

Towards fast and deterministic system tests

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9th Nov, 2020

Overview

- ▶ Explain the problem with current approaches to system tests;
- ▶ Give a high-level overview of test library we've started to develop that addresses said problems;
- ▶ Demo;
- ▶ More detailed explanation of how the test library works, in particular:
 - ▶ Lineage-driven fault injection;
 - ▶ Elle checker.
- ▶ Next steps and future work;
- ▶ Summary.

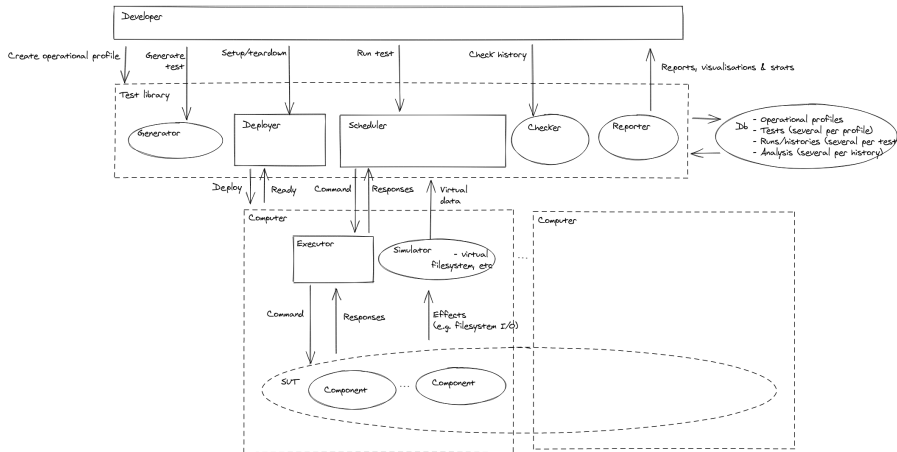
The problem

System tests, in general, are:

- ▶ Non-deterministic and slow
 - ▶ Running the same test twice can yield different outcomes, esp. around fault-injection;
- ▶ Ill-specified or provide weak guarantees
 - ▶ What exactly have we shown if the tests pass?
- ▶ Ephemeral
 - ▶ Hard to test performance over time, i.e. test one month worth of traffic, check if everything is fine, then test another month's worth of traffic the day after;
 - ▶ Hard to test upgrades, or backup and restore from crashes, etc;
- ▶ Language specific
 - ▶ Test libraries/frameworks/tools are programming language specific, while the components of systems under test are written in different languages.

Parts of the solution

- ▶ Generator: generates random test cases;
- ▶ Scheduler: deterministically controls the network traffic during the test;
- ▶ Executor: receives messages from the scheduler and executes them against the system under test (SUT);
- ▶ Ldfi: figures out which faults to inject;
- ▶ Checker: analyses the output of a test case execution and determines if it was a success or not.



Solution for non-determinism

- ▶ SUT is assumed to be written on reactor form, i.e. given an incoming message and some internal state, update the state and produce a set of outgoing messages;
- ▶ All messages get set via the Scheduler which randomly, but deterministically using a seed, determines the arrival order of the messages;
- ▶ Timeouts and retires are handled by explicit tick messages, that are also deterministically sent by the Scheduler.

Language agnostic solution

- ▶ In between the SUT and the Scheduler sits the Executor, whose job is to receive messages from the Scheduler via an http interface and pass them on to the SUT;
- ▶ The Executor is written in the same language as the SUT, so once it got the message via http it decodes the message from JSON into a datastructure in the native language and does a simple function call to the the SUT;
- ▶ Porting an Executor to a new programming language is simple, which means it's easy to test systems written using many languages.

Solution to ill-specified guarantees

- ▶ The Checker component uses Jepsen's state-of-the-art Elle checker, which provides precise models and guarantees;
- ▶ Lineage-driven fault injection is used to give guarantees in the presence faults;
- ▶ Operational profiles/usage models will later be used to drive test case generation, and guarantee system test coverage.

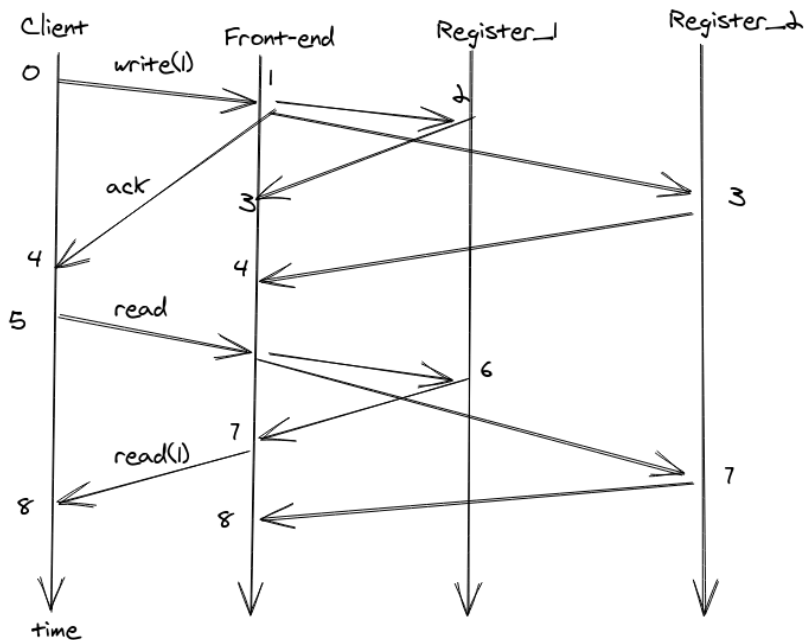
Solution to long-lived testing

- ▶ Every interaction that the developer can do, e.g. generation, execution, checking, can be done in isolation because the input and output comes and goes via a database;
- ▶ The above in combination with determinism means that we can replay an old test and bring the system to the state it was in at the end of a test, we can then extend the test can carry on from there.

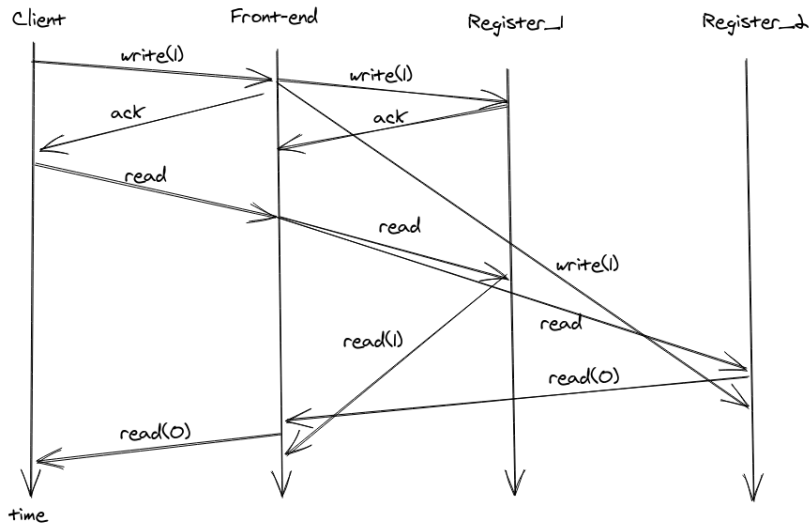
Demo: the SUT

- ▶ The example SUT is a integer-valued shared/distributed register;
- ▶ Any number of clients can write or read an integer from the register;
- ▶ The register is replicated to try to achieve fault tolerance.

Demo: shared register v1, success



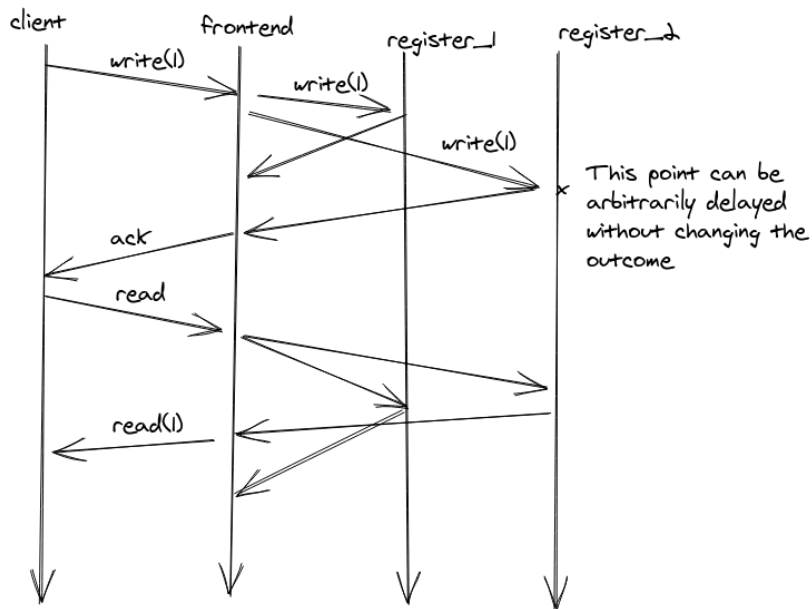
Demo: shared register v1, counterexample



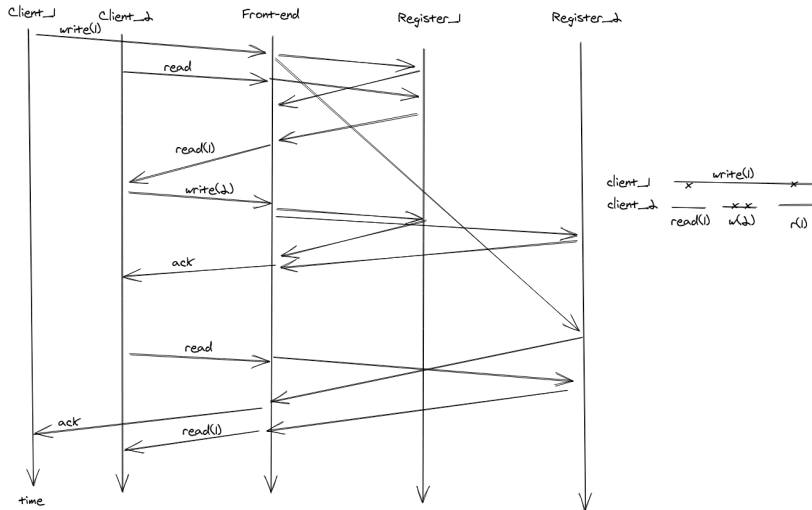
Demo: the testsuite of the SUT

- ▶ Show the code of `detsys/sut/register_test.go`;
- ▶ `go test`;
- ▶ Ensure that we find the problem.

Demo: shared register v2, success



Demo: shared register v2, counterexample



How does the Elle checker work?

How does lineage-driven fault injection work?

```
traces := []  
faults := {}  
result := ""  
  
forever:  
    inject(faults)  
    success, trace := run(test)  
    if !success:  
        result := failure(faults)  
        break  
    traces.append(trace)  
    faults := ldfi(traces)  
    if faults is empty:  
        result := "success"  
        break
```

How does lineage-driven fault injection work? #2

```
fun ldfi(list of trace) -> set of fault
```

```
type trace =  
  { message: Msg,  
    from: Node,  
    to: Node,  
    at: Time }
```

```
type fault  
  = omission { from: Node, to: Node, at: Time}  
  | ...
```

How does lineage-driven fault injection work? #3

- ▶ `fun ldfi(traces: list of trace) -> set of fault`
- ▶ Each trace contains possible messages to drop, so create a big OR-formula like:

`omission(msg0...) OR omission(msg1...) OR ...`

- ▶ For each run/trace we gather more constraints, so create a big AND-formula between traces, e.g.:

`(omission(msg0...) OR omission(msg1...) OR ...)
AND
(NOT(omission(msg0...)) OR omission(msg1...) OR ...)
AND ...`

- ▶ Solve this CNF-formula using SAT solver
 - ▶ Minimal solution = smallest set of faults that can potentially break the test
 - ▶ No solutions = no set of faults can break this particular test case

Next steps and future work

- ▶ Next steps
 - ▶ Regression tests;
 - ▶ Integration with Sean's work.
- ▶ Future work
 - ▶ Test case generation, including extending existing/already run test cases;
 - ▶ Support for deployment, for testing upgrades and backup/restore.

Summary

- ▶ We have seen how to solve the following problems of existing system tests:
 - ▶ Non-determinism and speed;
 - ▶ Weak guarantees;
 - ▶ Ephemeral;
 - ▶ Language specific.
- ▶ Key insights:
 - ▶ Treat system tests themselves as a long-running application;
 - ▶ Ask programmer to abstract away concurrency from programs, provide a bunch of tools for free in return.

Questions or comments?

References

Alvaro, Peter, Joshua Rosen, and Joseph M. Hellerstein. 2015. "Lineage-Driven Fault Injection." In *Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data, Melbourne, Victoria, Australia, May 31 - June 4, 2015*, edited by Timos K. Sellis, Susan B. Davidson, and Zachary G. Ives, 331–46. ACM. <https://doi.org/10.1145/2723372.2723711>.

Kingsbury, Kyle, and Peter Alvaro. 2020. "Elle: Inferring Isolation Anomalies from Experimental Observations." *CoRR* abs/2003.10554. <https://arxiv.org/abs/2003.10554>.