Predictable Efficiency for Reconfiguration of Service-Oriented Systems with Concerto

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Outline

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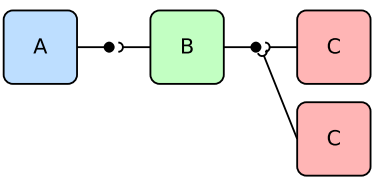
Distributed software systems

General definition

- Non monolithic code,
- modular units of code - **components**,
- software system = **architectural assembly** of component instances,
- interactions between components through **communications**.



- Master/workers,
- microservices,
- service-oriented,
- layered,
- etc.

Deployment, management, reconfiguration

Ever-running and long-running distributed systems

What is a reconfiguration?

- Reconfiguration through time
  - need to add/remove components and/or connections
  - need to change internal configurations
- A set of instructions to move from one state of the system to another.

Examples of reconfiguration reasons

- Faults or errors on services or hardware (e.g., re-deploy),
- dynamic energy or security constraints (e.g., change the set of components),
- dynamic improvement of performance (e.g., scaling),
- dynamic upgrade of some modules.

Our goals

1. Efficiency of the reconfiguration

- reach quickly a targeted configuration,
  - dynamic security requirements, more frequent reconfigurations (e.g., Fog Edge) etc.
- reduce disruption time
  - frequent faults or disconnections etc.

2. Execution time prediction

- better decisions on "when to perform the reconfiguration?"
- better decisions on "how to schedule concurrent reconfigurations?"

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Lifecycle

Contributions with a lifecycle abstraction

- fixed lifecycle: TOSCA, DEPLOYWARE, SMARTFROG, ENGAGE
  - easier to use, less flexible
- programmable lifecycle: AEOLUS, ANSIBLE (DevOps configuration tool)
  - more difficult to use, more flexible

Machine 1 **[WHERE]**

Database (DB) [WHAT]

[HOW] [LIFECYCLE]

1. Install
2. Configure
3. Start the service
4. Prepare the service

Machine 2 **[WHERE]**

Web-server (WS) [WHAT]

[HOW] [LIFECYCLE]

1. Install
2. Configure firewall
3. Download
4. Configure parameters
5. Start the service

Dependencies

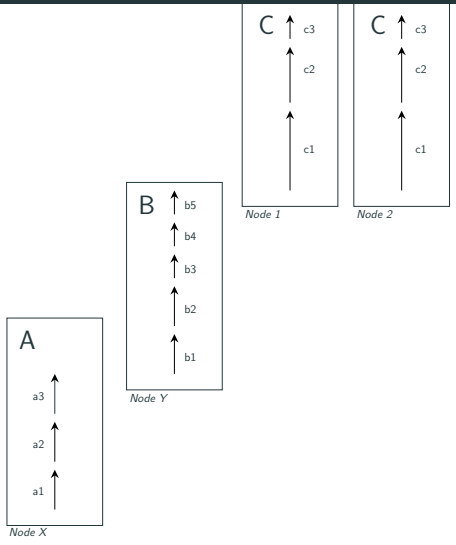
4 levels of dependencies

1. same component level: Ansible
2. component level: Tosca, Deployware
3. lifecycle level: Tosca, Engage, Aeolus
4. intra-lifecycle level: Concerto

Performance through parallelism and dependencies

level1: multiple nodes, same action

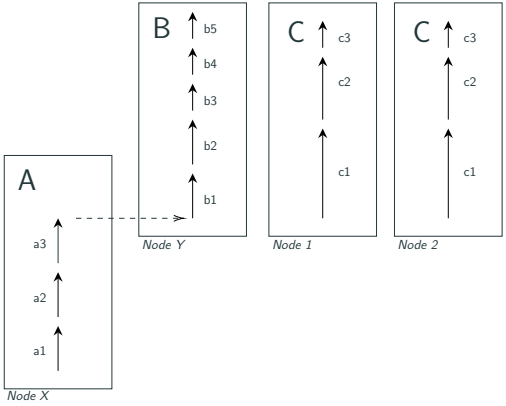
- no dependencies declared
- procedural execution order
- parallelism for the same component
- Ansible



Performance through parallelism and dependencies

level2: level1+non-dependent components

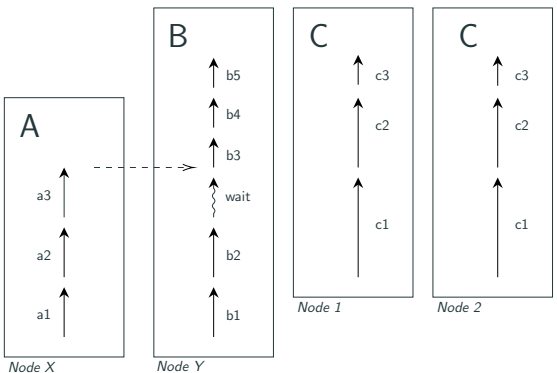
- dependencies at the component level
- DEPLOYWARE, (basic) TOSCA, ENGAGE



Performance through parallelism and dependencies

level3: level1 + level2 + inter-component

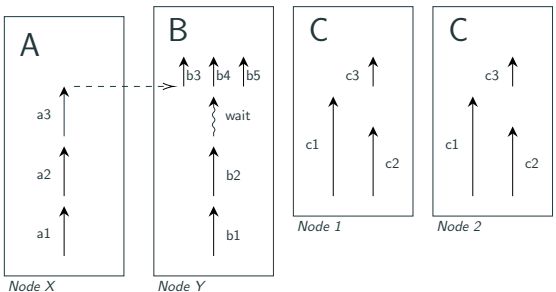
- dependencies at the lifecycle level between components
- (advanced) TOSCA, AEOLUS



Performance through parallelism and dependencies

level 4: level1 + level2 + level3 + intra-component

- parallelism within the lifecycle of one component
- CONCERTO



The finer the dependencies granularity is, the better is the efficiency

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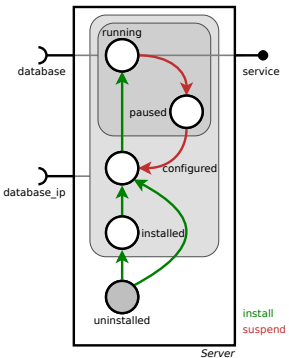
Control components

Written by the component developers

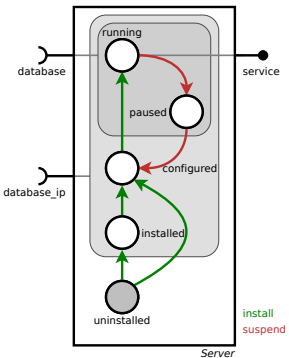


Internal net [LIFECYCLE]

- places = milestones
- transitions = actions to perform
  - concretely: scripts are attached to transitions
  - in the model: exact nature/effects of actions not represented, only coordination

Control components

Written by the component developers



Interfaces [DEPENDENCIES]

- data or service ports
  - use ports = requirements
  - provide ports = provisions
  - during execution: active/inactive
- behaviors
  - subset of transitions
  - during execution: active/inactive

Control components in practice

Written by the component developers

```
class Server(Component):
    def create(self):
        self.places = ['uninstalled','installed','configured','running','paused']

        self.initial_place = 'uninstalled'

        self.behaviors = ['b_install','b_suspend']

        self.transitions = {
            'install1': ('uninstalled','installed','b_install',self.install1),
            'install2': ('uninstalled','configured','b_install',self.install2),
            'configure': ('installed','configured','b_install',self.configure),
            'start': ('configured','running','b_install',self.start),
            'suspend1': ('running','paused','b_suspend',self.suspend1),
            'suspend2': ('paused','configured','b_suspend', self.suspend2)
        }
```

Control components in practice

Written by the component developers

```python
class Server(Component):
    def create(self):
        ...

        self.dependencies = {
            'database_ip': (DepType.USE, ['installed','configured','running','paused']),
            'database': (DepType.USE, ['running','paused']),
            'service': (DepType.PROVIDE, ['running'])
        }

    # Definition of the actions
    def install1(self):
        remote = SSHClient()
        remote.connect(host, user, pwd)
        remote.exec_command(cmd)
        ...
```

Reconfiguration language

Add/remove
Add/remove a component instance to the current assembly

Connect/disconnect
Connect/disconnect two component instances with compatible ports

Push behavior
Push a behavior to the behavior queue on a component instance

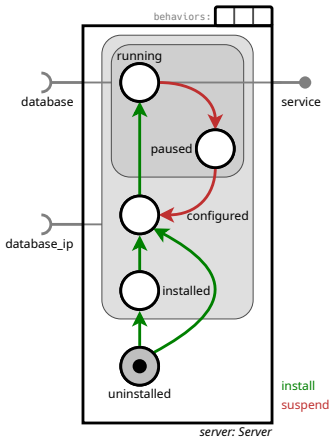
Wait
Wait for a given behavior of a component instance

Reconfiguration example - deployment

Written by the reconfiguration developer

Deployment program:

```
1 add(server: Server)
2 add(db: Database)
3 con(server.database_ip,db.ip)
4 con(server.database,db.service)
5 pushB(server, install)
6 pushB(db, deploy)
7 wait(server)
```



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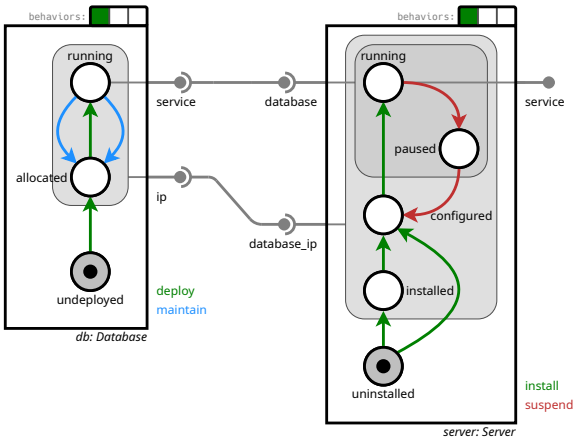

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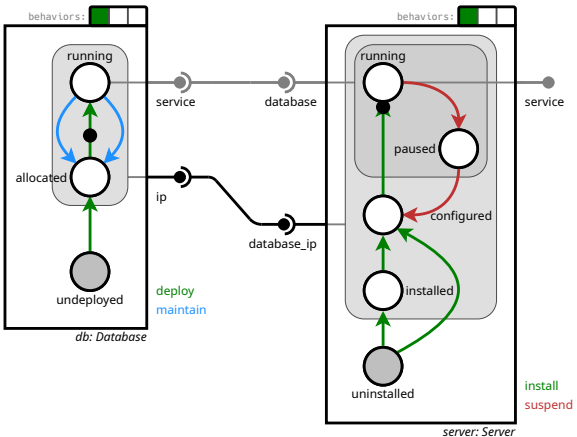

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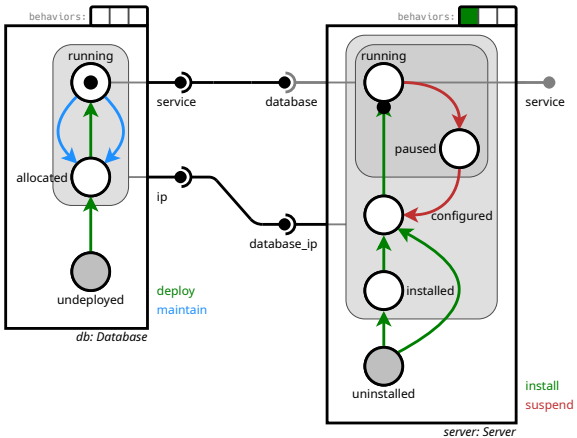
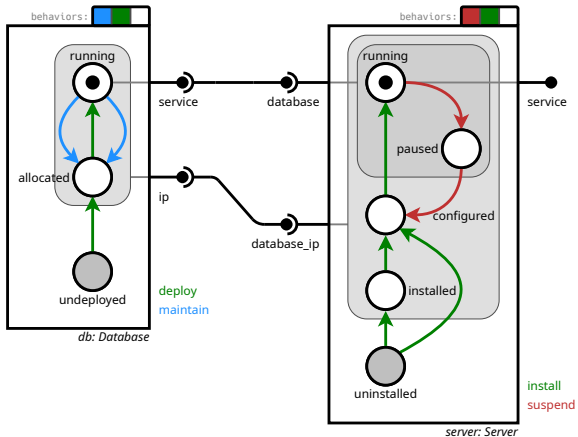


Reconfiguration example - maintenance

Written by the reconfiguration developer

Maintenance program:

```
1 pushB(db, maintain)
2 pushB(db, deploy)
3 pushB(server, suspend)
4 pushB(server, install)
5 wait(server)
```



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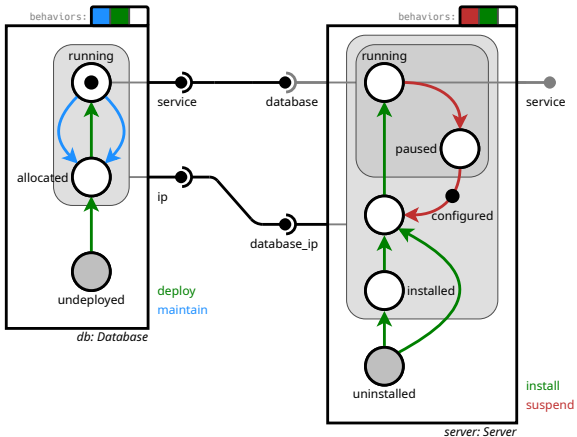

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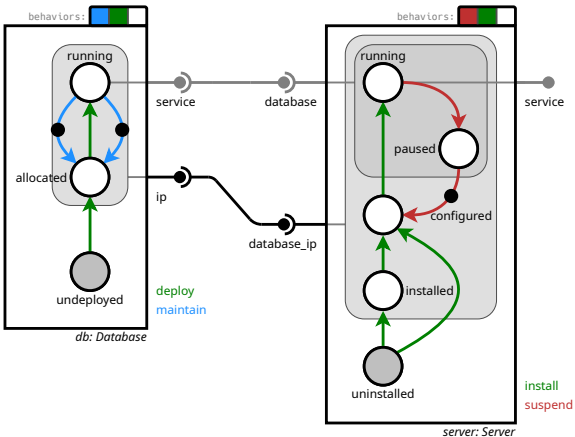


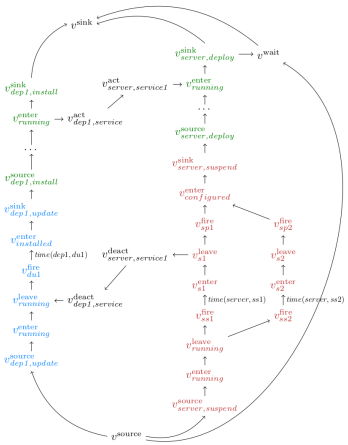
Performance prediction

Inputs:

- reconfiguration program
- time estimations for transitions

Dependency graph generation

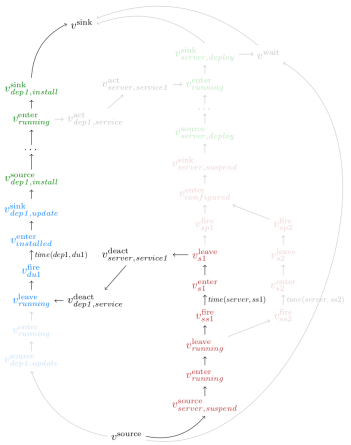
- nodes for events such as reaching/leaving place, firing transition
- transition arcs are weighted to reflect execution time
- other arcs are 0-weighted



Performance prediction

Critical path

- length = reconfiguration time (assuming hardware can execute as many concurrent threads as needed)
- highlights the transitions that should be optimized



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Evaluation on the reconfiguration of MariaDB

Real use-case extracted from the OpenStack Summit 2018 on a multi-region deployment of OpenSatck

Initial state

- centralized MariaDB running
- additional nodes running some generic components (docker, pip...)

decentralization

- replaces centralized DB with a distributed version with instances on n nodes
- requires a backup of the data, and a restart of the master node

scaling

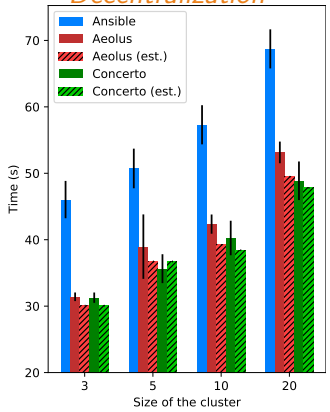
- deploys m new nodes with an instance of the distributed DB

Reproducible experiments

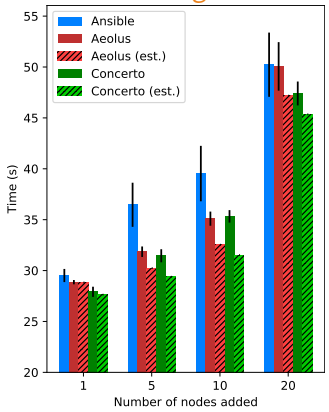
Evaluation on the reconfiguration of MariaDB

Results on nodes of UvB (Sophia) of Grid'5000 (2×6-core Intel Xeon X5670 CPUs, 96 GB RAM, 250 GB HDD, internal 40 Gbps InfiniBand, external 1 Gbps).

Decentralization



Scaling



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Conclusion

- Need for software engineering practices in reconfiguration (DevOps community)
- Need for efficiency and execution time prediction
  - reach quickly the new state
  - reduce disruption time
- Presentation of CONCERTO and its performance prediction model
- Evaluation on synthetic use-cases (see the paper) and a real use-case

Perspectives

- Automatic generation of a CONCERTO program from a goal
- Using CONCERTO to reconfigure cyber-physical systems and edge devices
  - PhD oppotunity! Contact me helene.coullon[at]imt-atlantique.fr