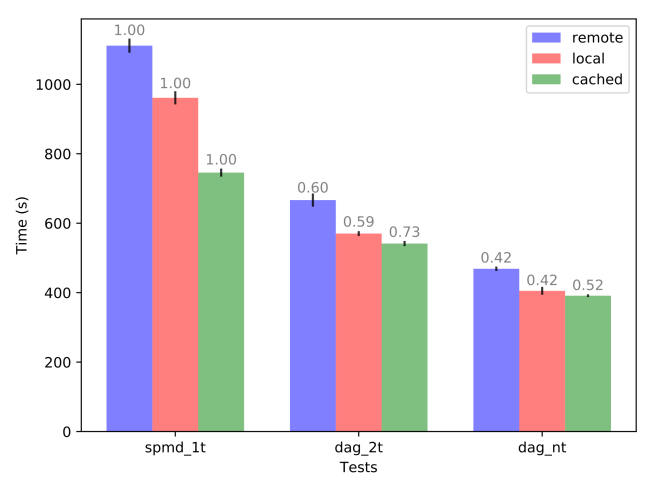
Docker image management

- remote (Docker Hub)
- local (dedicated local registry in the cluster)
- cached (all nodes already store docker images)

Cluster	CPU	Memory	Network
Taurus (g5k)	2 x 6 cores/CPU	32GB	10 Gbps

	Compute	Network	Control
Number of images	9	11	16
Total size (MB)	2767	2705	4916

Madeus - Evaluation

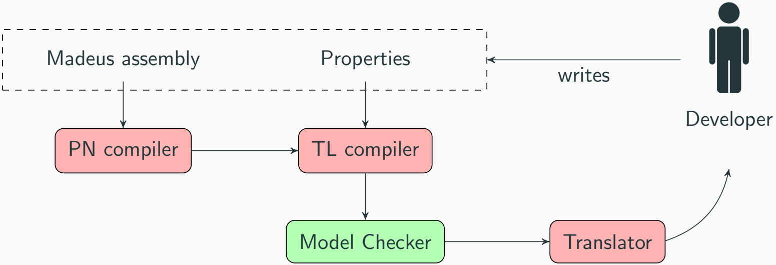


- 58% faster than Kolla-Ansible
- 32% faster than Blender-Aeolus

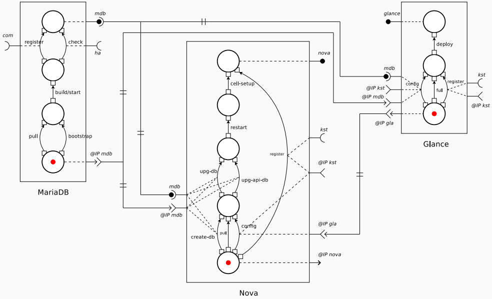
Deployment

Verification and Madeus

Madeus and Petri nets

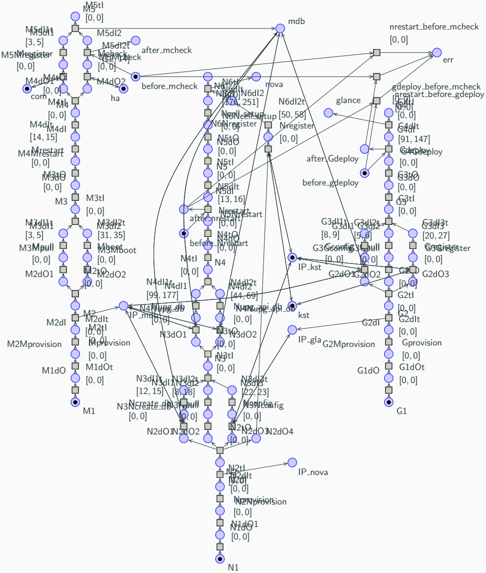


Madeus and Petri nets



- Madeus places ⟶ Petri net places
- Madeus docks ⟶ Petri net places
- Madeus transitions ⟶ Petri net places
- Madeus connections ⟶ Petri net places
- places and transitions of the Petri net connected such that the same semantics is applied
- specific case for groups, not detailed in this talk

Madeus and Petri nets



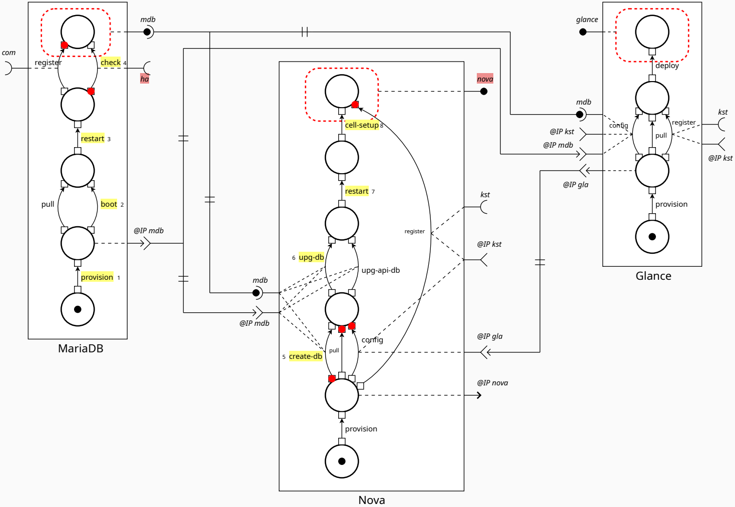
Property language

```
def addInterval(self, transition, min, max)
def addDeployment(self, name, list_places)
def deployability(self, name_deployment, with_intervals,
                  traces)
def sequentiality(self, transition1, transition2, ...)
def parallelism(self, full_assembly, list_components)
def boundaries(self, traces)
```

Properties to temporal logic

- deployability ⟶ inevitability
- sequence ⟶ observer subnet + invariant
- parallelism ⟶ max($\sum$(reachable markings))
- boundaries: min/max costs + critical path

Traces and debug



Perspectives

Perspectives

- Proof of semantic equivalence between Madeus and the Petri net
- Conditions and errors in Madeus
- Probabilistic model
- Game theory

Other ongoing work

Coq modelization of Madeus (proofs on the model)

Reconfiguration

Reconfiguration

Context

Context

Reconfiguration

- Deployment = specific reconfiguration
- Rolling upgrade
- Dynamic resources (add/remove nodes, failures)
- Dynamic software topology (add/remove/replace/new configuration)
- Other dynamic information (security/energy etc.)

State of the art

Metrics

- *Performance*: as fast as possible
  - minimize downtime
  - minimize execution time
- *Expressivity*: handling many kinds of reconfiguration
- *Separation of concerns* between developers and reconfiguration designers
  - each actor does what is in their area of expertise

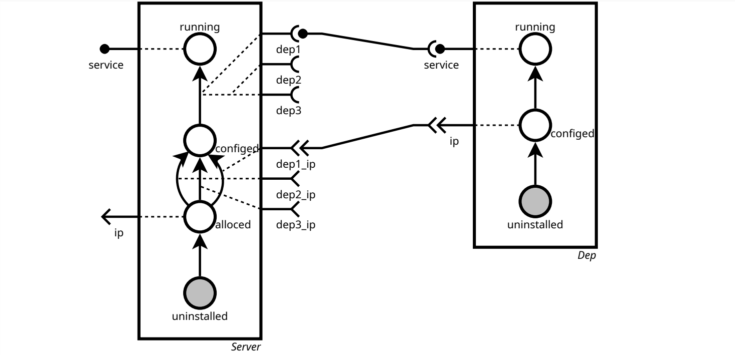
Objectives

- Extend Madeus with reconfiguration to inherite its efficiency
- Increase separation of concerns compared to Aeolus

Reconfiguration

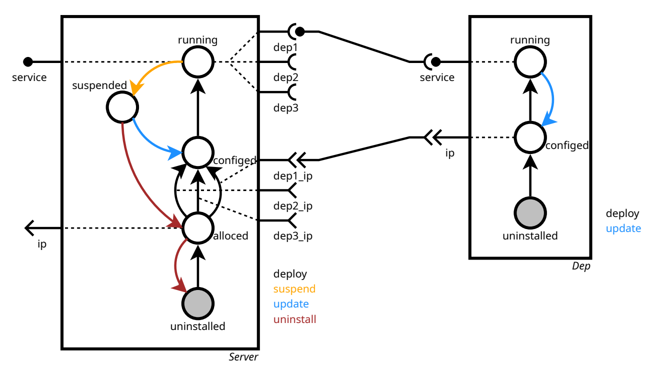
Madeus++

Madeus assembly



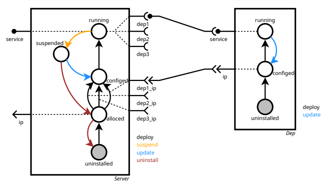
- Efficient deployment (programmable life-cycle, parallelism)
- No reconfiguration

Madeus++ assembly



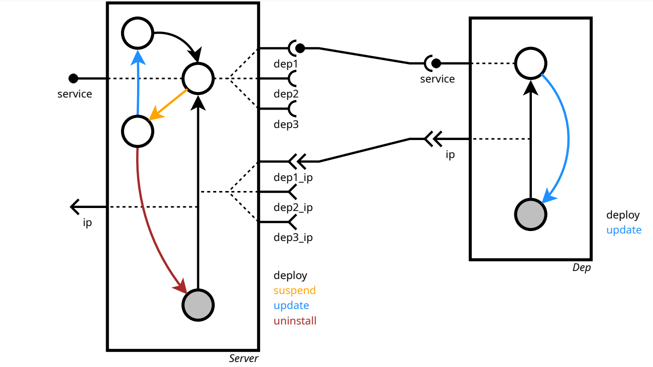
- Introduction of behaviors within Madeus
- Add a reconfiguration language composed of 6 operations: *add*, *del*, *connect*, *disconnect*, *changeBehavior*, *wait*

Madeus++ reconfiguration



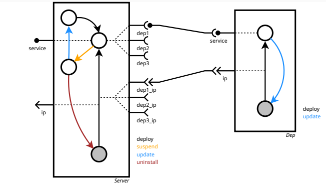
```
changeBehavior(server,suspend)
changeBehavior(dep,update)
wait(server)
disconnect(server,dep1,dep,service)
changeBehavior(server,update)
wait(dep)
changeBehavior(dep,install)
wait(server)
changeBehavior(server,install)
```

Behavioral interfaces



- Simplified interfaces for the reconfiguration designer
- Increases the separation of concerns

Madeus++ reconfiguration



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changeBehavior(dep,install)
wait(server)
changeBehavior(server,install)
```

Madeus++ ongoing work

- A prototype of MAD++ has been implemented in Python
- Experiments on real case study (database migration)
- Proof of equivalence between madeus++ and behavioral interfaces

Reconfiguration

VeRDi project

VeRDi project

Verified Reconfiguration Driven by execution

Automated reconfiguration execution

- programmable reconfiguration protocols
- efficient reconfiguration (parallelism)
- safe reconfiguration
- decentralized reconfiguration

A few challenges

- programmable protocols
- high level of parallelism
- static and dynamic verifications
- verification of decentralized reconfiguration (local knowledge)
- use verification as a tool to help the developer

Conclusion

Conclusion

- Deployment and Madeus
    - efficiency
    - evaluation on OpenStack
- Madeus and Petri nets
    - transformation of a Madeus assembly to a Petri net
    - transformation of the property language to temporal logic
    - use a model checker for verification and debug
- Reconfiguration and Madeus++
    - efficiency
    - separation of concerns
- The VeRDi project

People involved

Madeus and Madeus++

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