Statistical Verification of Distributed Programs Within SimGrid

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Inria Nancy Grand Est

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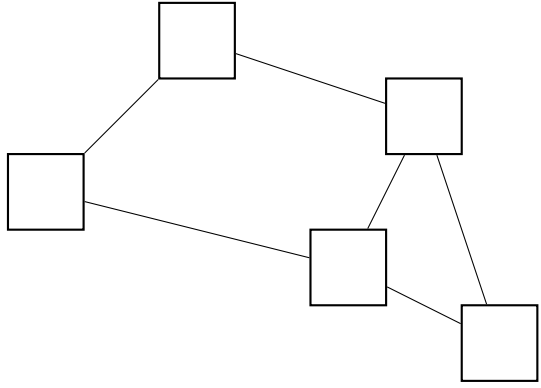

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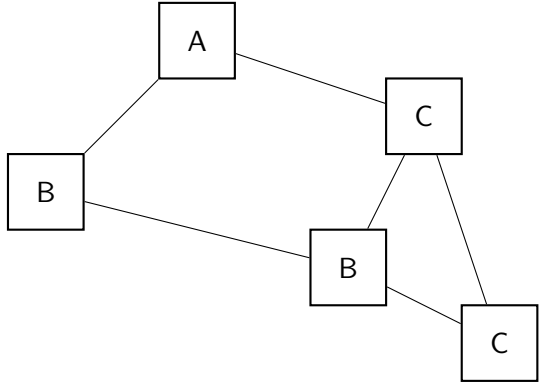

Stochastic models

Problem: «Reality is not perfect»

Idea: Model imperfection by probabilistic laws

Where ?

- Bandwidth of a link;
- Computation power;
- Latency of a link.

Different kinds of analysis

Transient analysis

- What is the probability that at a given moment all computers are busy ?
- How long, in average, does it take for the distributed program to complete ?

Stationary analysis

- What is the *average* energy consumption ?
- What is the probability of a synchronisation error ?

Two methods for model-checking of probabilistic models

Numerical model-checking

- Precise values
- Strong probabilistic hypotheses
- Large memory space

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Statistical model-checking

- Confidence interval
- Small memory requirements
- Easy to parallelize
- Weak probabilistic hypothesis
- Requires fully stochastic models
- Rare Event problem

Cosmos

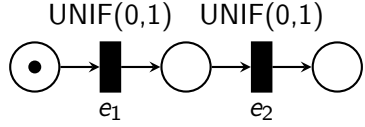
Description [Ballarini, Barbot, Duflot, Haddad, Pekergin 2015]

- Statistical model-checker for HASL over stochastic Petri nets;
- Free software (GPLv3); C++, Ocaml; `http://cosmos.lacl.fr`;
- Developers: Hilal Djafri (2009-2012), Paolo Ballarini (2010-2011), Benoît Barbot (since 2011), Yann duplouy (2015-2018).

Main Applications

- Flexible manufacturing systems;
- Biological networks [Barbot, Kiatkowska 2015];
- Embedded pacemaker model [Barbot, Kwiatkowska, Mereacre, Paoletti 2015].

Stochastic PN



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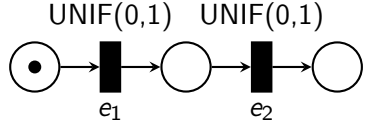
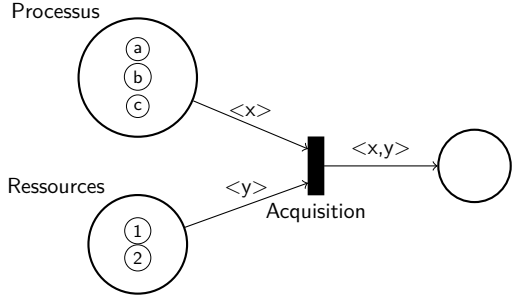


High-level PN



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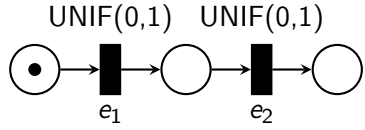

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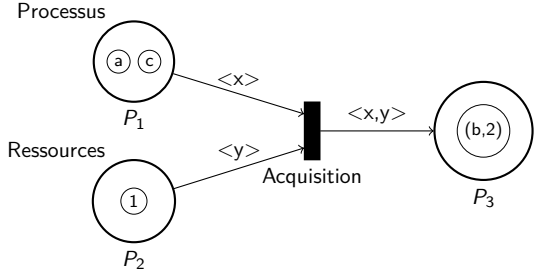
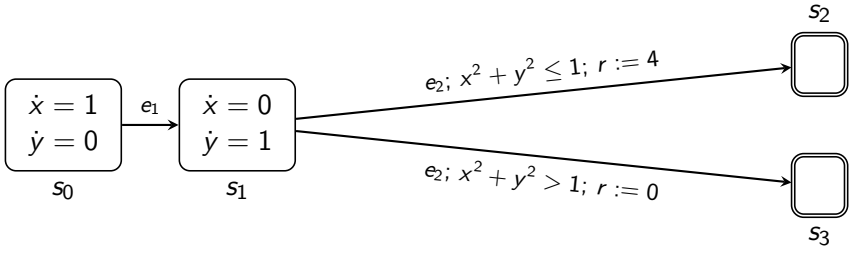


HASL formulas

A deterministic hybrid automaton and an expression



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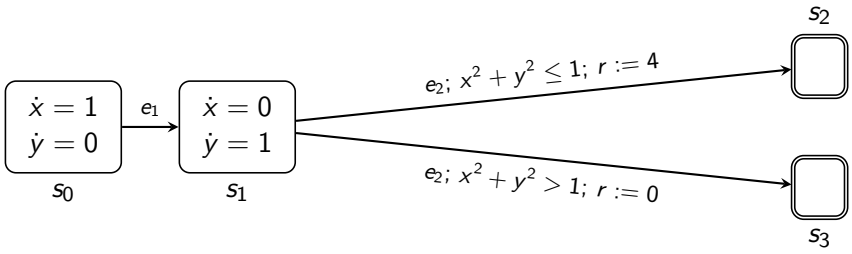

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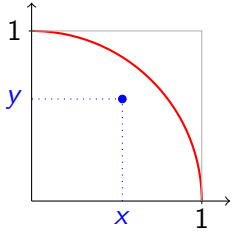
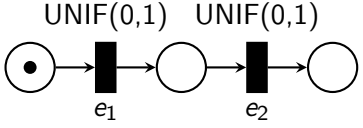
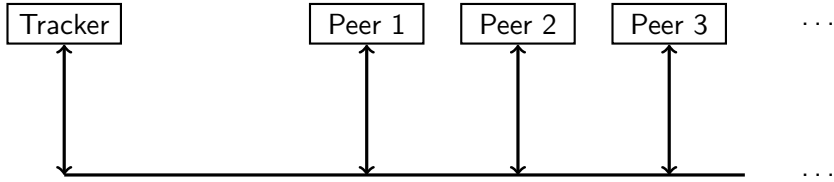




An overview of the BitTorrent protocol

Goal: Deliver a file through a peer-to-peer protocol;



- A **tracker**
- Multiple **peers**, that can be *seeders* or *leechers*

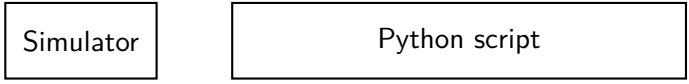
Example available in Simgrid distribution; modified to measure completion time.

Outside scenario generation

Another executable or script:

- Generate environments, given the stochastic description;
- Runs the simulator;
- Gather results from simulations.

Then we can use R (or other tools) to perform statistical analysis.



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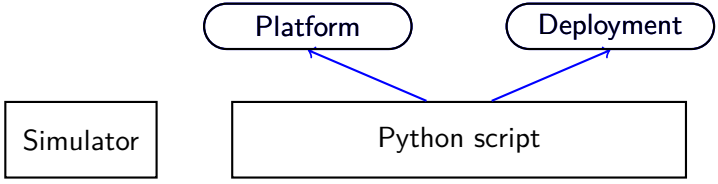

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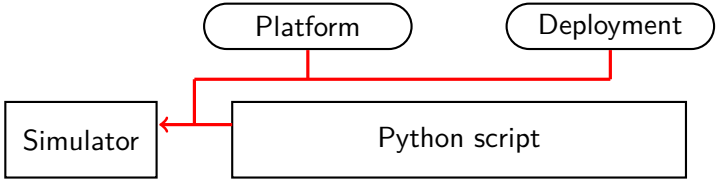

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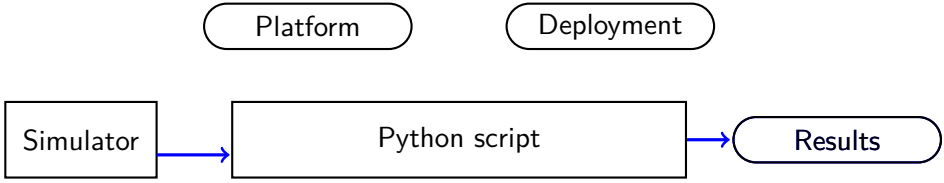

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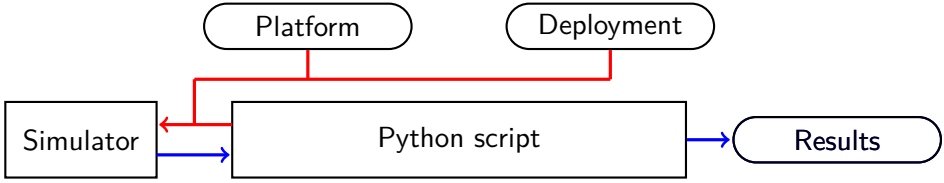

Quick results 1/2

Measuring *average* completion time (with 95% confidence level)

seeders \ leechers	25MB/s	$U_{\texttt{int}}(1024, 8191)$kB/s
25 MB/s	374s	896s
$U_{\texttt{int}}(1024, 8191)$ kB/s	520s	949s

Quick results 2/2

Introducing failures, generated up to 600 000 seconds:

1. Host becomes unavailable after EXP(20000)
2. Host becomes availables again after UNIF$(10, 20)$, repeat (1.)

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- if only seeders have failures:
  most (98%) simulations run under 670s,
  average simulation time 702s;
  but slowest simulation took 20 665 seconds;
- if seeders and leechers have failures:
  most (91%) simulations run under 680s,
  average simulation time 891s;
  but slowest took 25 576 seconds;

A cleaner approach ?

Add a few SimGrid modules:

- **Modify** the *profile* class to accept stochastic definitions
- **Implement** a statistical verification class:
  Measure an approximation of performance indexes
  Allow to restart simulations without multiple external calls to the simulator

Specification of probabilities

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Platforms now accept stochastic profiles.

Quick result – Stochastic Profile

Introducing failures, generated up to 600 000 seconds, with outside RNG seed generation:

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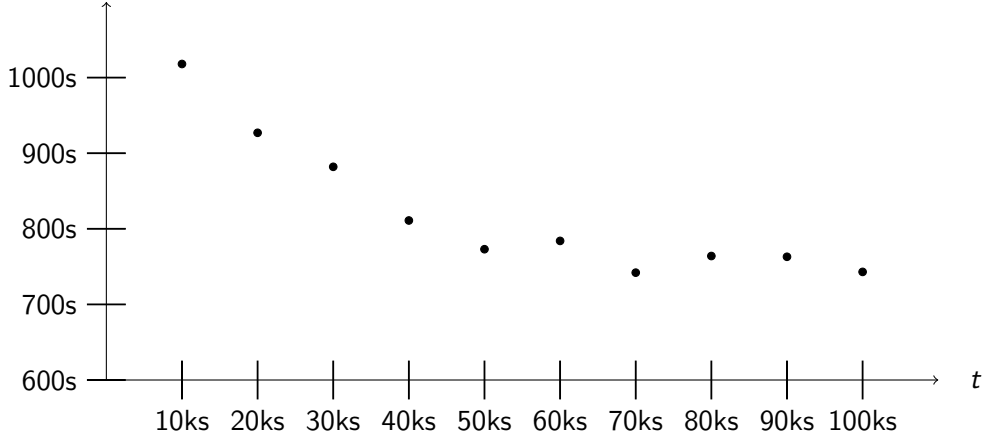
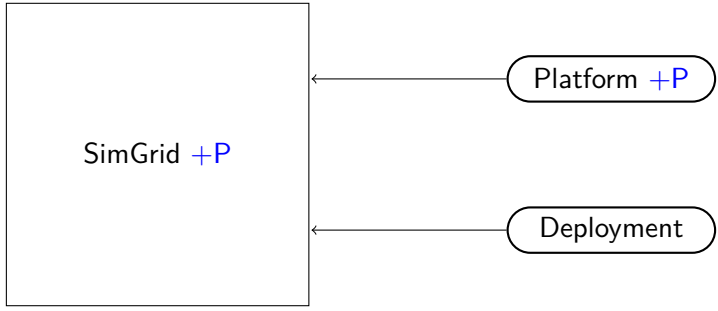
Average simulation time



Running multiple times



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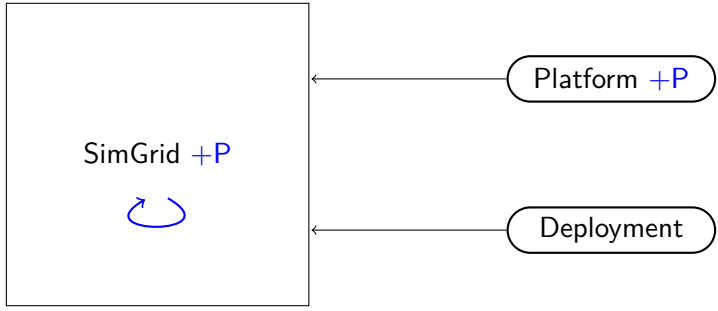

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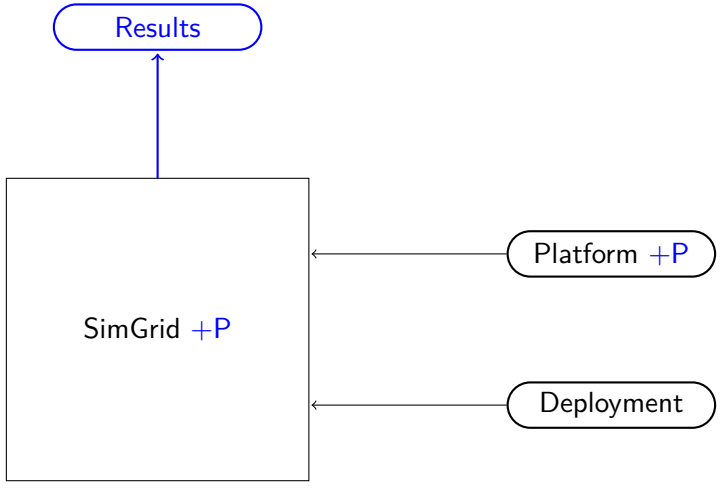

Conclusion

SimGrid is good for *reproducible* scenarios, but real scenarios are unpredictable

- Generating scenarios and deterministic profiles is inconvenient at best;
- Adding a module dedicated to statistical verification is a cleaner approach;
- Modifying the *profile* class is a first step;
- Implementing HASL into SimGrid would increase hugely the expressivity.