A workflow-inspired, modular and robust approach to experiments in distributed systems

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Research in distributed systems (1)

Large-scale systems do not submit themselves to formal analysis:

- too much complexity
- only 4% of papers use formal analysis
- researchers turn to experimental science

Proofs may not be possible!

Research in distributed systems (2)

Large-scale experiments are difficult:

- time-consuming
- difficult to do correctly
- complex and incomprehensible
- failure-prone

Up to 26% empirical papers in CS have no evaluation at all!

The standard way to experiment

Traditionally, the experiments are written as a set of scripts.

In this approach:

- the experiment is poorly documented
- the provenance of results is difficult to track
- the same experimental problems are addressed repeatedly
- the scalability problems arise
- the work is difficult to reproduce or extend
- the results are tied to a particular platform

Can we do better than that?

Agenda

Three axes of experiment control systems

Consider 3 different aspects of experimentation:

- experiment description
- experiment modularity
- execution robustness

All three are crucial for experimentation.

Experiment description

Different ways to provide description exist:

- imperative (Expo) – a standard programming language
- declarative (Plush) – a high-level description
- mixed (OMF, Splay)

Experiment modularity

Existing tools are not very modular or easy to extend, because:

- they focus on one-time studies (Splay)
- they focus on a single platform (Plush)
- they are not designed with that in mind

Execution robustness

Some tools can cope with execution failures automatically:

- failing nodes (Plush)
- adherence to platform specification (OMF)

These features tend to be platform-specific.

However, most of the tools require manual failure handling.

A workflow approach

We propose a new way to model and structure experiments.

We use a workflow representation based on Business Processes to model experiments:

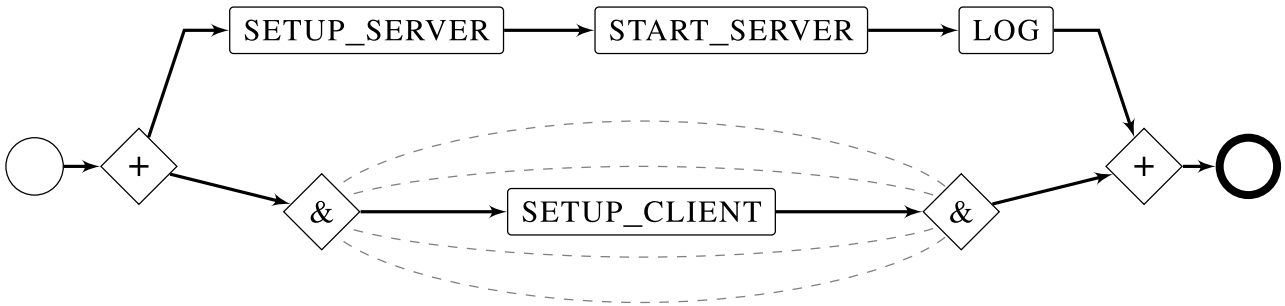
- they are build from simple, independent blocks
- standard patterns from Business Process Management are used
- workflows are built with a domain-specific language

In the paper, we show:

- advantages of workflow-based description
- modularity and extensibility of our approach
- the robustness of execution

A workflow approach (cont.)

```
1  process :setup_experiment do |clients, server|
2      parallel do
3          forall clients do |node|
4              run :setup_client, node
5          end
6          sequence do
7              run :setup_server, server
8              run :start_server, server
9              log "Server started"
10         end
11     end
12 end
```



BPM vs. WfM

Business Process Management:

- not a technology
- nothing to do with computer science
- BPM is a management discipline

Workflow Management:

- a set of technologies supporting BPM
- a computer science discipline

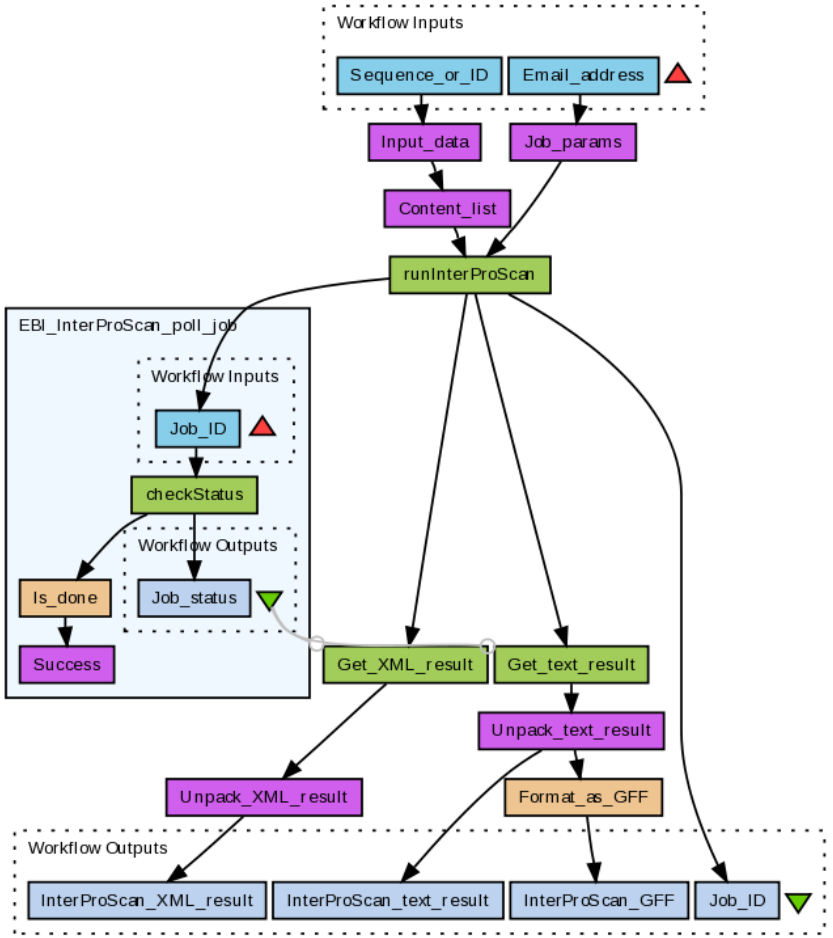
BPM vs. Scientific workflows

Business Process Management:

- workflows describe *control flow*
- arbitrary flows are possible
- difficult to reproduce

Scientific workflows:

- *data flows* transforming inputs
- constrained to DAGs
- computing platform is abstracted
- usually reproducible



Advantages of workflow-based description

The advantages of workflow-based description include:

- power of expressiveness
- automatic analysis
- graphical representation
- modularity
- integrated monitoring
- special workflow patterns ensure robustness

Modularity of the approach

Workflows are modular by design.

We show the modularity of our approach by:

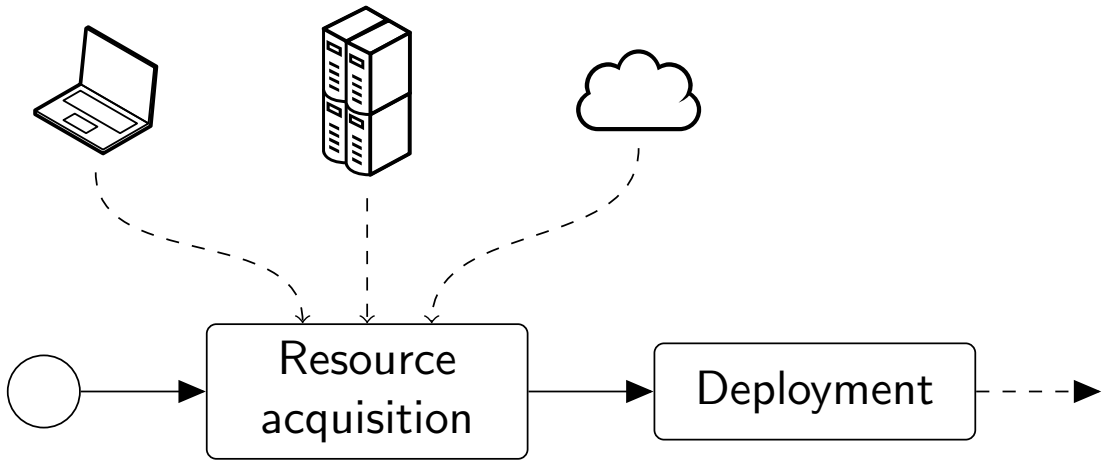
- running our experiment in 3 different testbeds
- building the experiment from reusable, smaller components

Modularity of the approach (2)

The experiment was run on:

- the author's machine using Linux Containers
- on Grid'5000 testbed
- on cloud testbed deployed on Grid'5000

The results were different for each testbed.



Modularity of the approach (3)

The exemplary experiment consists of:

- an HTTP benchmark
- a *minimal sample experiment* that adaptively retries the scalability experiment to achieve a desired precision
- a *scalability* experiment with varying number of clients

RUN THE BENCHMARK s TIMES

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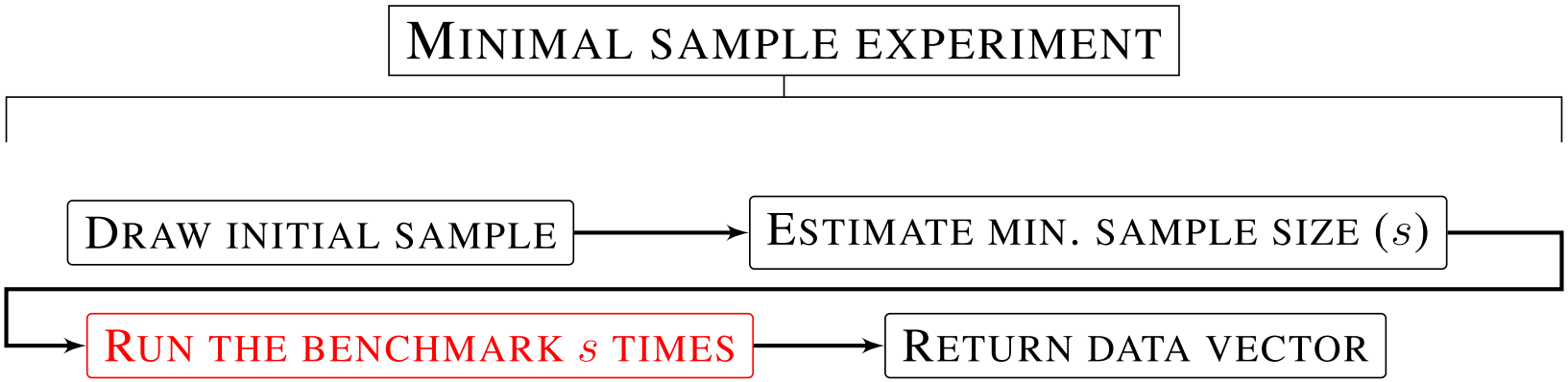

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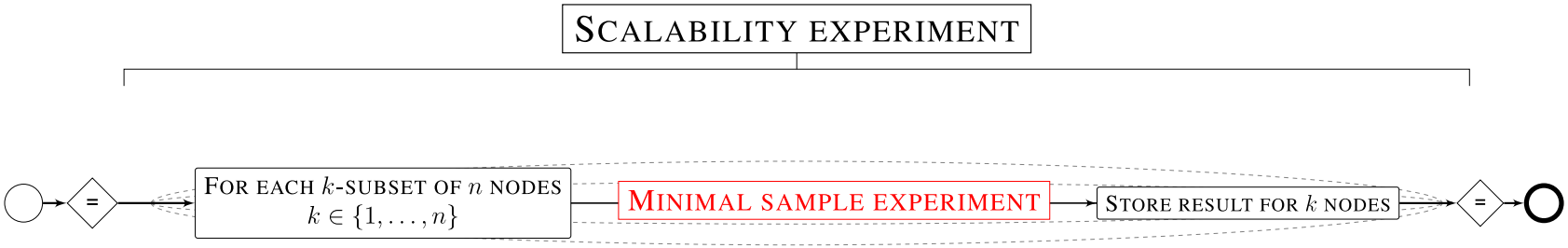


Workflow equivalence

Failures may change the outcome of the experiment.

Consider two executions *equivalent* if they lead to the same outcome.

How can we ensure that executions are equivalent despite failures?

Workflow properties

To address that we define a few properties of workflows:

- *restartability*
- *idempotency*
- *eventual success*
- *eventual idempotency*

These properties are not composable!

However, workflows with such properties may be composed and succeed despite execution failures.

Failure handling patterns

Two basic handling patterns exist in our approach:

- workflow retry pattern
- checkpoint (of the workflow state, not platform)

Some properties are required:

- retried workflow should be *eventually successful*
- checkpoint is followed by an *eventually idempotent* workflow

With these properties, any workflow can be executed and eventually succeed.

The experiment

In our exemplary, we measure scalability of the Nginx web server:

- with ApacheBench benchmark
- using Debian OS
- tested on 3 different testbeds
- we measure requests per second (TPS) as number of clients increases

3 experimental testbeds

An author's machine:

- used to prototype
- very low performance and scale

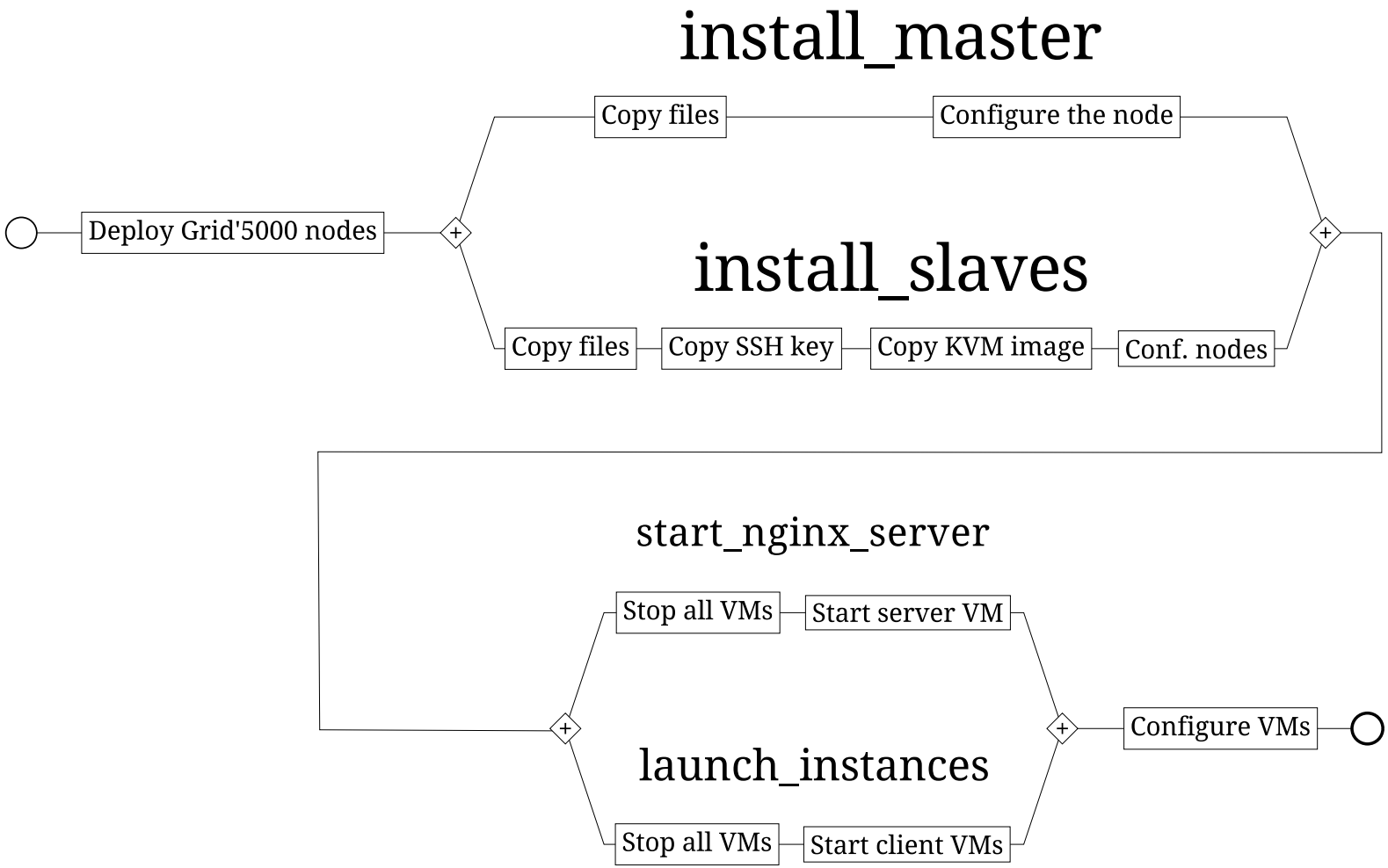
Grid'5000 testbed:

- uses real machines
- very good performance
- limited scale (199 nodes in our case)

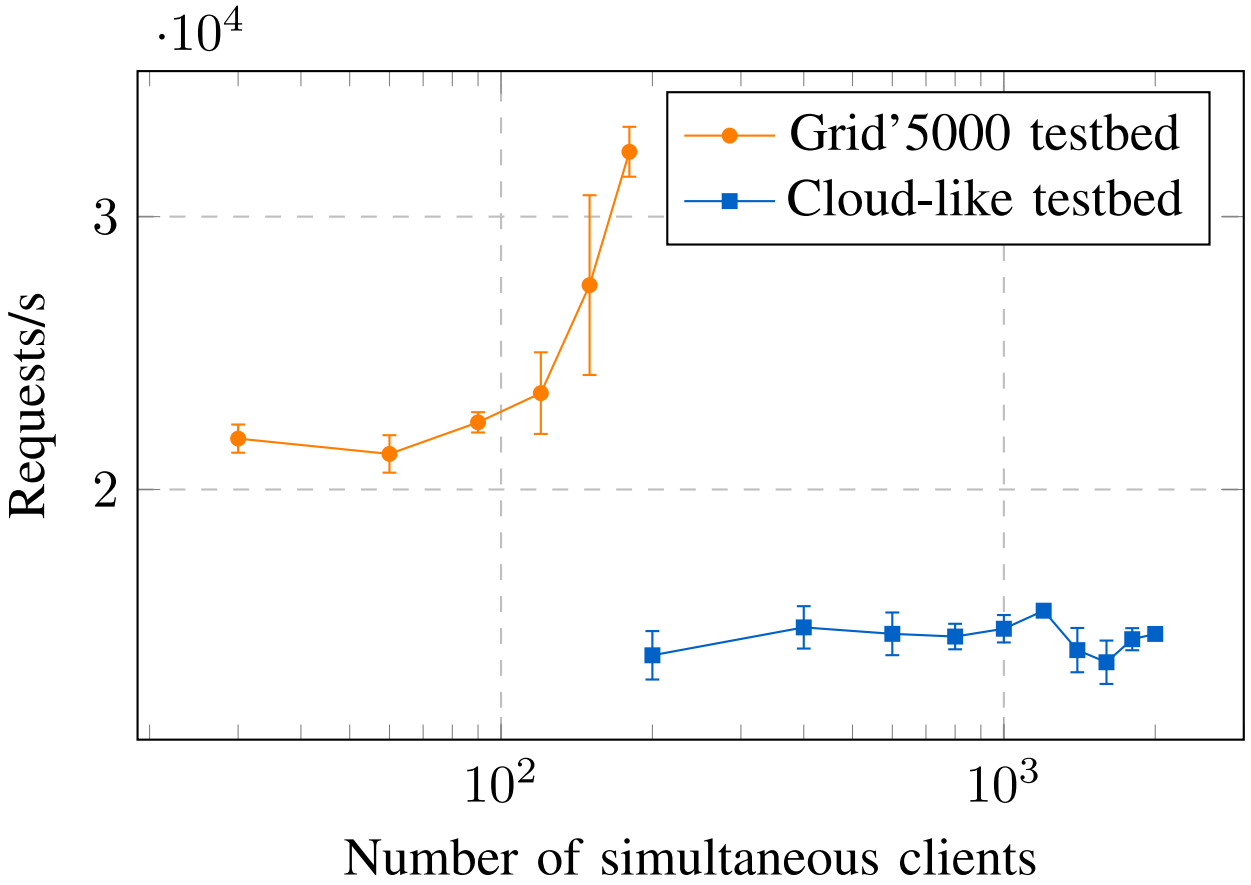
Cloud testbed:

- uses KVM
- limited performance
- scalable, we reached up to 2,033 clients in parallel

Workflow of the experiment



The results of the exemplary experiment



Conclusions

In our work, we have shown that our workflow approach:

- has a formal and malleable description
- enables modular structure of experiments
- provides useful special patterns to handle failures

Future work will include:

- provenance and visualization of results
- distributed execution of experiments
- release of XPFlow (our workflow engine)

Thank you for your attention. Questions?

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